Comments of

COALITION FOR SAFE BUILDING MATERIALS

(California Pipe Trades Council, California Professional Firefighters, Consumer Federation of California, Planning and Conservation League, Center for Environmental Health, Sierra Club of California and Communities for a Better Environment)

on the

DRAFT ENVIRONMENTAL IMPACT REPORT
FOR
ADOPTION OF REGULATIONS PERMITTING STATEWIDE RESIDENTIAL USE OF CHLORINATED POLYVINYL CHLORIDE (CPVC) PLASTIC PLUMBING PIPE WITHOUT FIRST MAKING A FINDING OF POTENTIAL PREMATURE METALLIC PIPE FAILURE DIE TO LOCAL WATER OR SOIL CONDITIONS
STATE CLEARINGHOUSE NO. 2006012044

VOLUME V

APPENDICES TO THE COMMENTS OF
ADAMS BROADWELL JOSEPH & CARDOZO

September 14, 2006

AIR

MATERIAL SAFETY DATA SHEET
This Material Safety Data Sheet complies with the U.S. OSHA Hazard Communication Standard 29CFR 1910.1200

CODE: M/L040

PRODUCT: TARAMET STERLING® LEAD-FREE SOLDER

TARACORP

NFPA/HMIS HAZARD CODES: HEALTH: 1/1 FIRE: 0/0 REACTIVITY: 0/0 SPECIAL: NA

0 = Minimal 1 = Slight 2 = Moderate 3 = Serious 4 = Severe

SECTION I

MANUFACTURERS NAME: Taracorp
1690 Lowery Street
Winston-Salem, NC 27101

ISSUE DATE: October 2004

INFORMATION PHONE: 336-777-8600

SECTION II HAZARDOUS INGREDIENTS

INGREDIENT	CAS NO.	US-NIOSH RTECS NO.	US OSHA AL	US OSHA PEL	ACGIH TLV	WT. PERCENT
Tin	7440-31-5	XP7320000	NE	2.0mg/m3	2.0mg/m3	Balance
Copper	7440-50-8 (dust) (fume)	GL5325000	NE	1.0mg/m3 0.1mg/m3	1.0mg/m3 0.2mg/m3	4.0 – 5.0
Selenium	7782-49-2	VS7700000	NE	0.2mg/m3	0.2mg/m3	.04 - .2

NE=None Established AL=Action Level PEL=Permissible Exposure Limit TLV=Threshold Limit Value

SECTION III PHYSICAL DATA

APPEARANCE & ODOR (AT NORMAL CONDITIONS): Solid -Silver to silver-gray metallic metal-No odor
SPECIFIC GRAVITY: 7.38
MELTING POINT RANGE: (degrees F) 410-418
BOILING POINT: (degrees C) Information not available
SOLUBILITY IN WATER: Insoluble
PH: Not applicable

SECTION IV FIRE & EXPLOSION HAZARD DATA

FLASH POINT: Non-flammable
FLAMMABLE LIMITS: Not Applicable
EXTINGUISHING MEDIA: No specific agents recommended
SPECIAL FIRE FIGHTING PROCEDURES: If involved in fire, use full protective clothing and NIOSH/MSHA approved self-contained breathing apparatus operated in a positive-pressure mode.
UNUSUAL FIRE & EXPLOSION HAZARDS: The solid metal form is not a fire hazard. However, it is possible that dust generated from processing operations may present a moderate fire or explosion hazard.

SECTION V REACTIVITY DATA

STABILITY: Stable
CONDITIONS TO AVOID: Not Applicable
INCOMPATIBILITY: Chlorine, Turpentine, Magnesium, and Acetylene Gas
HAZARDOUS DECOMPOSITION PRODUCTS: At temperatures above the melting point metal oxide fumes may be evolved.
HAZARDOUS POLYMERIZATION: Will not occur.

SECTION VI HEALTH HAZARD DATA

NOTE: Exposure to the solid form of this product presents few health hazards in itself. However, normal handling or processing of this material may result in exposure to product components and/or decomposition products, which may present a health hazard.

ROUTES OF ENTRY: Dust/fume inhalation; dust ingestion.

SYMPTOMS & EFFECTS OF OVEREXPOSURE:

Chronic (prolonged) overexposure to **tin** can result in benign pneumoconiosis (stannous). This form of pneumoconiosis produces progressive x-ray changes of the lungs as long as exposure exists, but there is no distinctive fibrosis, no evidence of disability and no special complicating factors.

Acute (severe short-term) overexposure to **tin** can cause irritation of the eyes, skin, mucous membranes and respiratory system. Acute overexposure to **copper** dust/fume can cause irritation of the eyes, nose, throat and skin, and under severe fume overexposure can cause metal fume fever with flu-like symptoms such as sweet metal taste, dry throat, coughing, fever and chills, tight chest, dyspnea, headache, blurred vision, back pain, nausea, vomiting, fatigue. Symptoms usually disappear within 24 hours. Copper may cause skin and hair discoloration. Inhalation of copper dusts may cause changes in the gums and mucous lining of the mouth which is generally attributable to localized tissue effect rather than general toxicity.

MEDICAL CONDITIONS POSSIBLY AGGRAVATED BY EXPOSURE: Pre-existing conditions of the lungs. Wilson's Disease (Genetic Trait)

CARCINOGENITY: Not listed as a carcinogen by NTP, IARC, OSHA, ACGIH

EMERGENCY & FIRST AID PROCEDURES:

SKIN: Normal hygiene and first aid procedures - wash with soap and water. If irritation develops or persists obtain medical attention get medical attention.

EYES: Flush well with running water to remove particulate. If irritation persists obtain medical attention.

ACUTE INHALATION: Remove from exposure. Obtain immediate medical attention. If breathing has stopped, initiate artificial resuscitation.

INGESTION: Give water; induce vomiting only in a conscious non-convulsing individual; Obtain immediate medical attention.

SECTION VII PROTECTION MEASURES

RESPIRATORY PROTECTION: Respiratory protection is required where airborne exposures exceed US-OSHA/ACGIH permissible air concentrations. Respirator selection shall be made in accordance with the U.S. OSHA Respiratory Protection Standard, 29CFR 1910.134.

VENTILATION: Ventilation, as described in "Industrial Ventilation, A Manual of Recommended Practice", by the American Conference of Governmental Industrial Hygienists, is recommended to maintain exposure levels below the permissible exposure limits (PEL's) or threshold limit values (TLV's) specified by US-OSHA or other local or state regulations.

PROTECTIVE GLOVES: Recommended for prolonged contact/heat.

EYE PROTECTION: Safety glasses or goggles are recommended where the possibility exists of getting dust particles in the eyes. Safety glasses or goggles with face-shield are recommended around molten metal.

OTHER PROTECTIVE EQUIPMENT: Safety equipment should be worn as appropriate for the work environment.

WORK/HYGIENIC PRACTICES: Do not permit eating, drinking, or the use of cosmetics or tobacco products while handling or processing material or in product work areas. Practice good personal hygiene procedures. Wash hands and face thoroughly before eating, drinking, applying cosmetics or using tobacco products. Avoid inhalation and ingestion of product, and activities, which generate dust or fume. Keep melting/soldering temperatures as low as possible to minimize the generation of fume.

SECTION VIII PRECAUTIONS FOR SAFE HANDLING & USE

PRECAUTIONS TO BE TAKEN IN HANDLING & STORING: Practice good housekeeping procedures to prevent dust accumulations. Keep material dry. Avoid storage near incompatible materials (See Section V). Keep product away from children and their environment and domestic animals.

OTHER PRECAUTIONS: Special attention is drawn to the requirements of the U.S. OSHA Respirator (1910.134) should airborne exposures exceed the U.S. OSHA PEL. Inadvertent contaminants to product such as moisture, ice, snow, grease or oil can cause an explosion when charged to a molten metal bath or melting furnace (preheating metal will remove moisture from the product).

SECTION IX SPILL OR LEAK PROCEDURES

SPILL OR LEAK PROCEDURES:

1. Material in dust form-minimize exposure. Clean up using dustless methods (i.e. HEPA Vacuum). Do not use compressed air.
2. Place in closed-labeled containers for recycling or disposal.
3. Keep out of waterways.

NOTE: Cleanup personnel should wear protective clothing and respiratory protection where significant dust/fume exposure exists.

OTHER PROCEDURES:
For large product users or involving large product quantities, we recommend that the purchaser establish a spill prevention, control and counter measure plan. This plan should include procedures for proper storage as well as clean up of spills or leaks. The procedures should conform to safe practices and provide for proper recovery and/or disposal. Depending on the quantity spilled, notification to the U.S. National Response Center (800-424-8802) may be required in case of hazardous substances. (See USEPA and USDOT regulations: also various state and local regulations.)
WASTE DISPOSAL METHODS: May have value on a recycled basis. If disposed of, dispose of in a permitted disposal site in accordance with all federal, state and local disposal or discharge regulations.

SECTION X UNITED STATES SARA TITLE III INFORMATION

This product/mixture contains the following toxic chemical(s) subject to the reporting requirements of Section 313 of title III of the U.S. Superfund Amendments and Reauthorization Act (SARA) of 1986 and 40 CFR Part 372. The percent by weight of each toxic chemical and its associated chemical abstract system (CAS) number are to be found in Section II of this Material Safety Data Sheet.

CHEMICAL NAME	EHS RQ (LBS) (*1)	EHS TPQ (LBS) (*2)	SEC.313 (*3)	313 CATEGORY (*4)	311-312 CATEGORIES (*5)
Copper	Not Applicable	Not Applicable	Yes	Copper	H-1

-FOOTNOTES-

*1= Reportable quantity of extremely hazardous substance, Section 302.
*2= Threshold planning quantity, extremely hazardous substance, Section 302.
*3= Toxic chemical list, Section 313
*4= Chemical category as required by Section 313 (40 CFR 372.42). Subject to annual release reporting requirements.
*5= Hazard category for SARA Section 311/312 reporting:

Health	H-1 = Immediate (ACUTE) Health Hazard	Physical	P-3 = Fire Hazard
	H-2 = Delayed (CHRONIC) Health Hazard		P-4 = Sudden Release of Pressure Hazard
			P-5 = Reactive Hazard

SECTION XI UNITED STATES CERCLA SECTION 103 INFORMATON

This product/mixture contains the following chemicals subject to the release reporting of Section 302.

CHEMICAL NAME	RQ (LBS)
Copper	5000 (*1)

-FOOTNOTES-

*1= Reportable quantity (RQ) under CERCLA Section 302. Spills to the environment exceeding the reportable quantity in any 24-hour period must be reported to the U.S. National Response Center (800) 424-8802. No reporting of releases of the hazardous substance(s) is required if the diameter of the pieces of the solid metal(s) released is equal to or exceeds 100 micrometers (0.004 inches).

SECTION XII TRANSPORTATION INFORMATION

PROPER SHIPPING NAME:	Non-regulated as shipped.
TECHNICAL NAME:	NA
HAZARD CLASS:	NA
UN NO.:	NA
PACKING GROUP:	NA
EMERGENCY RESPONSE GUIDE NUMBER:	NA
OTHER:	NA

SECTION XIII ADDITIONAL INFORMATION

NO ADDITIONAL INFORMATION

This Material Safety Data Sheet is offered solely for your information, consideration and investigation. Taracorp, Inc. provides no warranties, either express or implied, and assumes no responsibilities for the accuracy or completeness of the data contained in this document. The data in this Material Safety Data Sheet relates only to this product and does not relate to use in combination with any other material or in any process.

Plastic Pipe Cements

Primers, Cleaner & Accessories

SPECIFIC USES

Use Hercules plastic pipe cements, primers and cleaner for bonding rigid and flexible plastic pipe and fittings.

SPECIFIC APPLICATIONS*

All cements, primers and cleaner can be used on PVC, CPVC, ABS and styrene pipe and fittings as specified on individual tables.

WARNINGS OR CAUTIONS

- Plastic Pipe Cements and related products are necessarily formulated with flammable solvents and ingredients which are harmful or fatal if swallowed and hazardous when used with improper ventilation. Avoid contact with eyes or skin. Clear and detailed cautions appear on all labels of Hercules Plastic Pipe Cements and cleaner along with specific antidotes and recommended emergency treatment. It is suggested that all users familiarize themselves with the entire label, including precautions, prior to use. Use of respirator is recommended where ventilation is limited.
- Use of a respirator is recommended where ventilation is limited.
- Use splash goggles or other suitable eye protection.
- Containers should be kept tightly closed when not in use, and covered whenever possible during use.
- DO NOT mix cleaner or primer with cement.
- Do not use cement that is lumpy, curdled or thickened.
- Always keep this, and all other cements, out of reach of children.
- Plastic Pipe Cements, Primers and Cleaner should not be stored near heat or open flames, nor should they be allowed to freeze. Recommended temperature range for good shelf life should not go below 40°F nor above 100°F. If cements are subjected to freezing temperatures during shipment or for other reasons, they may thicken or gel. If placed in a warm (not hot) area, they will return to useable original condition.
- Hercules Plastic Pipe Cements are made to be used as received in the containers provided. Never attempt to change their viscosity by adding thinner.

DIRECTIONS FOR USE

1. Choose the cement appropriate for the pipe and fitting being used.
2. Stir or shake cement well before using. Wear protective gloves when using solvent cement. Do not use vinyl gloves.
3. Cut pipe square. If a pipe cutter is used, file off raised bead. Remove all burrs inside and outside pipe using a knife, file or reamer.
4. Wipe end of pipe and inside of fitting with clean cloth to remove dirt, grease and moisture. Moisture may slow cure. Dirt or grease may prevent adhesion. Cleaner (not to be confused with Primers) may be used for removal of grease and other foreign matter. Do not apply cement or primer until pipe is clean and dry.
5. Check dry fit of pipe and fitting. Pipe must enter at least 1/3 of the way for proper fit. If too tight, sand or file pipe to make good fit. Be sure pipe and/or fitting are not out of round. Pipe must bottom fully into fitting socket during final assembly with cement.
6. For PVC and CPVC connections, use Hercules Primer to remove gloss from pipe end and inside of fitting. Apply primer with its own dauber. (ABS pipe should only be wiped clean with a dry cloth.)
7. Apply a thin coat of the proper cement to outside of pipe and inside of fitting. Avoid getting excess cement past fitting socket. Then, quickly apply a liberal amount evenly on pipe end equal to socket depth. Since weather conditions affect priming and cementing action, repeated applications may be necessary before joining. In cold weather, more time is required for curing and full bond strength.
8. While the cement is still wet, insert pipe into fitting with a 1/4 turn twist until it bottoms.
9. Hold joint together 15 to 30 seconds (longer for larger pipe sizes) to prevent pipe from backing out of tapered socket. Check instructions on each specific cement for proper procedures.
10. After assembly, wipe excess cement from joint with a clean cloth. Avoid disturbing or moving the joint.
11. Allow sufficient time for good handling strength. This will depend on the temperature. On pressure lines, wait 24 hours or longer before applying full pressure. The presence of a strong solvent smell indicates the joint is not sufficiently cured. Short cure periods are satisfactory for high temperatures with low humidity, small pipe sizes and interference type fittings. Longer curing periods are necessary for low temperatures, larger pipe sizes, loose fits and high humidity. Do not try to speed up the cure by artificial means - this could cause porosity and blisters in the cement film.

For Delivery by Fax	Call 1-800-942-4636
Internet	See MSDS section of **www.herchem.com**
Mail	Contact Hercules at address below or any Hercules representative

* For special applications which may not be covered in this or other Hercules literature, please contact Hercules Technical Services Department by phone at 1-800-221-9330 or send a fax to 1-800-333-3456 or visit our web-site at www.herchem.com.

AVERAGE NUMBER OF JOINTS per 1 QT. HERCULES CEMENTS

Pipe Fitting Diameters	1/2"	3/4"	1"	1-1/4"	1-1/2"	2"	3"	4"	6"	8"	10"	12"	15"
PVC Gray	340	260	180	130	100	76	44	36	12	8	6	4	2
PVC Clear Heavy Duty	340	260	180	130	100	76	44	36	12	8	6	4	2
PVC Clear Medium	300	200	140	96	70	54	36	30	10	6	-	-	-
PVC Clear Regular	260	180	120	90	64	50	30	26	8	-	-	-	-
PVC Clear "Below Zero"	260	180	120	90	64	50	30	26	8	-	-	-	-
ABS	300	200	140	96	70	54	36	30	10	6	-	-	-
CPVC	260	180	120	90	64	50	30	26	8	-	-	-	-
MULTI-PURPOSE	260	180	120	90	64	50	30	26	8	-	-	-	-
ABS/PVC	260	180	120	90	64	50	30	26	8	-	-	-	-
PRIMER	235	160	110	80	58	45	25	20	6	-	-	-	-

ISO 9001: 2000 Certified

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Solvent Weld Joint Failures

Pipe And Fitting Related

Loose Fitting Components:

Failure of the pipe and or fittings to conform to the dimensional tolerances required by the respective specifications, resulting in a fit that when tested dry is loose enough to provide less than adequate surface contact with the fitting.

Tight Fitting Components:

Failure of the pipe and or fittings to conform to the dimensional tolerances required by respective specifications, resulting in a fit that when tested dry is so tight as to prevent proper assembly in addition to squeezing out the cement from inside the joint when assembled.

Out Of Round Egg Shaped Components:

Failure of the pipe and or fittings to conform to the out of round requirements of respective specifications, resulting in gaps that cannot be filled by a cement meeting the resin content requirements. Given the very nature of solvent cements, in which the overwhelming portion is subject to evaporation resulting in substantial shrinkage of the cement layer, even a PVC cement with double the minimum amount of resin specified will not possess gap filling properties of any consequence.

Extrusion Aids On Mating Surfaces (Wax And Silicone):

Occasionally, some pipe compounds contain an excessive amount of extrusion aids, such as metallic stearates and waxes, which result in finished pipe where these components are integrated at high levels into the entire matrix of the pipe wall. Similarly, the presence of molding release agents used to facilitate removal of molded fittings during manufacture, such as silicone, while not integrated into the plastic matrix of that component, are sometimes found at high concentrations on the fitting surface.

In any event, the result is the presence of materials on the mating surface that are either difficult to remove by conventional cleaners or primers. These slick, waxy chemicals can provide a very effective barrier to the flow together mechanism so essential to the solvent welding process.

From time to time one may encounter pipe and or fitting surfaces that are exceptionally hard and consequently very resistant to penetration by the solvents used in cements to soften the mating surfaces. While this phenomenon can be found on any surface, it is most often encountered on the interior surface of the bell section of bell end pipe due to the post heating process by which the bell is formed. This situation may be aggravated when attempting to make welds involving such surfaces in cold temperatures, which inhibit solvent action even on normal surfaces.

Quality cements that fully meet or exceed testing requirements may fail to adequately soften such surfaces, therefore, the industry has recommended the use of primers to aid in the elimination of this problem.

Workmanship Related

Failure To Test Pipe With Fitting For Proper Fit

The proper snugness of the pipe and fitting selected is essential to a successful joint. Even using components that are individually within the dimensional tolerances prescribed by respective specifications, it is possible to mismatch an almost oversize socket with a piece of undersize pipe, the result being a very loose match. Conversely, the opposite over tight condition which causes squeezing out of the cement when assembled, may present itself by selection of an almost oversize pipe section to be used with a undersize fitting.

Even worse, pipe and fittings that are actually oversize or undersize may, from time to time, be found on the job site. Failure to test for dry fit will eventually result in the use of such mismatched components and consequently cause joint failures.

Failure To Cut Pipe Square

An unsquare cut results in a portion of the socket area not being in physical contact with the pipe surface. This substantially reduces the actual area of joined components in much the same way as failure to insert the pipe fully to the socket depth. A compounding factor in this cause of failure is that the area not in contact is the most critical needed area of the joint.

Failure To Remove Burrs or Raised Edges

The burrs created from the sawing of plastic pipe if not removed, can as the pipe is inserted, plough small grooves in the interface of the joining area. Such grooves can be the source of leaks. Alternately, the raised leading edge created by cutting plastic pipe with conventional pipe cutters, if not removed will have the effect of forcing the cement out in front of it as the pipe is inserted into the fitting. This results in a less than adequate amount of cement left inside the joint to melt and join the surfaces.

Failure To Clean Surfaces And Remove Foreign Materials

In manufacture, handling, storage, and transportation of the pipe, and to a lesser degree, the fittings, a concentration of foreign material that may inhibit the solvent action and or the flow together action of the joined surfaces may accumulate on the area to be solvent welded. This may vary in character from diesel exhaust residue on the pipe acquired during transportation, to atmospheric residues acquired during outside storage, or simply grease and oil from the hands of the assembler or his helpers. Also, there are often some residual extrusion aids waxy in character, and in the case of fittings some residual molds release agents slippery in character, not removed by the manufacturer. If not removed, these surface contaminants provide a serious jeopardy to the making of a successful joint.

Failure To Use Primer

The function of primer is to pre-soften the mating surfaces of the pipe and fitting. Thus allowing the surfaces to be easily softened by the solvents in the cements. While in most

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cases the nature of the mating surfaces is such that the cement will provide an adequate weld by itself, conditions may exist that would require the use of a primer for adequate penetration. These include, but are not limited to, randomly encountering very hard pipe and fittings surfaces, along with cold weather cementing. Because these conditions are randomly encountered and are neither easily detected or predicted, and because a primer will always help and won't hurt, the use of a primer, especially on pressure systems is recommended. Remember, most codes call for the use of an approved primer during pressure installation. Always check with code authorities prior to eliminating the use of primer or other recommended procedures.

Failure To Assemble Joint While Cement Is Wet

The active ingredients of cements evaporate into the air very quickly. It is essential that these solvents be trapped within the assembled joint where they can actively soften the surfaces as a prerequisite to the desired flow together mating of the surfaces. Failure to work quickly enough, especially in the time frame between application of the cement and assembly of the joint, may result in the cement partially drying prior to assembly. This is one of the more common causes of joint failure, especially when working with larger diameter pipe and fittings in hot climates.

Failure To Apply An Adequate Layer Of Cement

A layer of cement of adequate proportions to fill any gaps or spaces that may exist between the pipe and fitting is

essential to a leak free joint. Failure to apply the cement in a manner consistent with this requirement will result in leaks due to voids or inadequate fusion of the mating surfaces because all components were not in direct physical contact at all joining areas. A study of joint failures suggests, this is perhaps the most common cause of joint failures.

Failure To Apply Cement Uniformly

Lack of uniformity in the cement layer will result in missed spots or areas that have less than the desired amount of cement or primers applied.

Failure To Insert Pipe To Full Socket Depth

In order to benefit by the entire socket area provided and to maximize the bond strength of the joint, the pipe must be inserted to the full depth of the socket. Failure to do so will result in a reduction of total bonded area. More importantly, due to the taper design of the socket, which causes it to be smaller in diameter at the shoulder than at the entrance, the reduction is in the most critical area of the joint.

Failure To Insert Pipe With A Twisting Action

The purpose of the twisting motion or the giving of a 1/4 turn while inserting the pipe into the socket insures the even distribution of the cement should any light or missed spots exist. Additionally, should there be any air bubbles present in the cement layer this will aid in their elimination. While failure to use a twisting motion may not be a direct cause of joint failures per se, use of the technique is helpful in eliminating other causes.

Failure To Hold Pipe In Place After Assembly

The taper design of the socket operating in conjunction with the pressures formed inside the joint by the swelling action of the cement, creates a strong tendency for the pipe to back out of the socket or fitting after assembly. This can and must be prevented by holding the assembly firmly until the cement has the opportunity to set. Failure to do so will result not only in a loss of total bonded area, but also a reduction in the most critical area of bonding surface. In addition, and just as important, backing out takes place as the cement is beginning to set, and movement at this stage can destroy any bonding and could cause joint failure.

Rough Handling Of Freshly Cemented Joints

Rough handling of an assembly that contains freshly cemented joints may result in enough movement at the interface of the mating surfaces to destroy the bond permanently. Rotation of only a few degrees of the socket on the pipe or any rough handling that results in a disruption of the cement resulting in a poor bond. A loose fitting socket, and especially one that is assembled during cold weather, is slower to set and consequently more subject to the harmful effects of rough handling.

Using Cement From A Can Left Open For A Prolonged Period

The active ingredients of any cement are very volatile and are subject to rapid evaporation into the atmosphere. A cement container left open when not in use, especially during hot weather, can lose enough of these key ingredients to

cause a complete imbalance of the formulated solvent blends. This would result in a cement that lacks the power to soften the pipe or fittings. A performance test should be applied to any questionable cement prior to application.

Pressure Testing Before Cement Has Adequately Cured

The application of pressure to an uncured joint may have the same effects as rough handling of a joint during the early stages of bond strength development. The stresses involved in even low pressure applications may be significant enough to cause the slight movement required to disrupt the welding process.

Selecting The Wrong Cement

Cements are produced in a variety of grades in an effort to tailor them for specific applications. Some contain a higher level of plastic than others and or slow evaporating solvents in the blends. These types of cements are designed for use on larger diameter pipe due to the requirement in situations for better gap filling properties and longer working time while the cement is being applied. Because of these differences, the use of cement not designed for a particular application can result in a failure caused by the cement drying prior to assembly, or less than required gap filling properties. Be safe, follow manufacturer's guidelines for selecting solvent cements.

Excess Solvent Cement

Excess cement will be forced out of the assembled joint as the pipe is inserted. Due to the tapered design of the socket

any excess that has been applied to the pipe end will be forced to the outside of the assembly where it can and should be wiped off. Any excess applied to the socket will be forced forward by the leading edge of the pipe to the inside of the assembly where it is inaccessible and will lie in a puddle or run down the inside of the pipe. The solvent penetration of the cement may in certain instances eat a hole in the wall of the pipe. This is commonly known as solvent weld pipe burn. This is especially a problem with thin wall pipe class 160 and below and bell end pipe where there is no shoulder provided as in the case of a molded fitting. In addition, the curve of the pipe where the base of the socket begins on a bell end consists of ordinary wall thickness pipe that has been stretched to form the bell. Stretching results in both a reduced thickness as well as a matrix that has less solvent resistance.

Use Of Hot Pipe Or Fittings

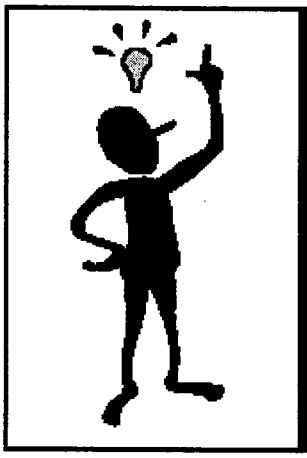
When exposed to the sunlight in a hot climate, the pipe surface temperature may reach 120-130 degrees Fahrenheit. Even in cooler temperatures the radiant energy of the sun will raise the exposed surface twenty or more degrees above the ambient conditions. Because application of cement to a hot surface may cause rapid flash off of the active ingredients resulting in partially dried cement at the time of assembly, this practice should be avoided. The pipe should be tested for surface temperature and if necessary, cooled down by a suitable method. One method is to wipe the surface with a wet cloth using caution to assure that the water is removed before cementing.

Stress On Joints

The practice of trying to bend the pipe around a slight curve in order to make it fit some pre-determined configuration rather than the use of a fitting that would provide the necessary offset, will result in a application of stress to fresh joints. This stress will of course result in a possible failure.

Failure to Snake Long Runs Of Pipe In A Ditch

Because of the expansion and contraction characteristics of most plastics, including PVC, long runs of pipe must be placed in a trench in a manner that will allow for contraction without placing undue stress on a freshly bonded joint. The method endorsed by the Plastic Pipe Industry is to snake the pipe in the ditch. Failure to do so may result in complete pullouts or enough disruption of the joint to result in leaks and joint failure.



Any one or a combination of these factors listed above can and most likely will cause leaks or failures. Solvent cements are not miracle workers. Follow all instructions, procedures, and manufacturer's recommendations when using any solvent cements, cleaners, and primers.
Solvent cements, cleaners, and primers are extremely flammable. Safety first, always use caution when working with these products.

Ineffective Solvent Cements, Cleaners, & Primers

Solvent cements are designed, formulated, and manufactured to soften PVC pipe and fittings for solvent welding. If solvent cements adequately soften the PVC surface it will make a

successful solvent welded joint. Characteristically solvent cements soften or it will not soften the pipe and fitting surfaces. In other words, if everything is equal during assembly application, and you make ten solvent welded joints, and you have only three that leak, it is most likely not the solvent cement. Some other variables have created the joint failures. That is not to say, solvent cement can not and will not it's strength. Evaporation and age are two common causes of strength loss in solvent cements. Solvent cements are formulated with resins, fillers, and aggressive solvents that evaporate very quickly. Each time the container is opened, solvents escape into the atmosphere, as the aggressive solvent evaporates the ratio of solvents to solids become unbalanced. This procedure alters the product viscosity causing it to become stringy, thick, and show signs of gelation. Solvent cements should not be applied when they show any of the altered descriptions above. Scrap test should be performed on any questionable solvent cement, cleaner, and primers before use in any application. These procedures are mentioned and outlined in ASTM D-2855 Standard Specifications for Making Solvent Cemented Joints. Like the pipe and fittings manufacturers' solvent cements and approved primers must meet or exceed ASTM testing standards.

Solvent cement formulations are tested, approved, and listed by several governing bodies. Products must be within these guidelines each and every time they are sampled and tested. Manufacturers' in violation or deviating from the original approved formulations could loose their product certification and listing. The test standards and approvals specifications for solvent cements and primers are listed below:

PVC SOLVENT CEMENTS	ASTM SPECIFICATION D-2564
CPVC SOLVENT CEMENTS	ASTM SPECIFICATION F-493
ABS SOLVENT CEMENTS	ASTM SPECIFICATION D-2235
ABS TO PVC CEMENTS	ASTM SPECIFICATION D-3138
PVC FLEX CEMENTS	ASTM SPECIFICATION D-2564
PRIMERS	ASTM SPECIFICATION F-656

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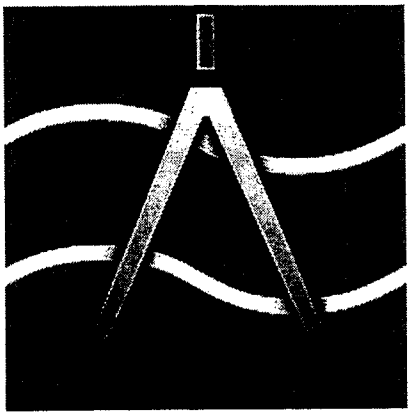
FLUID FLOW SOLUTIONS



TECHNICAL NOTES

CEMENT USAGE FOR PVC, CPVC

For estimating solvent cement needs, refer to the chart below.
Allow two joints for each coupling, three joints for each tee, etc.

No. of Joints per inch:*	1/4"	3/8"	1/2"	3/4"	1"	1-1/4"	1-1/2"	2"
Pint	150	150	130	80	70	50	35	20
Quart	300	300	260	160	140	100	70	40
Gallon	1200	1200	1040	640	560	400	280	160

No. of Joints per inch:*	2-1/2"	3"	4"	5"	6"	8"	10"	12"
Pint	17	15	10	8	–	–	–	–
Quart	34	30	20	16	8	3	–	–
Gallon	136	120	80	64	32	12	10	6

* Each joint represents one socket in a fitting.

RELATED INFORMATION:

- Solvent Cementing for Schedule 80 PVC

1-800-848-1141

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3/9/1 (Item 1 from file: 332)
DIALOG(R)File 332:Material Safety Data Sheets -
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00056297
OHS/MDL Record Number : OHSIX119
MATERIAL SAFETY DATA SHEET

SECTION 1 - CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

MDL Information Systems, Inc.
14600 Catalina Street
San Leandro CA 94577
1-800-635-0064 (Toll Free) or
1-510-895-1313

FOR EMERGENCY SOURCE INFORMATION
CONTACT: 1-615-366-2000 in USA

EU Number(EINICS) : 231-592-0

SUBSTANCE: OATEY #11 LIQUID FLUX

TRADE NAME/SYNONYM(S): FLUX FOR COPPER PIPE; OHSIX119

CREATION DATE: 19950119 REVISED: 20041209

SECTION 2 - COMPOSITION, INFORMATION ON INGREDIENTS

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1) Component Substance: ZINC CHLORIDE
   Component Percent: 30-35 %
   CAS Registry Number: 7646-85-7
2) Component Substance: HYDROCHLORIC ACID
   Component Percent: 12-15 %
   CAS Registry Number: 7647-01-0
3) Component Substance: AMMONIUM CHLORIDE
   Component Percent: 4-8 %
   CAS Registry Number: 12125-02-9
4) Component Substance: WATER
   Component Percent: 45-55 %
   CAS Registry Number: 7732-18-5

SECTION 3 - HAZARDS IDENTIFICATION

NFPA Ratings (scale 0-4): Health=1 Fire=0 Reactivity=0

EMERGENCY OVERVIEW:
COLOR: yellow
PHYSICAL FORM: liquid
ODOR: faint odor
MAJOR HEALTH HAZARDS: harmful if swallowed, skin burns, mucous membrane burns, respiratory tract irritation, eye irritation, allergic reactions
POTENTIAL HEALTH EFFECTS
INHALATION:
SHORT TERM EXPOSURE: irritation (possibly severe)
LONG TERM EXPOSURE: burns
SKIN CONTACT:
SHORT TERM EXPOSURE: irritation (possibly severe), allergic reactions
LONG TERM EXPOSURE: irritation (possibly severe), allergic reactions
EYE CONTACT:

SHORT TERM EXPOSURE: irritation (possibly severe)
LONG TERM EXPOSURE: irritation (possibly severe)
INGESTION:
SHORT TERM EXPOSURE: irritation (possibly severe), nausea,vomiting, death
LONG TERM EXPOSURE: burns, nausea, vomiting, bone disorders, coma

CARCINOGEN STATUS:
OSHA: No
NTP: No
IARC: No

SECTION 4 - FIRST AID MEASURES

INHALATION:
If adverse effects occur, remove to uncontaminated area. Give artificial respiration if not breathing. If breathing is difficult, oxygen should be administered by qualified personnel. Get immediate medical attention.
SKIN CONTACT:
Wash skin with soap and water for at least 15 minutes while removing contaminated clothing and shoes. Get immediate medical attention. Thoroughly clean and dry contaminated clothing and shoes before reuse. Destroy contaminated shoes.
EYE CONTACT:
Immediately flush eyes with plenty of water for at least 15 minutes. Then get immediate medical attention.
INGESTION:
Never make an unconscious person vomit or drink fluids. Give large amounts of water. DO NOT induce vomiting. If vomiting occurs, keep head lower than hips to help prevent aspiration. If person is unconscious, turn head to side. Get medical attention immediately.
NOTE TO PHYSICIAN:
For inhalation, consider oxygen.

SECTION 5 - FIRE FIGHTING MEASURES

FIRE AND EXPLOSION HAZARD:
Negligible fire hazard.
EXTINGUISHING MEDIA:
regular dry chemical, carbon dioxide, water, regular foam
Large fires: Use regular foam or flood with fine water spray.
FIREFIGHTING:
Move container from fire area if it can be done without risk. Cool containers with water spray until well after the fire is out. Stay away from the ends of tanks. Use extinguishing agents appropriate forsurrounding fire. Do not get water directly on material. Large fires:Flood with fine water spray. Reduce vapors with water spray. Cool containers with water spray until well after the fire is out. Apply water from a protected location or from a safe distance. Avoid inhalation of material or combustion by-products. Stay upwind and keep out of low areas.

FLASH POINT: No data available.

SECTION 6 - ACCIDENTAL RELEASE MEASURES

OCCUPATIONAL SPILL:
Do not touch spilled material. Stop leak if possible without personalrisk. Small spills: Absorb with sand or other non-combustible material. Collect spilled material in appropriate container for disposal. Small dry spills: Move containers away from spill to a safearea. Large

spills: Dike for later disposal. Keep unnecessary people away, isolate hazard area and deny entry. Notify Local Emergency Planning Committee and State Emergency Response Commission for release greater than or equal to RQ (U.S. SARA Section 304). If release occurs in the U.S. and is reportable under CERCLA Section 103, notify the National Response Center at (800)424-8802 (USA) or (202)426-2675 (USA).

SECTION 7 - HANDLING AND STORAGE

STORAGE: Store and handle in accordance with all current regulations and standards. Notify State Emergency Response Commission for storageor use at amounts greater than or equal to the TPQ (U.S. EPA SARA Section 302). SARA Section 303 requires facilities storing a materialwith a TPQ to participate in local emergency response planning (U.S. EPA 40 CFR 355.30). Keep separated from incompatible substances.

SECTION 8 - EXPOSURE CONTROLS, PERSONAL PROTECTION

EXPOSURE LIMITS:

ZINC CHLORIDE:

1 mg/m3 OSHA TWA (fume) 2 mg/m3 OSHA STEL (vacated by 58 FR 35338, June 30, 1993) 1 mg/m3 ACGIH TWA (fume) 2 mg/m3 ACGIH STEL (fume) 1 mg/m3 NIOSH recommended TWA 10 hour(s) (particulate) (fume) 2 mg/m3 NIOSH recommended STEL (fume) 1 mg/m3 UK OES TWA (fume) 2 mg/m3 UK OES STEL (fume)

MEASUREMENT METHOD: Particulate filter; Water; Flame atomic absorption spectrometry; OSHA # ID121 HYDROCHLORIC ACID: HYDROGEN CHLORIDE (HYDROCHLORIC ACID): 5 ppm (7 mg/m3) OSHA ceiling 2 ppm ACGIH ceiling 5 ppm (7 mg/m3) NIOSH recommended ceiling 7.6 mg/m3 (5 ml/m3) DFG MAK (peak limitation category - I, with excursion factor of 1) 10 ppm (15 mg/m3) EC OEL STEL 5 ppm (8 mg/m3) EC OEL TWA 5 ppm (8 mg/m3) UK OES STEL (gas) (mist) (ILV) 1 ppm (2 mg/m3) UK OES TWA (gas) (mist) (ILV) MEASUREMENT METHOD: Silica gel tube; Sodium bicarbonate/Sodium carbonate; Ion chromatography; NIOSH IV # 7903, Inorganic Acids AMMONIUM CHLORIDE: 10 mg/m3 OSHA TWA (particulate) (vacated by 58 FR 35338, June 30, 1993) 20 mg/m3 OSHA STEL (particulate) (vacated by 58FR 35338, June 30, 1993) 10 mg/m3 ACGIH TWA (fume) 20 mg/m3 ACGIH STEL (fume) 10 mg/m3 NIOSH recommended TWA 10 hour(s) (fume) 20 mg/m3NIOSH recommended STEL (fume) 10 mg/m3 UK OES TWA (fume) 20 mg/m3 UK OES STEL (fume) MEASUREMENT METHOD: Particulate filter; Water; Ion chromatography; OSHA # ID188

VENTILATION:

Provide local exhaust ventilation system. Ensure compliance with applicable exposure limits.

EYE PROTECTION:

Wear splash resistant safety goggles. Provide an emergency eye wash fountain and quick drench shower in the immediate work area. Provide an emergency eye wash fountain and quick drench shower in the immediate work area.

CLOTHING:

Wear appropriate chemical resistant clothing.

GLOVES:

Wear appropriate chemical resistant gloves.

PROTECTIVE MATERIAL TYPES:

rubber

RESPIRATOR:

Under conditions of frequent use or heavy exposure, respiratory protection may be needed. Respiratory protection is ranked in order from minimum to maximum. Consider warning properties before use. Any chemical cartridge respirator with acid gas cartridge(s). Any chemical cartridge

respirator with a full facepiece and acid gas cartridge(s). Any air-purifying respirator with a full facepiece and an acid gas canister.

For Unknown Concentrations or Immediately Dangerous to Life or Health - Any supplied-air respirator with full facepiece and operated in a pressure-demand or other positive-pressure mode in combination with a separate escape supply. Any self-contained breathing apparatus with a full facepiece.

SECTION 9 - PHYSICAL AND CHEMICAL PROPERTIES

DESCRIPTION: PHYSICAL STATE: liquid
COLOR: yellow
ODOR: faint odor
BOILING POINT: 208 F (98 C)
MELTING POINT: Not available
SPECIFIC GRAVITY: 1.14
pH: 2-3
VAPOR PRESSURE: Not available
VAPOR DENSITY: Not available
VOLATILITY: 60-65%
EVAPORATION RATE: Not available
ODOR THRESHHOLD: Not available
WATER SOLUBILITY: soluble

SECTION 10 - STABILITY AND REACTIVITY

REACTIVITY:
Stable at normal temperatures and pressure.
CONDITIONS TO AVOID:
Avoid heat, flames, sparks and other sources of ignition. Dangerous gases may accumulate in confined spaces. May ignite or explode on contact with combustible materials.
INCOMPATIBILITIES:
bases, cyanides, metals, reducing agents, amines, metal carbide, oxidizing materials, acids, halo carbons, combustible materials, halogens, metal salts
OATEY #11 LIQUID FLUX:
No data available

HYDROGEN CHLORIDE (HYDROCHLORIC ACID):
ACETIC ANHYDRIDE: Violent reaction

ALCOHOLIC HYDROGEN CYANIDE: Explosive reaction
ALUMINUM: Explosion

ALUMINUM-TITANIUM ALLOYS: Ignites or incandesces when heated

2-AMINOETHANOL: Violent reaction

AMMONIUM HYDROXIDE: Violentreaction

BASES: Violent reaction

BRASS: Corrodes

BRONZE: Corrodes

CALCIUM CARBIDE: Reacts with incandescence

CALCIUM HYPOCHLORITE: Ignition

CESIUM ACETYLIDE: Ignites on contact

CHLORINE + DINITROANILINES: Vigorous reaction with release of flammable hydrogengas fumes

CHLOROSULFONIC ACID: Violent reaction

1,1-DIFLUOROETHYLENE: Extremely exothermic decomposition reaction

DOWICIL 100: Decomposes

ETHYLENE DIAMINE: Violent reaction

ETHYLENEIMINE: Violent reaction

FLUORINE: Ignites on contact

HEXALITHIUM DISILICIDE: Incandescesent

IRON: Corrodes with evolution of flammable hydrogen gas

MAGNESIUM BORIDE: Produces a spontaneously flammable gas

MERCURIC SULFATE: Violent reaction at 125 C

METAL ACETYLIDES: Violent reaction

METALS: Severe corrosion with evolutionof flammable hydrogen gas

OLEUM: Violent reaction

OXIDIZERS (STRONG): Violent reaction

OXYGEN + PLATINUM: Ignites on contact

PERCHLORIC ACID: Violent reaction

PLASTICS, RUBBER, COATINGS: Attacks

POTASSIUM PERMANGANATE: Explosion hazard

BETA-PROPIOLACTONE: Violent reaction

PROPYLENE OXIDE: Violent reaction

RUBIDIUM ACETYLIDE: Ignites on contact

SILICA (GEL): Incompatible

SODIUM: Vigorous or explosive reaction

SULFURIC ACID: Explosive reaction with release of toxic hydrogen chloride gas

TETRASELENIUM TETRANITRIDE: Explodes on contact

VINYL ACETATE: Violent reaction

AMMONIUM CHLORIDE:
ACIDS (STRONG): Evolves corrosive hydrogen chloride gas

ALKALIS AND THEIR CARBONATES: Incompatible

AMMONIUM NITRATE: Violent decomposition

BASES (STRONG): Evolves corrosive ammonia gas

BROMINE PENTAFLUORIDE: Violent reaction with ignition

BROMINE TRIFLUORIDE: May cause explosion

COPPER AND ITS COMPOUNDS: May be attacked

HYROGEN CYANIDE: Formation of explosive nitrogen trichloride

IODINE HEPTAFLUORIDE: Violent reaction

LEAD SALTS: Incompatible

METALS: May be corroded in the presence of moisture

POTASSIUM CHLORATE: Violent reaction or explosion

SILVER SALTS: Formation of explosive silver compounds

ZINC CHLORIDE:
BASES: Possible violent reaction

CYANIDES: Release of toxic hydrogen cyanide gas

POTASSIUM: Forms impact-sensitive mixture
SULFIDE SALTS: Release of toxic hydrogen sulfide gas

ZINC: Forms flammable mixture

HAZARDOUS DECOMPOSITION:
Thermal decomposition products: oxides of carbon, hydrocarbons, hydrochloric acid
POLYMERIZATION:
Will not polymerize.

SECTION 11 - TOXICOLOGICAL INFORMATION

OATEY #11 LIQUID FLUX:

LOCAL EFFECTS:
Irritant: inhalation, eye Corrosive: inhalation, skin, eye, ingestion
TARGET ORGANS:
immune system (sensitizer)
ZINC CHLORIDE:

TOXICITY DATA:
169 mg/kg oral-child TDLo; 4800 mg/m3/30 minute(s) inhalation-man TCLo; 350 mg/kg oral-rat LD50; 1960 mg/m3/10 minute(s) inhalation-rat LCLo; 58 mg/kg intraperitoneal-rat LD50; 3690 ug/kg intravenous-rat LD50; >1500 ul/kg intratracheal-rat LD; 329 mg/kg oral-mouse LD50; 24 mg/kgintraperitoneal-mouse LD50; 330 mg/kg subcutaneous-mouse LD50; 9090 ug/kg intravenous-mouse LD50; 11 mg/kg intravenous-rabbit LDLo; 200 mg/kg

oral-guinea pig LD50; 173 mg/kg intraperitoneal-guinea pig LDLo; 2.04 mg/kg oral-mouse TDLo; 9.3 mg/kg intraperitoneal-rat TDLo;5690 mg/kg/13 week(s) intermittent oral-rat TDLo; 910 mg/kg/26 week(s) intermittent oral-rat TDLo; 1680 mg/kg/14 day(s) intermittentoral-rat TDLo; 6875 mg/kg/39 week(s) intermittent oral-mammal TDLo; 21504 mg/kg/12 week(s) continuous oral-mouse TDLo; 595 mg/kg/2 week(s) continuous oral-rat TDLo; 3360 mg/kg/12 week(s) continuous oral-rat TDLo; 13440 mg/kg/12 week(s) intermittent oral-mouse TDLo; 76.44 mg/kg/14 week(s) intermittent oral-mouse TDLo; 109.2 mg/kg/20 week(s) intermittent oral-mouse TDLo; 218.4 mg/kg/20 week(s) intermittent oral-mouse TDLo; 40 mg/kg/2 day(s) intermittent subcutaneous-rat TDLo

LOCAL EFFECTS:

Corrosive: inhalation, skin, eye, ingestion

ACUTE TOXICITY LEVEL:

Toxic: ingestion

TARGET ORGANS:

immune system (sensitizer)

TUMORIGENIC DATA:

17 mg/kg parenteral-hamster TDLo; 15 mg/kg parenteral-chicken TDLo

MUTAGENIC DATA:

mutation in microorganisms - Salmonella typhimurium 90 mmol/L (-S9); phage inhibition capacity - Escherichia coli 3200 umol/L; specific locus test - Drosophila melanogaster oral 6 mmol/L; micronucleus test - non-mammalian species other cell types 170 ug/L 48 hour(s); DNA damage - human fibroblast 2 mmol/L; unscheduled DNA synthesis - human lymphocyte 180 umol/L; DNA inhibition - human lymphocyte 360 umol/L; other mutation test systems - human lymphocyte2 mg; cytogenetic analysis - human lymphocyte 300 umol/L; cytogeneticanalysis - rat Ascites tumor 700 mg/kg; DNA inhibition - mouse parenteral 16 mg/kg; cytogenetic analysis - mouse oral 18 gm/kg 30 day(s)-continuous; host-mediated assay - mouse Salmonella typhimurium6 mg/kg; morphological transformation - hamster embryo 180 umol/L

REPRODUCTIVE EFFECTS DATA:

155 mg/kg oral-rat TDLo 33 day(s) male; 6gm/kg oral-rat TDLo 77 day(s) male day(s) pre pregnancy/77 day(s) post pregnancy/21 day(s) continuous; 30 gm/kg intraperitoneal-rat TDLo 7-8 day(s) pregnant female continuous; 37500 ug/kg parenteral-rat TDLo 10 day(s) pregnant female continuous; 20500 ug/kgintraperitoneal-mouse TDLo 8 day(s) pregnant female continuous; 12500ug/kg intraperitoneal-mouse TDLo 11 day(s) pregnant female continuous; 29184 ug/kg intravaginal-rabbit TDLo 1 day(s) pre pregnancy continuous; 1.8 gm/kg oral-rat TDLo 98 day(s) male day(s) pre pregnancy/98 day(s) post pregnancy/3 week(s) continuous; 7.1 gm/kg oral-rat TDLo 98 day(s) male day(s) pre pregnancy/98 day(s) post pregnancy/3 week(s) continuous; 186 mg/kg oral-mouse TDLo 98 day(s) male day(s) pre pregnancy/98 day(s) post pregnancy/3 week(s) continuous; 186 mg/kg oral-mouse TDLo multigenerations; 1.8 gm/kg oral-rat TDLo 98 day(s) male day(s) pre pregnancy/98 day(s) post pregnancy/3 week(s) continuous

HYDROCHLORIC ACID:

IRRITATION DATA:

5 mg/30 second(s) rinsed eyes-rabbit mild; 4 percent/24 hour(s) skin-human mild

TOXICITY DATA:

2857 ug/kg oral-man LDLo; 420 ul/kg oral-woman LDLo; 1300 ppm/30 minute(s) inhalation-human LCLo; 3000 ppm/5 minute(s) inhalation-human LCLo; 81 mg/kg unreported-man LDLo; 3124 ppm/1 hour(s) inhalation-rat LC50; 1108 ppm/1 hour(s) inhalation-mouse LC50; 40142 ug/kg intraperitoneal-mouse LD50; 900 mg/kg oral-rabbit LD50; 4413 ppm/30 minute(s) inhalation-rabbit LCLo;4413 ppm/30 minute(s) inhalation-guinea pig LCLo; 0.1 gm/m3 inhalation-mammal LC50; 5066 mg/m3/90 minute(s)

inhalation-rabbit LCLo; 5066 mg/m3/90 minute(s) inhalation-guinea pig LCLo; 6400 mg/m3/30 minute(s) inhalation-rabbit LCLo; 6400 mg/m3/30 minute(s) inhalation-guinea pig LCLo; 60938 mg/m3/5 minute(s) inhalation-rat LC50; 20487 mg/m3/5 minute(s) inhalation-mouse LC50; 7004 mg/m3/30 minute(s) inhalation-rat LC50; 3940 mg/m3/30 minute(s) inhalation-mouse LC50; 450 mg/m3/6 hour(s) inhalation-mammal TCLo; 7.3 mg/kg intratracheal-dog LDLo; 75 mg/m3 inhalation-human LCLo; 50 mg/m3 inhalation-human TCLo; 685 ug/m3/24 hour(s)-84 day(s) continuous inhalation-rat TCLo; 149 mg/m3/6 hour(s)-5 day(s) intermittent inhalation-rabbit TCLo; 150 mg/m3/6 hour(s)-50 day(s) intermittent inhalation-rabbit TCLo; 150 mg/m3/6 hour(s)-50 day(s) intermittent inhalation-cat TCLo

CARCINOGEN STATUS:
IARC: Human Inadequate Evidence, Animal Inadequate Evidence, Group 3; ACGIH: A4 -Not Classifiable as a Human Carcinogen

LOCAL EFFECTS:
Corrosive: inhalation, skin, eye, ingestion

ACUTE TOXICITY LEVEL:
Toxic: inhalation Moderately Toxic: ingestion

MUTAGENIC DATA:
DNA repair - Escherichia coli 25 ug/well; sex chromosone loss and non disjunction - Drosophila melanogaster inhalation 100 ppm 24 hour(s); sex chromosone loss and non disjunction - Drosophila melanogaster oral 100 ppm; cytogenetic analysis - grasshopper parenteral 20 mg; cytogenetic analysis - hamster lung 30 mmol/L; cytogenetic analysis -hamster ovary 8 mmol/L

REPRODUCTIVE EFFECTS DATA:
450 mg/m3 inhalation-rat TCLo/1 hour(s) 1 day(s) pre pregnancy continuous

AMMONIUM CHLORIDE:

IRRITATION DATA:
500 mg/24 hour(s) eyes-rabbit mild; 100 mg eyes-rabbit severe

TOXICITY DATA:
2 gm/kg oral-infant LDLo; 1650 mg/kg oral-rat LD50; 30 mg/kg intramuscular-rat LD50; 550 mg/kg unreported-rat LD50; 1300 mg/kg oral-mouse LD50; 485 mg/kg intraperitoneal-mouse LD50; 500 mg/kg subcutaneous-mouse LDLo; 358 mg/kg intravenous-mouse LD50; 200 mg/kg subcutaneous-rabbit LDLo; 78 mg/kg intravenous-rabbit LDLo; 72 mg/kg subcutaneous-guinea pig LDLo;220 mg/kg intravenous-guinea pig LDLo; 1500 mg/kg oral-domestic animal LDLo; 0.005 gm/kg oral-rabbit LDLo; 0.02 gm/kg oral-dog LDLo; 250 mg/kg intraperitoneal-mouse LDLo; 140 mg/kg intraperitoneal-rat LDLo; 51660 mg/kg/10 week(s) continuous oral-rat TDLo; 56100 mg/kg/170 day(s) intermittent oral-rat TDLo; 556 gm/kg/78 week(s) continuous oral-rat TDLo; 35.3 gm/kg/4 week(s) continuous oral-rat TDLo; 52.9 gm/kg/6 week(s) continuous oral-rat TDLo; 3500 mg/kg/1 week(s) continuous oral-rat TDLo; 29.4 gm/kg/4 week(s) continuous oral-rat TDLo; 455 gm/kg/130 week(s) continuous oral-rat TDLo; 44.1 gm/kg/6 week(s) continuous oral-rat TDLo

LOCAL EFFECTS:
Irritant: inhalation, eye

ACUTE TOXICITY LEVEL:
Moderately Toxic: ingestion

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE:
kidney disorders

MUTAGENICDATA:
cytogenetic analysis - hamster fibroblast 400 mg/L

ADDITIONAL DATA:
Interactions with drugs may occur.

HEALTH EFFECTS
INHALATION:
OATEY #11 LIQUID FLUX (Oatey Company has reported the following): If heated, fumes may produce respiratory irritation, fever, chills, muscular pain, vomiting and sweating.

ACUTE EXPOSURE:
ZINC CHLORIDE:Fumes may be severely irritating to the upper respiratory tract and may cause a metallic taste, lacrimation, sore throat, loss of voice, hoarseness, coughing with copious sputum, a constrictive sensation inthe chest, strider, chest pain and soreness. Gastrointestinal disturbances including nausea, abdominal pain and severe gastritis with vomiting may occur. Fever, dyspnea and tachypnea, shortness or breath, listlessness, pale, gray cyanosis, rapid pulse, tachycardia and coma have also been reported. Respiratory effects may include severe inflammation of the upper respiratory tract, rhinitis, hemorrhagic alveolitis, severe pneumonitis, tracheobronchitis, diffuse pulmonary infiltrations, acute interstitial and advanced pulmonary fibrosis, pulmonary edema and bronchopneumonia. Death may be due to pulmonary edema, respiratory failure and bronchopneumonia. Autopsy revealed red and edematous mucous membrane and pulmonary necrosis, active fibroblastic proliferation and cor pulmonale.

HYDROGEN CHLORIDE (HYDROCHLORIC ACID): Inhalation of fumes at levels of 5-35 ppm may cause irritation and burning of the throat, coughing and choking; 50-100 ppm may be barely tolerable for 1 hour. High levels may cause inflammation and occasionally ulceration of the nose, throat or larynx, bronchitis, pneumonia, palpitations and headache. Higher concentrations may cause necrosis of the tracheal and bronchial epithelium, nasoseptal perforation, atelectasis, emphysema, damage to pulmonary blood vessels and lesions of the liverand other organs. Death may be due to laryngeal spasm, bronchopneumonia or pulmonary edema. 1300-2000 ppm may be dangerous, even on brief exposures. Reproductive effects have been reported in animals.

AMMONIUM CHLORIDE: Inhalation of the dust may cause irritation with coughing, sore throat and difficult breathing. Laboratory animals exposed to 50 mg/m3 for 6 hours showed no signs ofintoxication. However, post mortem examination showed congestion of the trachea and bronchial mucosa; the lungs were distended and emphysematous with petechial hemorrhaging and hyperemia. Changes wereevident in the liver, spleen and adrenal medulla.

CHRONIC EXPOSURE:
ZINC CHLORIDE: Prolonged inhalation may result in ulceration of the nasal septum.

HYDROGEN CHLORIDE (HYDROCHLORIC ACID): Repeated or prolonged exposure may cause erosion and discoloration of exposed teeth, chronic bronchitis and gastritis.
AMMONIUM CHLORIDE: No data available.
SKIN CONTACT:
OATEY #11 LIQUID FLUX (Oatey Company has reported the following): Maycause irritation, burns or dermatitis.

ACUTE EXPOSURE:
ZINC CHLORIDE: Dust, fumes or solutions may cause severe irritation, redness, pain, papular and primary dermatitis, chemical burns, of theskin, boils, and ulceration of the fingers, hands and forearms. Sensitization reactions in the form of eczematoid dermatitis have been

reported.

HYDROGEN CHLORIDE (HYDROCHLORIC ACID): Contact may cause severe irritation, inflammation, ulceration, necrosis and chemical burns. Shock symptoms may develop including rapid pulse, sweating and collapse. Photosensitization reactions may occur in persons previously exposed.

AMMONIUM CHLORIDE: May cause irritation.

CHRONIC EXPOSURE:
ZINC CHLORIDE: Repeated or prolonged contact may cause boils, dermatitis or sensitization dermatitis in previously exposed persons. Repeated contact has produced fatigability, poor appetite, constipation and pains in the long bones of the legs.

HYDROGEN CHLORIDE (HYDROCHLORIC ACID): Repeated or prolonged contact with vapors or dilute solutions may cause dermatitis. Photosensitization may occur.

AMMONIUM CHLORIDE: Repeated or prolonged contact may cause dermatitis.

EYE CONTACT:
OATEY #11 LIQUID FLUX (Oatey Company has reported the following): Maycause irritation or corneal damage.

ACUTE EXPOSURE:
ZINC CHLORIDE: Contact may cause severe irritation and pain, redness, blurred visionand injuries including corneal burns, ulceration and vascularization,conjunctivitis, dermatitis, and iritis. A splash in the eye caused, initially, some redness and persistent discomfort, but within 6 days it lead to a discrete stromal opacity in the lower part of the corneawith irregularities of the overlying epithelium. From an accidental instillation of a drop of 50% zinc chloride solution, the corneal epithelium became eroded, the lids red and swollen, and a mucopurulent discharge developed. Large folds developed in the Descemet's membrane, and the corneal stroma became turbid. This was accompanied by severe iritis with small hemorrhages in the iris. Deepand superficial vascularization of the cornea followed.

HYDROGEN CHLORIDE (HYDROCHLORIC ACID): Contact may cause severe irritation, conjunctivitis, corneal necrosis and burns with impairment or permanent loss of vision. A drop of hydrochloric acid splashed in theeye and immediately washed out has produced a white coagulation of the corneal and conjunctival epithelium. Animals exposed to vapor concentrations of 1350 ppm for one and a half hours showed clouding of the cornea and 300 ppm for 6 hours showed slight erosion of the corneal epithelium.

AMMONIUM CHLORIDE: May cause irritation with redness and pain. Solutions less than 10% are generally well tolerated by the eye.

CHRONIC EXPOSURE:
ZINC CHLORIDE: Repeated and prolonged contact to dust or vapor may cause conjunctivitis.

HYDROGENCHLORIDE (HYDROCHLORIC ACID): Animals exposed to vapor at 100 ppm for6 hours daily for 50 days showed only slight unrest and irritation ofthe eyes, but no ocular injury. Effects are dependent upon concentration and duration of exposure. Conjunctivitis or effects similar to those for acute exposure may occur.

AMMONIUM CHLORIDE: Repeated or prolonged contact may cause conjunctivitis.

INGESTION:

OATEY #11 LIQUID FLUX (Oatey Company has reported the following): Maycause burns of the mouth and throat, vomiting, diarrhea, strictures, kidney disease, shock and death.

ACUTE EXPOSURE:

ZINC CHLORIDE: Ingestion may cause severe irritation of mucous membranes with corrosion, swollen lips, edema of the glottis, sore throat, chest pain and gastrointestinal disturbances including nausea, vomiting, bloody diarrhea, and abdominal pain. Perforation of the viscous may occur. Lethargy, bloody urine, albuminuria, gastritis and pyloric stenosis have been reported. Other effects may include cold skin, lowblood pressure, dyspnea and collapse with shock and hypocalcemia. Death has been reported. Delayed deaths have been ascribed to inanition following severe strictures of the esophagus and pyloris. Survivors of zinc salt ingestion may have residual nephritis.

HYDROGEN CHLORIDE (HYDROCHLORIC ACID): Ingestion of the acid may cause burns of the mouth, throat, esophagus and stomach with consequent pain, uneasiness, nausea, salivation, vomiting, diarrhea, chills, shock and intense thirst. Nephritis, fever and perforation ofthe intestinal tract, and circulatory collapse may occur. Death may be due to esophageal or gastric necrosis.

AMMONIUM CHLORIDE: May cause irritation of mouth and stomach with nausea or vomiting. Large doses may cause diuresis, systemic acidosis and ammonia poisoning.

CHRONIC EXPOSURE:

ZINC CHLORIDE: Reproductive effects have been reported in animals.

HYDROGEN CHLORIDE (HYDROCHLORIC ACID): No data available.

AMMONIUM CHLORIDE: Repeated ingestion may cause nausea, vomiting, acidosis, hypoproteinemia, demineralization of boney structures, and coma. Rabbits with damaged livers, and adrenals removed, were fed ammonium chloride for 120 days, resulting in permanent changes in the electroretinogram and degeneration of the ganglion cell layer of the retina.

SECTION 12 - ECOLOGICAL INFORMATION

SECTION 13 - DISPOSAL CONSIDERATIONS

Dispose in accordance with all applicable regulations.

SECTION 14 - TRANSPORT INFORMATION

U.S. DOT 49 CFR 172.101:

PROPER SHIPPING NAME: Corrosive liquids, n.o.s. (zinc chloride, hydrogen chloride) ID NUMBER: UN1760 HAZARD IATA/ICAO CLASS: 8 PACKING GROUP: II LABELING REQUIREMENTS: 8

CANADIAN TRANSPORTATION OF DANGEROUS GOODS:

No classification assigned.

LAND TRANSPORT ADR/RID:
PROPER SHIPPING NAME: Corrosive liquid, n.o.s. UN NUMBER: UN1760 CLASS: 8 CLASSIFICATION CODE: C9 PACKING GROUP: II LABELS: 8

AIR TRANSPORTIATA/ICAO:
PROPER SHIPPING NAME: Corrosive liquid, n.o.s. UN NUMBER: UN1760 IATA/ICAO CLASS: 8 LABELS: 8 UN PACKING GROUP: II

MARITIME TRANSPORT IMDG:
PROPER SHIPPING NAME: Corrosive liquid, n.o.s. UN NUMBER: UN1760 PACKING GROUP: II

SECTION 15 - REGULATORY INFORMATION

TSCA Status : Listed on inventory.
TSCA 12(b) export notification : Not listed.
SARA Section 302 (40 CFR 355.30) : HYDROGEN CHLORIDE (HYDROCHLORIC ACID): 500 LBS TPQ (gas) TPQ
SARA Section 304 (40 CFR 355.40) : HYDROGEN CHLORIDE (HYDROCHLORIC ACID): 5000 LBS RQ (gas) RQ
California Prop 65 Status : Not regulated.
SARA ACUTE Hazard : Yes
SARA CHRONIC Hazard : Yes
SARA FIRE Hazard : No
SARA REACTIVITY Hazard : No
SARA SUDDEN RELEASE Hazard : No

SECTION 16 - OTHER INFORMATION

No other information is currently available for this record
?

T S3/9/3

3/9/3 (Item 3 from file: 332)
DIALOG(R)File 332:Material Safety Data Sheets -
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00053665
OHS/MDL Record Number : OHSIR549

MATERIAL SAFETY DATA SHEET

SECTION 1 - CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

MDL Information Systems, Inc.
14600 Catalina Street
San Leandro CA 94577
1-800-635-0064 (Toll Free) or
1-510-895-1313

FOR EMERGENCY SOURCE INFORMATION
CONTACT: 1-615-366-2000 in USA

EU Number(EINICS) : 232-373-2

SUBSTANCE: OATEY #5 PASTE FLUX

TRADE NAME/SYNONYM(S): FLUX FOR COPPER PIPE; OHSIR549

CREATION DATE: 19950620 REVISED: 20041209

SECTION 2 - COMPOSITION, INFORMATION ON INGREDIENTS

---

1) Component Substance: PETROLATUM
   Component Percent: 65-75 %
   CAS Registry Number: 8009-03-8
2) Component Substance: ZINC CHLORIDE
   Component Percent: 20-25 %
   CAS Registry Number: 7646-85-7
3) Component Substance: AMMONIUM CHLORIDE
   Component Percent: 1-5 %
   CAS Registry Number: 12125-02-9

SECTION 3 - HAZARDS IDENTIFICATION

NFPA Ratings (scale 0-4): Health=3 Fire=0 Reactivity=0

EMERGENCY OVERVIEW:
COLOR: yellow
PHYSICAL FORM: paste
ODOR: faint odor
MAJOR HEALTH HAZARDS: harmful if swallowed, respiratory tract burns, skin burns, eye burns, mucous membrane burns, allergic reactions, suspect cancer hazard (in animals)

POTENTIAL HEALTH EFFECTS
INHALATION:
SHORT TERM EXPOSURE: irritation (possibly severe)
LONG TERM EXPOSURE: burns
SKIN CONTACT:
SHORT TERM EXPOSURE: irritation (possibly severe), allergic reactions
LONG TERM EXPOSURE: irritation (possibly severe), allergic reactions, skin disorders
EYE CONTACT:
SHORT TERM EXPOSURE: irritation (possibly severe), blurred vision

LONG TERM EXPOSURE: irritation (possibly severe)
INGESTION:
SHORT TERM EXPOSURE: irritation (possibly severe), nausea,vomiting, diarrhea, stomach pain, death
LONG TERM EXPOSURE: burns, nausea, vomiting, loss of appetite, bone disorders, coma

CARCINOGEN STATUS:
OSHA: No
NTP: No
IARC: No

SECTION 4 - FIRST AID MEASURES

INHALATION:
If adverse effects occur, remove to uncontaminated area. Give artificial respiration if not breathing. If breathing is difficult, oxygen should be administered by qualified personnel. Get immediate medical attention.
SKIN CONTACT:
Wash skin with soap and water for at least 15 minutes while removing contaminated clothing and shoes. Get immediate medical attention. Thoroughly clean and dry contaminated clothing and shoes before reuse. Destroy contaminated shoes.
EYE CONTACT:
Immediately flush eyes with plenty of water for at least 15 minutes. Then get immediate medical attention.
INGESTION:
Never make an unconscious person vomit or drink fluids. Give large amounts of water. DO NOT induce vomiting. If vomiting occurs, keep head lower than hips to help prevent aspiration. If person is unconscious, turn head to side. Get medical attention immediately.
NOTE TO PHYSICIAN:
For inhalation, consider oxygen.

SECTION 5 - FIRE FIGHTING MEASURES

FIRE AND EXPLOSION HAZARD:
Negligible fire hazard.
EXTINGUISHING MEDIA:
carbon dioxide, regular dry chemical, regular foam, water
FIREFIGHTING:
Move container from fire area if it can be done without risk. Cool containers with water spray until well after the fire is out. Do not get water directly on material. Avoid inhalation of material or combustion by-products. Stay upwind and keep out of low areas.

FLASH POINT: 540 F (282 C)
FLAMMABILITY CLASS (OSHA): IIIB

SECTION 6 - ACCIDENTAL RELEASE MEASURES

OCCUPATIONAL SPILL:
Do not touch spilled material. Stop leak if possible without personalrisk. Small spills: Absorb with sand or other non-combustible material. Small dry spills: Collect spilled material in appropriate container for disposal. Keep unnecessary people away, isolate hazard area and deny entry. Notify Local Emergency Planning Committee and State Emergency Response Commission for release greater than or equalto RQ (U.S. SARA Section 304). If release occurs in the U.S. and is reportable under CERCLA Section 103, notify the National Response Center at

(800)424-8802 (USA) or (202)426-2675 (USA).

SECTION 7 - HANDLING AND STORAGE

STORAGE: Store and handle in accordance with all current regulations and standards. Keep separated from incompatible substances. See original container for storage recommendations.

SECTION 8 - EXPOSURE CONTROLS, PERSONAL PROTECTION

EXPOSURE LIMITS:
OATEY #5 PASTE FLUX:

PARAFFIN WAX FUME:
2 mg/m3 OSHA TWA (vacated by58 FR 35338, June 30, 1993)
2 mg/m3 ACGIH TWA
2 mg/m3 NIOSH recommended TWA 10 hour(s)
2 mg/m3 UK OES TWA
6 mg/m3 UK OES STEL
MINERAL OIL MIST:
5 mg/m3 OSHA TWA
5 mg/m3 ACGIH TWA
10 mg/m3 ACGIH STEL
5 mg/m3 NIOSH recommended TWA 10 hour(s)
10 mg/m3 NIOSH recommended STEL
5 mg/m3 UK OES TWA (excluding metalworking fluids)
10 mg/m3 UK OES STEL (excluding metalworking fluids)
MEASUREMENT METHOD: Particulate filter; Carbon tetrachloride; Infrared spectrometry; NIOSH IV # 5026 ZINC CHLORIDE: 1 mg/m3 OSHA TWA (fume) 2 mg/m3 OSHA STEL (vacated by 58 FR 35338, June 30, 1993) 1 mg/m3 ACGIH TWA (fume) 2 mg/m3 ACGIH STEL (fume) 1 mg/m3 NIOSH recommended TWA 10 hour(s) (particulate) (fume) 2 mg/m3 NIOSH recommended STEL (fume) 1 mg/m3 UK OES TWA (fume) 2 mg/m3 UK OES STEL (fume) MEASUREMENT METHOD: Particulate filter; Water; Flame atomic absorption spectrometry; OSHA # ID121 AMMONIUM CHLORIDE: 10 mg/m3 OSHA TWA (particulate) (vacated by 58 FR 35338, June 30, 1993) 20 mg/m3 OSHA STEL (particulate) (vacated by 58 FR 35338, June 30, 1993)10 mg/m3 ACGIH TWA (fume) 20 mg/m3 ACGIH STEL (fume) 10 mg/m3 NIOSH recommended TWA 10 hour(s) (fume) 20 mg/m3 NIOSH recommended STEL (fume) 10 mg/m3 UK OES TWA (fume) 20 mg/m3 UK OES STEL (fume) MEASUREMENT METHOD: Particulate filter; Water; Ion chromatography; OSHA # ID188

VENTILATION:
Provide local exhaust ventilation system. Ensure compliance with applicable exposure limits.

EYE PROTECTION:
Wear splash resistant safety goggles with a faceshield. Provide an emergency eye wash fountain and quick drench shower in the immediate work area.

CLOTHING:
Wear appropriate chemical resistant clothing.

GLOVES:
Wear appropriate chemical resistant gloves.

PROTECTIVE MATERIAL TYPES:
rubber

RESPIRATOR:
No respirator is required under normal conditions of use. Under conditions of frequent use or heavy exposure, respiratory protection may be needed. Any dust, mist, and fume respirator. Any air-purifyingrespirator with a high-efficiency particulate filter. Any powered, air-purifying respirator with a dust, mist, and fume filter. Any

powered, air-purifying respirator with a high-efficiency particulate filter.

For Unknown Concentrations or Immediately Dangerous to Life or Health - Any supplied-air respirator with full facepiece and operated in a pressure-demand or other positive-pressure mode in combination with a separate escape supply. Any self-contained breathing apparatus with a full facepiece.

SECTION 9 - PHYSICAL AND CHEMICAL PROPERTIES

DESCRIPTION: PHYSICAL STATE: liquid
COLOR: yellow
PHYSICAL FORM: paste
ODOR: faintodor
BOILING POINT: 639 F (337 C)
MELTING POINT: Not available
SPECIFIC GRAVITY: Not available
pH: Not available
VAPOR PRESSURE: Not available
VAPOR DENSITY: >1
VOLATILITY: 7-10%
EVAPORATION RATE: Not available
ODOR THRESHHOLD: Not available
WATER SOLUBILITY: almost insoluble
SOLVENT SOLUBILITY: Soluble: dichloromethane

SECTION 10 - STABILITY AND REACTIVITY

REACTIVITY:
Stable at normal temperatures and pressure.
CONDITIONS TO AVOID:
Avoid heat, flames, sparks and other sources of ignition. May ignite or explode on contact with combustible materials.
INCOMPATIBILITIES:
No data available

ZINC CHLORIDE:
BASES: Possible violent reaction

CYANIDES: Release of toxic hydrogen cyanide gas

POTASSIUM: Forms impact-sensitive mixture

SULFIDE SALTS: Release of toxic hydrogen sulfide gas

ZINC: Forms flammable mixture

AMMONIUM CHLORIDE:
ACIDS (STRONG): Evolves corrosive hydrogen chloride gas

ALKALIS AND THEIR CARBONATES: Incompatible

AMMONIUM NITRATE: Violent decomposition

BASES (STRONG): Evolves corrosive ammonia gas

BROMINE PENTAFLUORIDE:Violent reaction with ignition

BROMINE TRIFLUORIDE: May cause explosion

COPPER AND ITS COMPOUNDS: May be attacked

HYROGEN CYANIDE: Formation of explosive nitrogen trichloride

IODINE HEPTAFLUORIDE: Violent reaction
LEAD SALTS: Incompatible

METALS: May be corroded in the presence of moisture

POTASSIUM CHLORATE: Violent reaction or explosion

SILVER SALTS: Formation of explosive silver compounds

PETROLATUM:
CALCIUM HYPOCHLRITE: Incompatible

CHLORINE (LIQUID): Incompatible

OXIDIZERS (STRONG): Fire and explosion hazard

OXYGEN (CONCENTRATED): Incompatible

SODIUM HYPOCHLORITE: Incompatible

HAZARDOUS DECOMPOSITION:
Thermal decomposition products: oxides of carbon, hydrochloric acid, hydrocarbons, smoke
POLYMERIZATION:
Will not polymerize.

SECTION 11 - TOXICOLOGICAL INFORMATION

PETROLATUM:

TOXICITY DATA:
>50 gm/kg intraperitoneal-mouse LD50; 100 ml/kg/30 day(s) intermittent skin-rabbit TDLo
CARCINOGEN STATUS:
IARC: Human Inadequate Evidence, Animal Inadequate Evidence, Group 3 (Highly refined oils); EC: Category 2
ACUTE TOXICITY LEVEL:
Insufficient Data.
ZINC CHLORIDE:

TOXICITY DATA:
169 mg/kg oral-child TDLo; 4800 mg/m3/30 minute(s) inhalation-man TCLo; 350 mg/kg oral-rat LD50; 1960 mg/m3/10 minute(s) inhalation-rat LCLo; 58 mg/kg intraperitoneal-rat LD50; 3690 ug/kg intravenous-rat LD50; >1500 ul/kg intratracheal-rat LD; 329 mg/kg oral-mouse LD50; 24 mg/kgintraperitoneal-mouse LD50; 330 mg/kg subcutaneous-mouse LD50; 9090 ug/kg intravenous-mouse LD50; 11 mg/kg intravenous-rabbit LDLo; 200 mg/kg oral-guinea pig LD50; 173 mg/kg intraperitoneal-guinea pig LDLo; 2.04 mg/kg oral-mouse TDLo; 9.3 mg/kg intraperitoneal-rat TDLo;5690 mg/kg/13 week(s) intermittent oral-rat TDLo; 910 mg/kg/26 week(s) intermittent oral-rat TDLo; 1680 mg/kg/14 day(s) intermittentoral-rat TDLo; 6875 mg/kg/39 week(s) intermittent oral-mammal TDLo; 21504 mg/kg/12 week(s) continuous oral-mouse TDLo; 595 mg/kg/2 week(s) continuous oral-rat TDLo; 3360 mg/kg/12 week(s) continuous oral-rat TDLo; 13440 mg/kg/12 week(s) intermittent oral-mouse TDLo; 76.44 mg/kg/14 week(s) intermittent

oral-mouse TDLo; 109.2 mg/kg/20 week(s) intermittent oral-mouse TDLo; 218.4 mg/kg/20 week(s) intermittent oral-mouse TDLo; 40 mg/kg/2 day(s) intermittent subcutaneous-rat TDLo
LOCAL EFFECTS:
Corrosive: inhalation, skin, eye, ingestion
ACUTE TOXICITY LEVEL:
Toxic: ingestion
TARGET ORGANS:
immune system (sensitizer)
TUMORIGENIC DATA:
17 mg/kg parenteral-hamster TDLo; 15 mg/kg parenteral-chicken TDLo
MUTAGENIC DATA:
mutation in microorganisms - Salmonella typhimurium 90 mmol/L (-S9); phage inhibition capacity - Escherichia coli 3200 umol/L; specific locus test - Drosophila melanogaster oral 6 mmol/L; micronucleus test - non-mammalian species other cell types 170 ug/L 48 hour(s); DNA damage - human fibroblast 2 mmol/L; unscheduled DNA synthesis - human lymphocyte 180 umol/L; DNA inhibition - human lymphocyte 360 umol/L; other mutation test systems - human lymphocyte2 mg; cytogenetic analysis - human lymphocyte 300 umol/L; cytogeneticanalysis - rat Ascites tumor 700 mg/kg; DNA inhibition - mouse parenteral 16 mg/kg; cytogenetic analysis - mouse oral 18 gm/kg 30 day(s)-continuous; host-mediated assay - mouse Salmonella typhimurium6 mg/kg; morphological transformation - hamster embryo 180 umol/L
REPRODUCTIVE EFFECTS DATA:
155 mg/kg oral-rat TDLo 33 day(s) male; 6gm/kg oral-rat TDLo 77 day(s) male day(s) pre pregnancy/77 day(s) post pregnancy/21 day(s) continuous; 30 gm/kg intraperitoneal-rat TDLo 7-8 day(s) pregnant female continuous; 37500 ug/kg parenteral-rat TDLo 10 day(s) pregnant female continuous; 20500 ug/kgintraperitoneal-mouse TDLo 8 day(s) pregnant female continuous; 12500ug/kg intraperitoneal-mouse TDLo 11 day(s) pregnant female continuous; 29184 ug/kg intravaginal-rabbit TDLo 1 day(s) pre pregnancy continuous; 1.8 gm/kg oral-rat TDLo 98 day(s) male day(s) pre pregnancy/98 day(s) post pregnancy/3 week(s) continuous; 7.1 gm/kg oral-rat TDLo 98 day(s) male day(s) pre pregnancy/98 day(s) post pregnancy/3 week(s) continuous; 186 mg/kg oral-mouse TDLo 98 day(s) male day(s) pre pregnancy/98 day(s) post pregnancy/3 week(s) continuous; 186 mg/kg oral-mouse TDLo multigenerations; 1.8 gm/kg oral-rat TDLo 98 day(s) male day(s) pre pregnancy/98 day(s) post pregnancy/3 week(s) continuous
AMMONIUM CHLORIDE:

IRRITATION DATA:
500 mg/24 hour(s) eyes-rabbit mild; 100 mg eyes-rabbit severe
TOXICITY DATA:
2 gm/kg oral-infant LDLo; 1650 mg/kg oral-rat LD50; 30 mg/kg intramuscular-rat LD50; 550 mg/kg unreported-rat LD50; 1300 mg/kg oral-mouse LD50; 485 mg/kg intraperitoneal-mouse LD50; 500 mg/kg subcutaneous-mouse LDLo; 358 mg/kg intravenous-mouse LD50; 200 mg/kg subcutaneous-rabbit LDLo; 78 mg/kg intravenous-rabbit LDLo; 72 mg/kg subcutaneous-guinea pig LDLo; 220 mg/kg intravenous-guinea pig LDLo; 1500 mg/kg oral-domestic animal LDLo; 0.005 gm/kg oral-rabbit LDLo; 0.02 gm/kg oral-dog LDLo; 250 mg/kg intraperitoneal-mouse LDLo;140 mg/kg intraperitoneal-rat LDLo; 51660 mg/kg/10 week(s) continuousoral-rat TDLo; 56100 mg/kg/170 day(s) intermittent oral-rat TDLo; 556gm/kg/78 week(s) continuous oral-rat TDLo; 35.3 gm/kg/4 week(s) continuous oral-rat TDLo; 52.9 gm/kg/6 week(s) continuous oral-rat TDLo; 3500 mg/kg/1 week(s) continuous oral-rat TDLo; 29.4 gm/kg/4 week(s) continuous oral-rat TDLo; 455 gm/kg/130 week(s) continuous oral-rat TDLo; 44.1 gm/kg/6 week(s) continuous oral-rat TDLo
LOCAL EFFECTS:

Irritant: inhalation, eye
ACUTE TOXICITY LEVEL:
ModeratelyToxic: ingestion
MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE:
kidney disorders
MUTAGENIC DATA:
cytogenetic analysis - hamster fibroblast 400 mg/L
ADDITIONAL DATA:
Interactions with drugs may occur.

HEALTH EFFECTS
INHALATION:
ACUTE EXPOSURE:
PETROLATUM: High concentrations may cause irritationof the respiratory tract.

ZINC CHLORIDE: Fumes may be severely irritating to the upper respiratory tract and may cause a metallic taste, lacrimation, sore throat, loss of voice, hoarseness, coughing with copious sputum, a constrictive sensation in the chest, strider, chest pain and soreness. Gastrointestinal disturbances including nausea, abdominal pain and severe gastritis with vomiting may occur. Fever, dyspnea and tachypnea, shortness or breath, listlessness, pale, gray cyanosis, rapid pulse, tachycardia and coma have also beenreported. Respiratory effects may include severe inflammation of the upper respiratory tract, rhinitis, hemorrhagic alveolitis, severe pneumonitis, tracheobronchitis, diffuse pulmonary infiltrations, acute interstitial and advanced pulmonary fibrosis, pulmonary edema and bronchopneumonia. Death may be due to pulmonary edema, respiratory failure and bronchopneumonia. Autopsy revealed red and edematous mucous membrane and pulmonary necrosis, active fibroblasticproliferation and cor pulmonale.

AMMONIUM CHLORIDE: Inhalation of thedust may cause irritation with coughing, sore throat and difficult breathing. Laboratory animals exposed to 50 mg/m3 for 6 hours showed no signs of intoxication. However, post mortem examination showed congestion of the trachea and bronchial mucosa; the lungs were distended and emphysematous with petechial hemorrhaging and hyperemia. Changes were evident in the liver, spleen and adrenal medulla.
CHRONIC EXPOSURE:
PETROLATUM: Rarely, prolonged or repeatedinhalation of mist has caused shortness of breath, cough and lipid pneumonia.

ZINC CHLORIDE: Prolonged inhalation may result in ulceration of the nasal septum.

AMMONIUM CHLORIDE: No data available.
SKIN CONTACT:
ACUTE EXPOSURE:
PETROLATUM: May cause slight irritation. Rarely, hypersensitivity reactions and dermatitis have been reported.

ZINC CHLORIDE: Dust, fumes or solutions may cause severe irritation, redness, pain, papular and primary dermatitis, chemical burns, of theskin, boils, and ulceration of the fingers, hands and forearms. Sensitization reactions in the form of eczematoid dermatitis have been reported.

AMMONIUM CHLORIDE: May cause irritation.

CHRONIC EXPOSURE:
PETROLATUM: Repeated or prolonged exposure from cosmetic use may result in acniform eruptions, irritation and pigmentation. Mice tested by twice-weekly application of 60 uL produced 5 papillomas but no cancer. The study showed no significant difference of papillomas when compared with controls.

ZINC CHLORIDE: Repeated orprolonged contact may cause boils, dermatitis or sensitization dermatitis in previously exposed persons. Repeated contact has produced fatigability, poor appetite, constipation and pains in the long bones of the legs.

AMMONIUM CHLORIDE: Repeated or prolonged contact may cause dermatitis.
EYE CONTACT:
ACUTE EXPOSURE:
PETROLATUM: May cause irritation.

ZINC CHLORIDE: Contact may cause severe irritation and pain, redness, blurred visionand injuries including corneal burns, ulceration and vascularization,conjunctivitis, dermatitis, and iritis. A splash in the eye caused, initially, some redness and persistent discomfort, but within 6 days it lead to a discrete stromal opacity in the lower part of the corneawith irregularities of the overlying epithelium. From an accidental instillation of a drop of 50% zinc chloride solution, the corneal epithelium became eroded, the lids red and swollen, and a mucopurulent discharge developed. Large folds developed in the Descemet's membrane, and the corneal stroma became turbid. This was accompanied by severe iritis with small hemorrhages in the iris. Deepand superficial vascularization of the cornea followed.

AMMONIUM CHLORIDE: May cause irritation with redness and pain. Solutions less than 10% are generally well tolerated by the eye.

CHRONIC EXPOSURE:
PETROLATUM: No data available.

ZINC CHLORIDE: Repeated and prolonged contact to dust or vapor may cause conjunctivitis.

AMMONIUM CHLORIDE:Repeated or prolonged contact may cause conjunctivitis.
INGESTION:
ACUTE EXPOSURE:
PETROLATUM: Large amounts may cause abdominal pain and diarrhea. Aspiration may result in chemical pneumonitis.
ZINC CHLORIDE: Ingestion may cause severe irritation of mucous membranes with corrosion, swollen lips, edema of the glottis, sore throat, chest pain and gastrointestinal disturbances including nausea, vomiting, bloody diarrhea, and abdominal pain. Perforation of the viscous may occur. Lethargy, bloody urine, albuminuria, gastritis andpyloric stenosis have been reported. Other effects may include cold skin, low blood pressure, dyspnea and collapse with shock and hypocalcemia. Death has been reported. Delayed deaths have been ascribed to inanition following severe strictures of the esophagus and pyloris. Survivors of zinc salt ingestion may have residual nephritis.

AMMONIUM CHLORIDE: May cause irritation of mouth and stomach with nausea or vomiting. Large doses may cause diuresis, systemic acidosis and ammonia poisoning.

CHRONIC EXPOSURE:

PETROLATUM: If the liquid form is taken continuously for therapeutic use, large amounts may impair the appetite, reduce the absorption of fat soluble vitamins and possibly cause changes in the liver and mesenteric lymph nodes. Rats fed various grades of petrolatum at 5% in the diet for 2 years showed no treatment-related tumor increase.
ZINC CHLORIDE: Reproductive effects have been reported in animals.

AMMONIUM CHLORIDE: Repeated ingestion may cause nausea, vomiting, acidosis, hypoproteinemia, demineralization of boney structures, and coma. Rabbits with damaged livers, and adrenals removed, were fed ammonium chloride for 120 days, resulting in permanent changes in theelectroretinogram and degeneration of the ganglion cell layer of the retina.

SECTION 12 - ECOLOGICAL INFORMATION

SECTION 13 - DISPOSAL CONSIDERATIONS

Dispose in accordance with all applicable regulations.

SECTION 14 - TRANSPORT INFORMATION

U.S. DOT 49 CFR 172.101:
PROPER SHIPPING NAME: Corrosive liquids, n.o.s. (zinc chloride) ID NUMBER: UN1760 HAZARD IATA/ICAO CLASS: 8 PACKING GROUP: II LABELING REQUIREMENTS: 8
CANADIAN TRANSPORTATION OF DANGEROUS GOODS:
No classification assigned.

LAND TRANSPORT ADR/RID:
PROPER SHIPPING NAME: Corrosive liquid, n.o.s. UN NUMBER: UN1760 CLASS: 8 CLASSIFICATION CODE: C9 PACKING GROUP: II LABELS: 8

AIR TRANSPORT IATA/ICAO:
PROPER SHIPPING NAME: Corrosive liquid, n.o.s. UN NUMBER: UN1760 IATA/ICAO CLASS:8 LABELS: 8 UN PACKING GROUP: II

MARITIME TRANSPORT IMDG:
PROPER SHIPPING NAME: Corrosive liquid, n.o.s. UN NUMBER: UN1760 PACKING GROUP: II

SECTION 15 - REGULATORY INFORMATION

TSCA Status	: Listed on inventory.
TSCA 12(b) export notification	: Not listed.
SARA Section 302 (40 CFR 355.30)	: Not regulated. TPQ
SARA Section 304 (40 CFR 355.40)	: Not regulated. RQ
California Prop 65 Status	: Not regulated.
SARA ACUTE Hazard	: Yes
SARA CHRONIC Hazard	: Yes
SARA FIRE Hazard	: No
SARA REACTIVITY Hazard	: No
SARA SUDDEN RELEASE Hazard	: No
WHMIS Classification	: Not regulated.

SECTION 16 - OTHER INFORMATION

No other information is currently available for this record
?

Subj: **flux composition**
Date: 4/1/2005 4:51:48 PM Pacific Standard Time
From: Phyllisfox
To: ASBritton

See if you can find the composition of flush used to solder copper pipe in drinking water systems. See page 44. I suggests finding a material safety data sheet, MSDS, for some typical fluxes. Fluxes are used to solder all kinds of things, so be sure you have one used for drinking water systems. I'm looking for percent organics.

http://64.90.169.191/applications/plumbing/techref/cth/handbook.pdf

T S3/9/3

3/9/3 (Item 3 from file: 332)
DIALOG(R)File 332:Material Safety Data Sheets -
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00053665
OHS/MDL Record Number : OHSIR549
MATERIAL SAFETY DATA SHEET

SECTION 1 - CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

MDL Information Systems, Inc.
14600 Catalina Street
San Leandro CA 94577
1-800-635-0064 (Toll Free) or
1-510-895-1313

FOR EMERGENCY SOURCE INFORMATION
CONTACT: 1-615-366-2000 in USA

EU Number(EINICS) : 232-373-2

SUBSTANCE: OATEY #5 PASTE FLUX

TRADE NAME/SYNONYM(S): FLUX FOR COPPER PIPE; OHSIR549

CREATION DATE: 19950620 REVISED: 20041209

SECTION 2 - COMPOSITION, INFORMATION ON INGREDIENTS

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1) Component Substance: PETROLATUM
   Component Percent: 65-75 %
   CAS Registry Number: 8009-03-8
2) Component Substance: ZINC CHLORIDE
   Component Percent: 20-25 %
   CAS Registry Number: 7646-85-7
3) Component Substance: AMMONIUM CHLORIDE
   Component Percent: 1-5 %
   CAS Registry Number: 12125-02-9

SECTION 3 - HAZARDS IDENTIFICATION

NFPA Ratings (scale 0-4): Health=3 Fire=0 Reactivity=0

EMERGENCY OVERVIEW:
COLOR: yellow
PHYSICAL FORM: paste
ODOR: faint odor
MAJOR HEALTH HAZARDS: harmful if swallowed, respiratory tract burns, skin burns, eye burns, mucous membrane burns, allergic reactions, suspect cancer hazard (in animals)

POTENTIAL HEALTH EFFECTS
INHALATION:
SHORT TERM EXPOSURE: irritation (possibly severe)
LONG TERM EXPOSURE: burns
SKIN CONTACT:
SHORT TERM EXPOSURE: irritation (possibly severe), allergic reactions
LONG TERM EXPOSURE: irritation (possibly severe), allergic reactions, skin disorders
EYE CONTACT:
SHORT TERM EXPOSURE: irritation (possibly severe), blurred vision

04/01/05 FRI 20:05 FAX 510 4651639 ALISON S BRITTON →→→ PHYLLIS FOX 001

LONG TERM EXPOSURE: irritation (possibly severe)
INGESTION:
SHORT TERM EXPOSURE: irritation (possibly severe), nausea,vomiting, diarrhea, stomach pain, death
LONG TERM EXPOSURE: burns, nausea, vomiting, loss of appetite, bone disorders, coma

CARCINOGEN STATUS:
OSHA: No
NTP: No
IARC: No

SECTION 4 - FIRST AID MEASURES

INHALATION:
If adverse effects occur, remove to uncontaminated area. Give artificial respiration if not breathing. If breathing is difficult, oxygen should be administered by qualified personnel. Get immediate medical attention.
SKIN CONTACT:
Wash skin with soap and water for at least 15 minutes while removing contaminated clothing and shoes. Get immediate medical attention. Thoroughly clean and dry contaminated clothing and shoes before reuse. Destroy contaminated shoes.
EYE CONTACT:
Immediately flush eyes with plenty of water for at least 15 minutes. Then get immediate medical attention.
INGESTION:
Never make an unconscious person vomit or drink fluids. Give large amounts of water. DO NOT induce vomiting. If vomiting occurs, keep head lower than hips to help prevent aspiration. If person is unconscious, turn head to side. Get medical attention immediately.
NOTE TO PHYSICIAN:
For inhalation, consider oxygen.

SECTION 5 - FIRE FIGHTING MEASURES

FIRE AND EXPLOSION HAZARD:
Negligible fire hazard.
EXTINGUISHING MEDIA:
carbon dioxide, regular dry chemical, regular foam, water
FIREFIGHTING:
Move container from fire area if it can be done without risk. Cool containers with water spray until well after the fire is out. Do not get water directly on material. Avoid inhalation of material or combustion by-products. Stay upwind and keep out of low areas.

FLASH POINT: 540 F (282 C)
FLAMMABILITY CLASS (OSHA): IIIB

SECTION 6 - ACCIDENTAL RELEASE MEASURES

OCCUPATIONAL SPILL:
Do not touch spilled material. Stop leak if possible without personalrisk. Small spills: Absorb with sand or other non-combustible material. Small dry spills: Collect spilled material in appropriate container for disposal. Keep unnecessary people away, isolate hazard area and deny entry. Notify Local Emergency Planning Committee and State Emergency Response Commission for release greater than or equalto RQ (U.S. SARA Section 304). If release occurs in the U.S. and is reportable under CERCLA Section 103, notify the National Response Center at

04/01/05 FRI 20:06 FAX 510 4651639 ALISON S BRITTON →→→ PHYLLIS FOX 002

(800)424-8802 (USA) or (202)426-2675 (USA).

SECTION 7 - HANDLING AND STORAGE

STORAGE: Store and handle in accordance with all current regulations and standards. Keep separated from incompatible substances. See original container for storage recommendations.

SECTION 8 - EXPOSURE CONTROLS, PERSONAL PROTECTION

EXPOSURE LIMITS:

OATEY #5 PASTE FLUX:

PARAFFIN WAX FUME:
2 mg/m3 OSHA TWA (vacated by58 FR 35338, June 30, 1993)
2 mg/m3 ACGIH TWA
2 mg/m3 NIOSH recommended TWA 10 hour(s)
2 mg/m3 UK OES TWA
6 mg/m3 UK OES STEL
MINERAL OIL MIST:
5 mg/m3 OSHA TWA
5 mg/m3 ACGIH TWA
10 mg/m3 ACGIH STEL
5 mg/m3 NIOSH recommended TWA 10 hour(s)
10 mg/m3 NIOSH recommended STEL
5 mg/m3 UK OES TWA (excluding metalworking fluids)
10 mg/m3 UK OES STEL (excluding metalworking fluids)
MEASUREMENT METHOD: Particulate filter; Carbon tetrachloride; Infrared spectrometry; NIOSH IV # 5026 ZINC CHLORIDE: 1 mg/m3 OSHA TWA (fume) 2 mg/m3 OSHA STEL (vacated by 58 FR 35338, June 30, 1993) 1 mg/m3 ACGIH TWA (fume) 2 mg/m3 ACGIH STEL (fume) 1 mg/m3 NIOSH recommended TWA 10 hour(s) (particulate) (fume) 2 mg/m3 NIOSH recommended STEL (fume) 1 mg/m3 UK OES TWA (fume) 2 mg/m3 UK OES STEL (fume) MEASUREMENT METHOD: Particulate filter; Water; Flame atomic absorption spectrometry; OSHA # ID121 AMMONIUM CHLORIDE: 10 mg/m3 OSHA TWA (particulate) (vacated by 58 FR 35338, June 30, 1993) 20 mg/m3 OSHA STEL (particulate) (vacated by 58 FR 35338, June 30, 1993)10 mg/m3 ACGIH TWA (fume) 20 mg/m3 ACGIH STEL (fume) 10 mg/m3 NIOSH recommended TWA 10 hour(s) (fume) 20 mg/m3 NIOSH recommended STEL (fume) 10 mg/m3 UK OES TWA (fume) 20 mg/m3 UK OES STEL (fume) MEASUREMENT METHOD: Particulate filter; Water; Ion chromatography; OSHA # ID188

VENTILATION:
Provide local exhaust ventilation system. Ensure compliance with applicable exposure limits.

EYE PROTECTION:
Wear splash resistant safety goggles with a faceshield. Provide an emergency eye wash fountain and quick drench shower in the immediate work area.

CLOTHING:
Wear appropriate chemical resistant clothing.

GLOVES:
Wear appropriate chemical resistant gloves.

PROTECTIVE MATERIAL TYPES:
rubber

RESPIRATOR:
No respirator is required under normal conditions of use. Under conditions of frequent use or heavy exposure, respiratory protection may be needed. Any dust, mist, and fume respirator. Any air-purifyingrespirator with a high-efficiency particulate filter. Any powered, air-purifying respirator with a dust, mist, and fume filter. Any

04/01/05 FRI 20:06 FAX 510 4651639 ALISON S BRITTON →→ PHYLLIS FOX 003

powered, air-purifying respirator with a high-efficiency particulate filter.

For Unknown Concentrations or Immediately Dangerous to Life or Health - Any supplied-air respirator with full facepiece and operated in a pressure-demand or other positive-pressure mode in combination with a separate escape supply. Any self-contained breathing apparatus with a full facepiece.

SECTION 9 - PHYSICAL AND CHEMICAL PROPERTIES

DESCRIPTION: PHYSICAL STATE: liquid
COLOR: yellow
PHYSICAL FORM: paste
ODOR: faintodor
BOILING POINT: 639 F (337 C)
MELTING POINT: Not available
SPECIFIC GRAVITY: Not available
pH: Not available
VAPOR PRESSURE: Not available
VAPOR DENSITY: >1
VOLATILITY: 7-10%
EVAPORATION RATE: Not available
ODOR THRESHHOLD: Not available
WATER SOLUBILITY: almost insoluble
SOLVENT SOLUBILITY: Soluble: dichloromethane

SECTION 10 - STABILITY AND REACTIVITY

REACTIVITY:
Stable at normal temperatures and pressure.
CONDITIONS TO AVOID:
Avoid heat, flames, sparks and other sources of ignition. May ignite or explode on contact with combustible materials.
INCOMPATIBILITIES:
No data available

ZINC CHLORIDE:
BASES: Possible violent reaction

CYANIDES: Release of toxic hydrogen cyanide gas

POTASSIUM: Forms impact-sensitive mixture

SULFIDE SALTS: Release of toxic hydrogen sulfide gas

ZINC: Forms flammable mixture

AMMONIUM CHLORIDE:
ACIDS (STRONG): Evolves corrosive hydrogen chloride gas

ALKALIS AND THEIR CARBONATES: Incompatible

AMMONIUM NITRATE: Violent decomposition

BASES (STRONG): Evolves corrosive ammonia gas

BROMINE PENTAFLUORIDE:Violent reaction with ignition

BROMINE TRIFLUORIDE: May cause explosion

COPPER AND ITS COMPOUNDS: May be attacked

HYROGEN CYANIDE: Formation of explosive nitrogen trichloride

IODINE HEPTAFLUORIDE: Violent reaction
LEAD SALTS: Incompatible

METALS: May be corroded in the presence of moisture

POTASSIUM CHLORATE: Violent reaction or explosion

SILVER SALTS: Formation of explosive silver compounds

PETROLATUM:
CALCIUM HYPOCHLRITE: Incompatible

CHLORINE (LIQUID): Incompatible

OXIDIZERS (STRONG): Fire and explosion hazard

OXYGEN (CONCENTRATED): Incompatible

SODIUM HYPOCHLORITE: Incompatible

HAZARDOUS DECOMPOSITION:
Thermal decomposition products: oxides of carbon, hydrochloric acid, hydrocarbons, smoke
POLYMERIZATION:
Will not polymerize.

SECTION 11 - TOXICOLOGICAL INFORMATION

PETROLATUM:

TOXICITY DATA:
>50 gm/kg intraperitoneal-mouse LD50; 100 ml/kg/30 day(s) intermittent skin-rabbit TDLo
CARCINOGEN STATUS:
IARC: Human Inadequate Evidence, Animal Inadequate Evidence, Group 3 (Highly refined oils); EC: Category 2
ACUTE TOXICITY LEVEL:
Insufficient Data.
ZINC CHLORIDE:

TOXICITY DATA:
169 mg/kg oral-child TDLo; 4800 mg/m3/30 minute(s) inhalation-man TCLo; 350 mg/kg oral-rat LD50; 1960 mg/m3/10 minute(s) inhalation-rat LCLo; 58 mg/kg intraperitoneal-rat LD50; 3690 ug/kg intravenous-rat LD50; >1500 ul/kg intratracheal-rat LD; 329 mg/kg oral-mouse LD50; 24 mg/kgintraperitoneal-mouse LD50; 330 mg/kg subcutaneous-mouse LD50; 9090 ug/kg intravenous-mouse LD50; 11 mg/kg intravenous-rabbit LDLo; 200 mg/kg oral-guinea pig LD50; 173 mg/kg intraperitoneal-guinea pig LDLo; 2.04 mg/kg oral-mouse TDLo; 9.3 mg/kg intraperitoneal-rat TDLo;5690 mg/kg/13 week(s) intermittent oral-rat TDLo; 910 mg/kg/26 week(s) intermittent oral-rat TDLo; 1680 mg/kg/14 day(s) intermittentoral-rat TDLo; 6875 mg/kg/39 week(s) intermittent oral-mammal TDLo; 21504 mg/kg/12 week(s) continuous oral-mouse TDLo; 595 mg/kg/2 week(s) continuous oral-rat TDLo; 3360 mg/kg/12 week(s) continuous oral-rat TDLo; 13440 mg/kg/12 week(s) intermittent oral-mouse TDLo; 76.44 mg/kg/14 week(s) intermittent

04/01/05 FRI 20:06 FAX 510 4651639 ALISON S BRITTON →→→ PHYLLIS FOX 005

oral-mouse TDLo; 109.2 mg/kg/20 week(s) intermittent oral-mouse TDLo; 218.4 mg/kg/20 week(s) intermittent oral-mouse TDLo; 40 mg/kg/2 day(s) intermittent subcutaneous-rat TDLo

LOCAL EFFECTS:

Corrosive: inhalation, skin, eye, ingestion

ACUTE TOXICITY LEVEL:

Toxic: ingestion

TARGET ORGANS:

immune system (sensitizer)

TUMORIGENIC DATA:

17 mg/kg parenteral-hamster TDLo; 15 mg/kg parenteral-chicken TDLo

MUTAGENIC DATA:

mutation in microorganisms - Salmonella typhimurium 90 mmol/L (-S9); phage inhibition capacity - Escherichia coli 3200 umol/L; specific locus test - Drosophila melanogaster oral 6 mmol/L; micronucleus test - non-mammalian species other cell types 170 ug/L 48 hour(s); DNA damage - human fibroblast 2 mmol/L; unscheduled DNA synthesis - human lymphocyte 180 umol/L; DNA inhibition - human lymphocyte 360 umol/L; other mutation test systems - human lymphocyte2 mg; cytogenetic analysis - human lymphocyte 300 umol/L; cytogeneticanalysis - rat Ascites tumor 700 mg/kg; DNA inhibition - mouse parenteral 16 mg/kg; cytogenetic analysis - mouse oral 18 gm/kg 30 day(s)-continuous; host-mediated assay - mouse Salmonella typhimurium6 mg/kg; morphological transformation - hamster embryo 180 umol/L

REPRODUCTIVE EFFECTS DATA:

155 mg/kg oral-rat TDLo 33 day(s) male; 6gm/kg oral-rat TDLo 77 day(s) male day(s) pre pregnancy/77 day(s) post pregnancy/21 day(s) continuous; 30 gm/kg intraperitoneal-rat TDLo 7-8 day(s) pregnant female continuous; 37500 ug/kg parenteral-rat TDLo 10 day(s) pregnant female continuous; 20500 ug/kgintraperitoneal-mouse TDLo 8 day(s) pregnant female continuous; 12500ug/kg intraperitoneal-mouse TDLo 11 day(s) pregnant female continuous; 29184 ug/kg intravaginal-rabbit TDLo 1 day(s) pre pregnancy continuous; 1.8 gm/kg oral-rat TDLo 98 day(s) male day(s) pre pregnancy/98 day(s) post pregnancy/3 week(s) continuous; 7.1 gm/kg oral-rat TDLo 98 day(s) male day(s) pre pregnancy/98 day(s) post pregnancy/3 week(s) continuous; 186 mg/kg oral-mouse TDLo 98 day(s) male day(s) pre pregnancy/98 day(s) post pregnancy/3 week(s) continuous; 186 mg/kg oral-mouse TDLo multigenerations; 1.8 gm/kg oral-rat TDLo 98 day(s) male day(s) pre pregnancy/98 day(s) post pregnancy/3 week(s) continuous

AMMONIUM CHLORIDE:

IRRITATION DATA:

500 mg/24 hour(s) eyes-rabbit mild; 100 mg eyes-rabbit severe

TOXICITY DATA:

2 gm/kg oral-infant LDLo; 1650 mg/kg oral-rat LD50; 30 mg/kg intramuscular-rat LD50; 550 mg/kg unreported-rat LD50; 1300 mg/kg oral-mouse LD50; 485 mg/kg intraperitoneal-mouse LD50; 500 mg/kg subcutaneous-mouse LDLo; 358 mg/kg intravenous-mouse LD50; 200 mg/kg subcutaneous-rabbit LDLo; 78 mg/kg intravenous-rabbit LDLo; 72 mg/kg subcutaneous-guinea pig LDLo; 220 mg/kg intravenous-guinea pig LDLo; 1500 mg/kg oral-domestic animal LDLo; 0.005 gm/kg oral-rabbit LDLo; 0.02 gm/kg oral-dog LDLo; 250 mg/kg intraperitoneal-mouse LDLo;140 mg/kg intraperitoneal-rat LDLo; 51660 mg/kg/10 week(s) continuousoral-rat TDLo; 56100 mg/kg/170 day(s) intermittent oral-rat TDLo; 556gm/kg/78 week(s) continuous oral-rat TDLo; 35.3 gm/kg/4 week(s) continuous oral-rat TDLo; 52.9 gm/kg/6 week(s) continuous oral-rat TDLo; 3500 mg/kg/1 week(s) continuous oral-rat TDLo; 29.4 gm/kg/4 week(s) continuous oral-rat TDLo; 455 gm/kg/130 week(s) continuous oral-rat TDLo; 44.1 gm/kg/6 week(s) continuous oral-rat TDLo

LOCAL EFFECTS:

04/01/05 FRI 20:07 FAX 510 4651639 ALISON S BRITTON →→→ PHYLLIS FOX 006

Irritant: inhalation, eye
ACUTE TOXICITY LEVEL:
ModeratelyToxic: ingestion
MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE:
kidney disorders
MUTAGENIC DATA:
cytogenetic analysis - hamster fibroblast 400 mg/L
ADDITIONAL DATA:
Interactions with drugs may occur.

HEALTH EFFECTS
INHALATION:
ACUTE EXPOSURE:
PETROLATUM: High concentrations may cause irritationof the respiratory tract.

ZINC CHLORIDE: Fumes may be severely irritating to the upper respiratory tract and may cause a metallic taste, lacrimation, sore throat, loss of voice, hoarseness, coughing with copious sputum, a constrictive sensation in the chest, strider, chest pain and soreness. Gastrointestinal disturbances including nausea, abdominal pain and severe gastritis with vomiting may occur. Fever, dyspnea and tachypnea, shortness or breath, listlessness, pale, gray cyanosis, rapid pulse, tachycardia and coma have also beenreported. Respiratory effects may include severe inflammation of the upper respiratory tract, rhinitis, hemorrhagic alveolitis, severe pneumonitis, tracheobronchitis, diffuse pulmonary infiltrations, acute interstitial and advanced pulmonary fibrosis, pulmonary edema and bronchopneumonia. Death may be due to pulmonary edema, respiratory failure and bronchopneumonia. Autopsy revealed red and edematous mucous membrane and pulmonary necrosis, active fibroblasticproliferation and cor pulmonale.

AMMONIUM CHLORIDE: Inhalation of thedust may cause irritation with coughing, sore throat and difficult breathing. Laboratory animals exposed to 50 mg/m3 for 6 hours showed no signs of intoxication. However, post mortem examination showed congestion of the trachea and bronchial mucosa; the lungs were distended and emphysematous with petechial hemorrhaging and hyperemia. Changes were evident in the liver, spleen and adrenal medulla.
CHRONIC EXPOSURE:
PETROLATUM: Rarely, prolonged or repeatedinhalation of mist has caused shortness of breath, cough and lipid pneumonia.

ZINC CHLORIDE: Prolonged inhalation may result in ulceration of the nasal septum.

AMMONIUM CHLORIDE: No data available.
SKIN CONTACT:
ACUTE EXPOSURE:
PETROLATUM: May cause slight irritation. Rarely, hypersensitivity reactions and dermatitis have been reported.

ZINC CHLORIDE: Dust, fumes or solutions may cause severe irritation, redness, pain, papular and primary dermatitis, chemical burns, of theskin, boils, and ulceration of the fingers, hands and forearms. Sensitization reactions in the form of eczematoid dermatitis have been reported.

AMMONIUM CHLORIDE: May cause irritation.

04/01/05 FRI 20:07 FAX 510 4651639 ALISON S BRITTON →→→ PHYLLIS FOX 007

CHRONIC EXPOSURE:

PETROLATUM: Repeated or prolonged exposure from cosmetic use may result in acniform eruptions, irritation and pigmentation. Mice tested by twice-weekly application of 60 uL produced 5 papillomas but no cancer. The study showed no significant difference of papillomas when compared with controls.

ZINC CHLORIDE: Repeated orprolonged contact may cause boils, dermatitis or sensitization dermatitis in previously exposed persons. Repeated contact has produced fatigability, poor appetite, constipation and pains in the long bones of the legs.

AMMONIUM CHLORIDE: Repeated or prolonged contact may cause dermatitis.

EYE CONTACT:

ACUTE EXPOSURE:

PETROLATUM: May cause irritation.

ZINC CHLORIDE: Contact may cause severe irritation and pain, redness, blurred visionand injuries including corneal burns, ulceration and vascularization,conjunctivitis, dermatitis, and iritis. A splash in the eye caused, initially, some redness and persistent discomfort, but within 6 days it lead to a discrete stromal opacity in the lower part of the corneawith irregularities of the overlying epithelium. From an accidental instillation of a drop of 50% zinc chloride solution, the corneal epithelium became eroded, the lids red and swollen, and a mucopurulent discharge developed. Large folds developed in the Descemet's membrane, and the corneal stroma became turbid. This was accompanied by severe iritis with small hemorrhages in the iris. Deepand superficial vascularization of the cornea followed.

AMMONIUM CHLORIDE: May cause irritation with redness and pain. Solutions less than 10% are generally well tolerated by the eye.

CHRONIC EXPOSURE:

PETROLATUM: No data available.

ZINC CHLORIDE: Repeated and prolonged contact to dust or vapor may cause conjunctivitis.

AMMONIUM CHLORIDE:Repeated or prolonged contact may cause conjunctivitis.

INGESTION:

ACUTE EXPOSURE:

PETROLATUM: Large amounts may cause abdominal pain and diarrhea. Aspiration may result in chemical pneumonitis.

ZINC CHLORIDE: Ingestion may cause severe irritation of mucous membranes with corrosion, swollen lips, edema of the glottis, sore throat, chest pain and gastrointestinal disturbances including nausea, vomiting, bloody diarrhea, and abdominal pain. Perforation of the viscous may occur. Lethargy, bloody urine, albuminuria, gastritis andpyloric stenosis have been reported. Other effects may include cold skin, low blood pressure, dyspnea and collapse with shock and hypocalcemia. Death has been reported. Delayed deaths have been ascribed to inanition following severe strictures of the esophagus and pyloris. Survivors of zinc salt ingestion may have residual nephritis.

AMMONIUM CHLORIDE: May cause irritation of mouth and stomach with nausea or vomiting. Large doses may cause diuresis, systemic acidosis and ammonia poisoning.

CHRONIC EXPOSURE:

04/01/05 FRI 20:07 FAX 510 4651639 ALISON S BRITTON →→→ PHYLLIS FOX 008

PETROLATUM: If the liquid form is taken continuously for therapeutic use, large amounts may impair the appetite, reduce the absorption of fat soluble vitamins and possibly cause changes in the liver and mesenteric lymph nodes. Rats fed various grades of petrolatum at 5% in the diet for 2 years showed no treatment-related tumor increase.
ZINC CHLORIDE: Reproductive effects have been reported in animals.

AMMONIUM CHLORIDE: Repeated ingestion may cause nausea, vomiting, acidosis, hypoproteinemia, demineralization of boney structures, and coma. Rabbits with damaged livers, and adrenals removed, were fed ammonium chloride for 120 days, resulting in permanent changes in theelectroretinogram and degeneration of the ganglion cell layer of the retina.

SECTION 12 - ECOLOGICAL INFORMATION

SECTION 13 - DISPOSAL CONSIDERATIONS

Dispose in accordance with all applicable regulations.

SECTION 14 - TRANSPORT INFORMATION

U.S. DOT 49 CFR 172.101:
PROPER SHIPPING NAME: Corrosive liquids, n.o.s. (zinc chloride) ID NUMBER: UN1760 HAZARD IATA/ICAO CLASS: 8 PACKING GROUP: II LABELING REQUIREMENTS: 8
CANADIAN TRANSPORTATION OF DANGEROUS GOODS:
No classification assigned.

LAND TRANSPORT ADR/RID:
PROPER SHIPPING NAME: Corrosive liquid, n.o.s. UN NUMBER: UN1760 CLASS: 8 CLASSIFICATION CODE: C9 PACKING GROUP: II LABELS: 8

AIR TRANSPORT IATA/ICAO:
PROPER SHIPPING NAME: Corrosive liquid, n.o.s. UN NUMBER: UN1760 IATA/ICAO CLASS:8 LABELS: 8 UN PACKING GROUP: II

MARITIME TRANSPORT IMDG:
PROPER SHIPPING NAME: Corrosive liquid, n.o.s. UN NUMBER: UN1760 PACKING GROUP: II

SECTION 15 - REGULATORY INFORMATION

TSCA Status	: Listed on inventory.
TSCA 12(b) export notification	: Not listed.
SARA Section 302 (40 CFR 355.30)	: Not regulated. TPQ
SARA Section 304 (40 CFR 355.40)	: Not regulated. RQ
California Prop 65 Status	: Not regulated.
SARA ACUTE Hazard	: Yes
SARA CHRONIC Hazard	: Yes
SARA FIRE Hazard	: No
SARA REACTIVITY Hazard	: No
SARA SUDDEN RELEASE Hazard	: No
WHMIS Classification	: Not regulated.

SECTION 16 - OTHER INFORMATION

No other information is currently available for this record
?

04/01/05 FRI 20:08 FAX 510 4651639 ALISON S BRITTON ---> PHYLLIS FOX 009

1.5 Liquefied Petroleum Gas Combustion

1.5.1 General[1]

Liquefied petroleum gas (LPG or LP-gas) consists of propane, propylene, butane, and butylenes; the product used for domestic heating is composed primarily of propane. This gas, obtained mostly from gas wells (but also, to a lesser extent, as a refinery by-product) is stored as a liquid under moderate pressures. There are three grades of LPG available as heating fuels: commercial-grade propane, engine fuel-grade propane (also known as HD-5 propane), and commercial-grade butane. In addition, there are high-purity grades of LPG available for laboratory work and for use as aerosol propellants. Specifications for the various LPG grades are available from the American Society for Testing and Materials and the Gas Processors Association. A typical heating value for commercial-grade propane and HD-5 propane is 90,500 British thermal units per gallon (Btu/gal), after vaporization; for commercial-grade butane, the value is 97,400 Btu/gal.

The largest market for LPG is the domestic/commercial market, followed by the chemical industry (where it is used as a petrochemical feedstock) and the agriculture industry. Propane is also used as an engine fuel as an alternative to gasoline and as a standby fuel for facilities that have interruptible natural gas service contracts.

1.5.2 Firing Practices[2]

The combustion processes that use LPG are very similar to those that use natural gas. Use of LPG in commercial and industrial applications may require a vaporizer to provide the burner with the proper mix of air and fuel. The burner itself will usually have different fuel injector tips as well as different fuel-to-air ratio controller settings than a natural gas burner since the LPG stoichiometric requirements are different than natural gas requirements. LPG is fired as a primary and backup fuel in small commercial and industrial boilers and space heating equipment and can be used to generate heat and process steam for industrial facilities and in most domestic appliances that typically use natural gas.

1.5.3 Emissions[1,3-5]

1.5.3.1 Criteria Pollutants -

LPG is considered a "clean" fuel because it does not produce visible emissions. However, gaseous pollutants such as nitrogen oxides (NO_x), carbon monoxide (CO), and organic compounds are produced as are small amounts of sulfur dioxide (SO_2) and particulate matter (PM). The most significant factors affecting NO_x, CO, and organic emissions are burner design, burner adjustment, boiler operating parameters, and flue gas venting. Improper design, blocking and clogging of the flue vent, and insufficient combustion air result in improper combustion and the emission of aldehydes, CO, hydrocarbons, and other organics. NO_x emissions are a function of a number of variables, including temperature, excess air, fuel and air mixing, and residence time in the combustion zone. The amount of SO_2 emitted is directly proportional to the amount of sulfur in the fuel. PM emissions are very low and result from soot, aerosols formed by condensable emitted species, or boiler scale dislodged during combustion. Emission factors for LPG combustion are presented in Table 1.5-1.

Table 1.5-1 presents emission factors on a volume basis (lb/10^3gal). To convert to an energy basis (lb/MMBtu), divide by a heating value of 91.5 MMBtu/10^3gal for propane and 102 MMBtu/10^3gal for butane.

Table 1.5-1. EMISSION FACTORS FOR LPG COMBUSTION[a]

EMISSION FACTOR RATING: E

Pollutant	Butane Emission Factor ($lb/10^3$ gal)		Propane Emission Factor ($lb/10^3$ gal)	
	Industrial Boilers[b] (SCC 1-02-010-01)	Commercial Boilers[c] (SCC 1-03-010-01)	Industrial Boilers[b] (SCC 1-02-010-02)	Commercial Boilers[c] (SCC 1-03-010-02)
PM[d]	0.6	0.5	0.6	0.4
SO_2[e]	0.09S	0.09S	0.10S	0.10S
NO_x[f]	21	15	19	14
N_2O[g]	0.9	0.9	0.9	0.9
CO_2[h,j]	14,300	14,300	12,500	12,500
CO	3.6	2.1	3.2	1.9
TOC	0.6	0.6	0.5	0.5
CH_4[k]	0.2	0.2	0.2	0.2

[a] Assumes emissions (except SO_x and NO_x) are the same, on a heat input basis, as for natural gas combustion. The NO_x emission factors have been multiplied by a correction factor of 1.5, which is the approximate ratio of propane/butane NO_x emissions to natural gas NO_x emissions. To convert from $lb/10^3$ gal to $kg/10^3$ L, multiply by 0.12. SCC = Source Classification Code.

[b] Heat input capacities generally between 10 and 100 million Btu/hour.

[c] Heat input capacities generally between 0.3 and 10 million Btu/hour.

[d] Filterable particulate matter (PM) is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train. For natural gas, a fuel with similar combustion characteristics, all PM is less than 10 μm in aerodynamic equivalent diameter (PM-10).

[e] S equals the sulfur content expressed in gr/100 ft^3 gas vapor. For example, if the butane sulfur content is 0.18 gr/100 ft^3, the emission factor would be (0.09 x 0.18) = 0.016 lb of $SO_2/10^3$ gal butane burned.

[f] Expressed as NO_2.

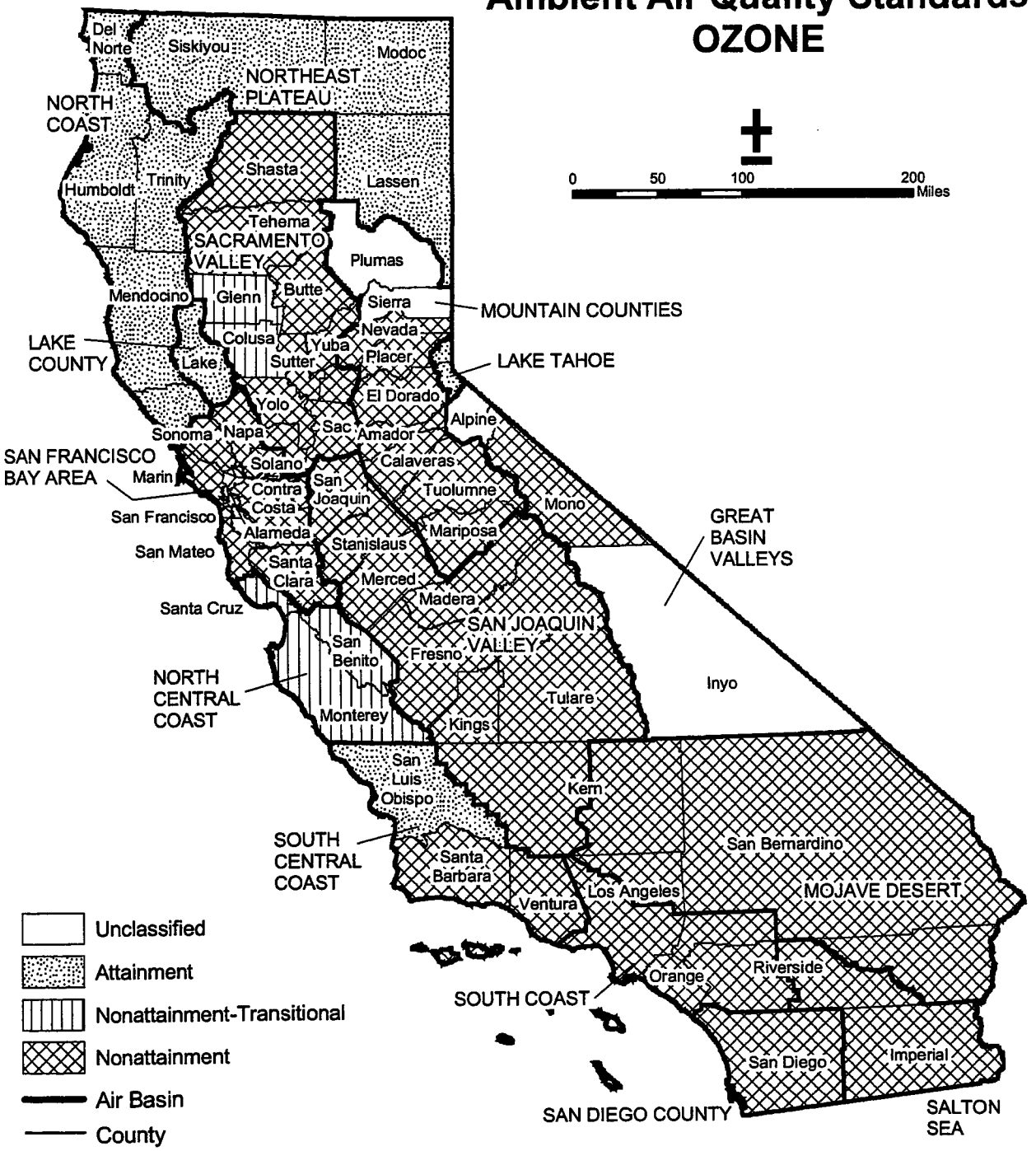
[g] Reference 12.

[h] Assuming 99.5% conversion of fuel carbon to CO_2.

[j] EMISSION FACTOR RATING = C.

[k] Reference 13.

2004
Area Designations for State Ambient Air Quality Standards
OZONE



Source Date:
October 2003
Emission Inventory Branch, PTSD

October 18, 2004

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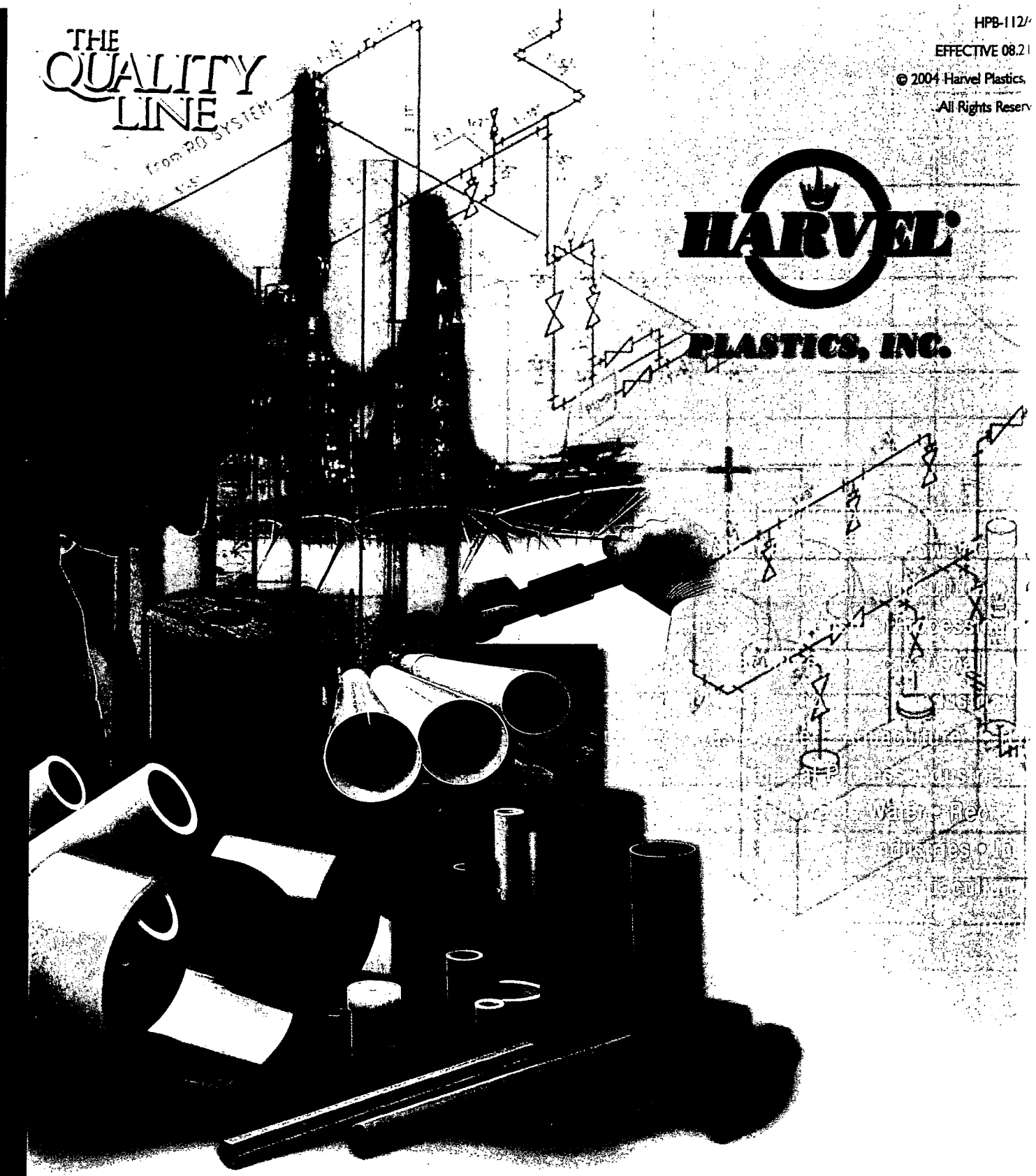

Engineering & Installation Guide

PVC and CPVC extruded pipe, duct, and machining stock.

Copper Tube Size (CTS) CPVC Pipe

Solvent Cement Joining Techniques

It is important to follow proper storage and handling, joining, assembly, and other installation techniques to ensure a quality system installation. A properly designed and installed CPVC plumbing system will provide years of trouble-free service, lasting much longer than metallic systems due to the products inherent corrosion resistance and other factors. The following information is provided as a general guide toward that end.

Harvel CTS CPVC pipe is joined by the solvent cementing process; a reliable joining technique field-proven for more than 30 years. When properly conducted, this method provides a strong, homogenous joining area in which the mating surfaces are chemically fused together, producing a strong, leak-tight seal when cured. Prior to solvent cementing, appropriate safety precautions should be taken:

- Use only CPVC cement conforming to ASTM F493
- Follow the solvent cement manufacturer's instructions
- Avoid breathing vapors
- Use only with adequate ventilation
- Avoid frequent contact with skin
- Avoid contact with eyes
- Eliminate all ignition sources
- Store primer and solvent cement in the shade between 40°F and 110°F
- Close containers tight when not in use, and cover as much as possible during use
- Follow all manufacturer-recommended precautions when using power tools
- Flush the system for a minimum of 10 minutes after pressure testing to remove trace amounts of solvents or other system components

Exercise special care when assembling Harvel CTS CPVC pipe in extremely low temperatures (below 40°F) or extremely high temperatures (above 80°F). Extra set and handling times must be allowed in colder temperatures. Make certain cement has not "gelled" when cementing pipe and fittings in colder temperatures. Make certain both surfaces being joined are wet with cement during assembly when working in extremely hot temperatures.

1. Cutting

Harvel pipe must be cut square to obtain the proper insertion depth and to provide the maximum bonding area for solvent cementing. Harvel pipe can easily be cut with a wheel-type plastic tubing cutter, ratchet-style cutter, fine-toothed hand saw (hack saw), or power saws. A miter box should be used when working with saws to ensure a square cut. If ratchet-style cutters are used, their blades must be sharpened regularly. The use of ratchet cutters with dull blades, or their use in cold weather, will tend to compress the pipe prior to cutting which can result in hairline fracturing. The raised bead left on the pipe O.D. after cutting must be removed prior to solvent cementing—see step number 2 regarding beveling. Any cuts, fractures, splits, or other damaged areas must be removed prior to joining. Cut off at least 2" beyond any visible fracture.

2. Beveling/Deburring

Burrs, filings, shavings etc. caused by the cutting process must be removed from the outside and inside of the pipe. Shavings and other debris will prevent proper contact of the joining surfaces and can lead to joint failure. Chamfering tools are available for this purpose, however, pocket knives or files are also suitable. A slight bevel is required on the pipe end to help ease entry into the fitting socket, and to prevent solvent cement from being pushed ahead of the pipe during the assembly process. Many chamfering tools designed for use with plastic are readily available. These tools are specifically designed to remove burrs and provide a proper bevel simultaneously.

3. Fitting Preparation

Wipe dirt, debris, and moisture from the pipe end and fitting socket using a clean, dry rag. Moisture will slow the cure time and reduce joint strength. Inspect piping and components for damage or irregularities prior to assembly. Do not use components that appear irregular or that do not fit properly; contact the appropriate manufacturer of the product in question to determine usability. Check the dry fit of the pipe and fitting prior to assembly. The pipe should enter the fitting socket easily one-quarter to three-quarters of the way.

4. Solvent Cement Application

USE ONLY CPVC CEMENT that conforms to ASTM F493. The use of the wrong cement can result in failure. Harvel recommends the use of IPS 713 CPVC cement, P-68 primer or IPS Low VOC one-step CPVC cement or equivalent. Two solvent cementing processes are available; the two-step solvent cement and primer process, and the one-step process. The two-step process utilizes the application of primer to the outside of the pipe and the interior fitting socket prior to applying the solvent cement. When using primer, it must be applied to both the pipe and fittings using the appropriate size applicator. A dauber or paint brush approximately half the size of the pipe diameter is appropriate. A rag must not be used. Apply primer to the fitting socket, then to the outside of the pipe end, re-dipping the applicator as necessary to ensure the entire joining surfaces are wet; apply solvent cement immediately after primer application while primed surfaces are tacky. Cement application for one- or two-step process: Apply a heavy, even coat of cement to the outside pipe end. Apply a medium coat to the fitting socket. A second application of cement should be applied to the pipe end if there was little or no interference when the dry fit was checked. Do not allow excess cement to puddle in the pipe or fitting.

Copper Tube Size (CTS) CPVC Pipe

5. Assembly

Immediately insert the pipe into the fitting while rotating the pipe one-quarter turn to help distribute cement. Properly align the fitting for installation at this time. Pipe must bottom completely to the stop in the fitting. Hold the assembly for 10 to 15 seconds to ensure initial bonding. A continuous bead of cement should be evident around the pipe and fitting juncture. If the bead is not continuous, it may indicate that insufficient cement was applied. If insufficient cement is applied the fitting must be cut out, discarded and begun again. Cement in excess of the bead should be wiped off with a rag.

6. Set and Cure Times

Assembled joints must be allowed to set and cure properly prior to testing the system. Set and cure times are a function of type of cement used, pipe size, temperature, humidity, and tightness of fit. Drying time is faster for drier environments, smaller sizes, higher temperatures and tighter fits. The assembly must be allowed to set without any stress on the joint for one to five minutes depending on the pipe size and temperature. Following the initial set period, the assembly can be handled carefully. FOLLOW THE CEMENT MANUFACTURER'S RECOMMENDED CURE TIMES PRIOR TO PRESSURE TESTING - FAILURE TO DO SO WILL RESULT IN JOINT FAILURE.

Minimum Cure Time Prior to Testing at 150 psi with Cold Water (based on use of IPS one-step CPVC cement and 713 two-step cement)

Pipe Size (in.)	Ambient Temperature During Cure Time >60°F	40°F - 60°F	<40°F
3/8	1 hr	2 hrs	4 hrs
1/2	1 hr	2 hrs	4 hrs
3/4	1 hr	2 hrs	4 hrs
1	1 hr	2 hrs	4 hrs
1-1/4	2 hrs	4 hrs	8 hrs
1-1/2	2 hrs	4 hrs	8 hrs
2	2 hrs	4 hrs	8 hrs

NOTE Wait 24 hours prior to putting system into hot water service when installed at cure temperatures above 60°F; wait 48 hours prior to putting system into hot water service when installed at cure temperatures below 40°F Solvent Cement Joining

Hangers & Supports

Proper support spacing is critical to ensure that deflection is kept to a minimum. Hangers used must have an adequate load bearing surface free of any rough or sharp edges that could damage the pipe during use. They must also not restrict linear movement of the system due to the effects of expansion and contraction; overtightening must be avoided.

Pipe Size (in.)	Maximum Hanger Support Spacing
3/8	3 ft
1/2	3 ft
3/4	3 ft
1	3 ft
1-1/4	4 ft
1-1/2	4 ft
2	4 ft

Wall Penetration

Building codes require that a fire-rated wall or floor must be sealed back to its original integrity when penetrated. Several sealants and materials are suitable for use with Harvel CTS CPVC pipe to construct an appropriate UL Classified penetration system (fire-rated penetration system). When installed properly, these systems will provide a two-hour fire rating. Consult local building code requirements.

⚠CAUTION Certain fire-stopping sealants and components contain stress cracking agents and other chemicals which may cause damage to CPVC piping; contact the appropriate manufacturer for compatibility with CPVC prior to use.

NOTE When installing CPVC in areas where the system must be drained to protect it from freezing, the lines must be sloped to drain.

Transition Connections

Harvel CTS CPVC pipe can be connected to copper, brass, valves, and other piping materials using transition unions, compression fittings, specialty reinforced male and female adapters, and other readily available transition fittings. Follow the fitting manufacturer's installation instructions for the specific connection being used to ensure a proper leak-free joint. When using compression fittings utilizing brass ferrules, it is recommended that Teflon tape be wrapped around the ferrule prior to assembly to help compensate for differences in expansion rates between CPVC and metallics. Teflon tape is also the recommended thread sealant for threaded connections. Certain pipe joint pastes and sealant compounds contain substances which could be damaging to CPVC and result in system failure. If joint sealant other than Teflon® tape is used, contact the sealant manufacturer for compatibility with CPVC. Caution must be exercised to prevent overtightening of threaded connections and compression fittings.

Where water temperatures are 150°F or higher, use transition fittings incorporating rubber seals or other approved specialty transition fittings at the plastic to metal changeover. Follow appropriate safety precautions and manufacturer's recommendations when working with or near open flame during soldering operations. Extreme care must be used when soldering to prevent flame contact with CPVC tubing.

Water Heater Connections

Care should be used to prevent contact of the CPVC pipe with heat-producing sources. Gas water heaters require the use of a metallic nipple or appliance connector at least six inches long to be installed above the flue piping as a transition piece to prevent damage to the CPVC by excessive heat build-up from the flue. CPVC can be installed directly onto electric water heaters with special transition fittings. Some codes require metal connectors on electric water heaters; consult applicable code requirements prior to installation.

IPS WELD·ON

IMPORTANT

NOTICE!

MOST JOINT FAILURES ARE CAUSED BY "DRY JOINTS"!

"DRY JOINT" failures occur between plastic pipe and fittings when insufficient coatings of solvent cement are applied to pipe and fitting surfaces. It is our conservative estimate that 90% of joint failures reported to us would not have occurred if an adequate coating of cement had been applied.

3 REASONS WHY ADEQUATE LAYERS OF SOLVENT CEMENT ARE ESSENTIAL

1. Cement must be wet when joints are assembled. (A very thin layer of cement will dry very quickly, but a thicker layer will stay wet for thirty to ninety seconds depending on which cement is used.)
2. An adequate layer of cement ensures that sufficient solvent remains to soften (bite into) pipe and fitting so they will fuse together in tight parts of the joint.
3. It is necessary to have more than sufficient cement to fill the space between pipe and fitting.

A MAJOR CAUSE OF "DRY JOINTS" IS THE USE OF TOO SMALL AN APPLICATOR FOR THE SIZE OF PIPE AND FITTING – Too thin a layer too slowly applied = "Dry Joint"

BE SURE TO SELECT AN APPLICATOR BIG ENOUGH FOR THE JOB!

IPS WELD-ON APPLICATORS ARE RECOMMENDED FOR THE FOLLOWING PIPE SIZES:

Small ¾"dia. wool dauber cap (standard in our small applicator cans) ..... ⅜" thru 1¼"

Large 1½" dia. wool dauber cap ..... ¾" thru 3"

BCP-1 reusable 1" brush cap (interchangeable with caps on pt. & qt. cans) ..... ¾" thru 2"

3020 – 2" dia. "Roll-A-Weld" Roller for use on qt. TT (paint type) cans ..... 3" thru 6"

7020 – Giant 7" roller, 2" dia., for use with gal. F style, 2⅞" sc. cap cans ..... 6" thru 12"

4020 – Large cotton swab, 4" x 2" dia., for use with gal. F style, 2⅞" sc. cap cans .... 6" thru 12"

For addition information ask your cement supplier or contact us directly.

Product bulletins for specific Weld-On cements and detailed solvent cementing instructions are available.

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IPS CORPORATION · 455 W. VICTORIA · COMPTON, CA 90220 · (310) 898-3300 · P.O. BOX 379, GARDENA, CA 90248 U.S.A.

MANUFACTURERS AND FORMULATORS OF ADHESIVE CEMENTS FOR EPOXY • VINYLS • NYLONS • ACRYLICS • FIBRE GLASS • POLYESTER • ABS FOAMS • BUTYRATE • STYRENE • URETHANE • POLYETHYLENE FILM • RUBBER • WOOD • METAL • MASONRY • GLASS • CERAMICS • MANY OTHERS

pictures of grapes, San Francisco cable car, electronic organizer, city skyline, the Hollywood sign and cypress tree

FACILITY DETAILS

Facility Information

Facility Name : Ips Corp
Facility ID : 800367
Street : 17109 S Main St
SIC Code : 2891
City : Gardena
Zip : 90248 0
Phone : (310) 898-3300
County : Los Angeles
Air Basin : South Coast
District : South Coast Aqmd

Facility Prioritization	Inventory Year	Above High Threshold?	District Prioritization Threshold	
			High	Low
Cancer Prioritization			10	1
Chronic Prioritization			10	1
Acute Prioritization			10	1

Prioritization scores determine whether a facility must conduct a risk assessment for the "Hot Spots" program. The scores themselves are not an accurate measurement of facility risk.

Health Risk Assessment	Inventory Year	Value	District Notification Level	District RRAP Level
Cancer Risk			>=10	25
Chronic Hazard Index			>1; lead THI >.5	3
Acute Hazard Index			>1; lead THI >.5	3

The facility health risk assessment (HRA) and prioritization score data were collected under the Air Toxic 'Hot Spots' Program. The risk data, submitted to the ARB, may not have been derived from the same toxic emission data that was reported to CEIDARS. Because the facility may have taken action to reduce risks pursuant to the risk assessment, the risk from the facility may have been substantially reduced since the risk assessment was conducted. To determine if more recent data is available, please contact the district.

Program Status :

Emissions Data

	Pollutant	Emissions	Unit
Data from 2002	TOG	21.5	Tons/Yr
Download CSV file	ROG	18.2	Tons/Yr
	CO	0	Tons/Yr
	NOX	0	Tons/Yr
	SOX	0	Tons/Yr
	PM	0	Tons/Yr
	PM10	0	Tons/Yr
	PM2.5	0	Tons/Yr
TOXIC DATA MAY COME FROM VARIOUS YEARS			
	Methylene Chlor	102	Lbs/Yr
Download CSV file	TCE	69.6	Lbs/Yr

The emission inventory data provided here may have been developed over several years and is the most recent information available at ARB for this inventory year. Many facilities are only required to update their toxic emission data if there has been an increase in emissions. Therefore, the toxic emission data presented here should generally be viewed as maximum emission values which may have decreased since this information was reported. If you have questions regarding data updates, please contact the local air district. Note: If this facility has diesel-fueled internal combustion engines, then a portion of the PM10 shown is considered to be diesel exhaust PM10.

[Start a new search] [Report an Error]

ARB Homepage

A department of the California Environmental Protection Agency

pictures of grapes, San Francisco cable car, electronic organizer, city skyline, the Hollywood sign and cypress tree

FACILITY DETAILS

Facility Information

Facility Name : Oatey Company
Street : 6600 Smith Avenue
City : Newark
Phone : (510) 797-4672
County : Alameda
Air Basin : San Francisco Bay Area
District : Bay Area Aqmd

Facility ID : 970
SIC Code : 2821
Zip : 94560

Facility Prioritization	Inventory Year	Above High Threshold?	District Prioritization Threshold High	Low
Cancer Prioritization			10	1
Chronic Prioritization			10	1
Acute Prioritization			10	1

Prioritization scores determine whether a facility must conduct a risk assessment for the "Hot Spots" program. The scores themselves are not an accurate measurement of facility risk.

Health Risk Assessment	Inventory Year	Value	District Notification Level	District RRAP Level
Cancer Risk			10	100
Chronic Hazard Index			>10	none
Acute Hazard Index			>10	none

The facility health risk assessment (HRA) and prioritization score data were collected under the Air Toxic 'Hot Spots' Program. The risk data, submitted to the ARB, may not have been derived from the same toxic emission data that was reported to CEIDARS. Because the facility may have taken action to reduce risks pursuant to the risk assessment, the risk from the facility may have been substantially reduced since the risk assessment was conducted. To determine if more recent data is available, please contact the district.

Program Status :

Emissions Data

	Pollutant	Emissions	Unit
Data from 2002	TOG	19.7	Tons/Yr
Download CSV file	ROG	16.7	Tons/Yr
	CO	0	Tons/Yr
	NOX	0	Tons/Yr
	SOX	0	Tons/Yr
	PM	0.3	Tons/Yr
	PM10	0.3	Tons/Yr
	PM2.5	0.3	Tons/Yr

The emission inventory data provided here may have been developed over several years and is the most recent information available at ARB for this inventory year. Many facilities are only required to update their toxic emission data if there has been an increase in emissions. Therefore, the toxic emission data presented here should generally be viewed as maximum emission values which may have decreased since this information was reported. If you have questions regarding data updates, please contact the local air district. Note: If this facility has diesel-fueled internal combustion engines, then a portion of the PM10 shown is considered to be diesel exhaust PM10.

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FACTS Faxed FAST! SM

OSHA-Required Health And Safety Information!

This Material Safety Data Sheet (MSDS) was requested moments ago from Hercules Automated Fax Information System. Please forward it immediately to the person in charge of MSDS's, or retain it at the machine until claimed.

Section 1

MATERIAL SAFETY DATA SHEET # 61

Hercules CPVC Cement

HERCULES® MATERIAL SAFETY INFORMATION SERVICE

Date Prepared: 3/27/1989 **Last Reviewed:** 2/11/2002

Meets OSHA 29 CFR 1910.1200

Hercules Chemical Company Inc.
111 South Street
Passaic NJ 07055
Phone (800) 221-9330
Fax (800) 333-3456

Section 2 - Hazardous Ingredients/Identity Information

Hazardous Components (Specific Chemical Identity; Common Name(s), CAS Numbers)	OSHA PEL	ACGIH TLV	Other Limits	Upper Bound Limit if SARA Reportable
Tetrahydrofuran (109-99-9)	200PPM	200PPM	N/A	- -
Cyclohexanone (108-94-1)	25PPM	25PPM	N/A	- -

HMIS Hazard Rating: Health: 3 Flammability: 4 Reactivity: 1 Personal Protection: G

Section 3 - Physical/Chemical Characteristics

Boiling Point (°C):	Specific Gravity (H2O = 1):	Vapor Density (Air = 1):	Vapor Pressure (mm Hg):
151° F Based on first boiling component-THF	0.935 ± 0.03	2.0 to 2.5	143 Based on first boiling component-THF

Melting Point (° F)	Evaporation Rate: (Butyl Acetate = 1)	Solubility in Water:
N/A	7-11	60% to 85%

Appearance And Color: Orange Viscous Liquid **Odor:** Ethereal & Acetone-like

Section 4 - Fire And Explosion Hazard Data

Flash Point:	Flammable Limits: LEL:	UEL:
6.0° F (T.C.C.) (Based on THF)	2%	11.8%

Extinguishing Media: Foam/Dry Chemical/Carbon Dioxide

Special Firefighting Procedures:
Handle as flammable liquid. wear self-contained breathing apparatus & chemical goggles. Water may be ineffective, but should be used to keep fire-exposed containers cool.

Unusual Fire And Explosion Hazards:
Vapor is heavier than air and travels considerable distance to source of ignition and flashback. On long standing may form peroxides which may cause violent reaction especially upon evaporation to dryness.

Continued on Next Page

Section 5 - Reactivity Data

Stability: Stable **Conditions To Avoid:** Keep in closed containers away from sparks & open flames.

Incompatability (Materials To Avoid): Strong oxidizing materials, Lithium Aluminum Hydride, Sodium Aluminum Hydroxide, Sodium & Potassium Hydroxides.

Hazardous Decomposition: Carbon dioxide and carbon monoxide are formed. Irritating peroxide fumes formed when heated to decomposition.

Hazardous Polymerization: Avoid excessive exposure to air and cationic initiators like Lewis Acids.

Section 6 - Health Hazard Data

Routes of Entry: **Inhalation** YES/Primary **Skin** YES/Primary **Ingestion** YES/Secondary

Health Hazards:

Corrosive to eyes & skin irritant. Severe overexposure can cause headache, dizziness, & narcosis. May cause dermatosis & dermatitis with prolonged repeated contact.

Carcinogenicity: **NTP** NO **IARC** NO **OSHA Regulated** NO

Signs And Symptoms of Exposure:

INGESTION: No effect of exposure expected. INHALATION: Will cause irritation of mucous membranes, nose, eyes, & throat coughing, difficulty of breathing. Exposure to high vapor concentration may cause headache, dizziness, nausea, narcosis. SKIN CONTACT: Prolonged contact causes common solvent defatting effect. EYE CONTACT: Vapors slightly uncomfortable, splashes irritating. Will cause painful burning or stinging of eyes and lids, watering of eyes and inflammation of conjunctiva.

Medical Conditions Generally Aggravated By Exposure:

No data found

Emergency And First Aid Procedures:

INGESTION: DO NOT INDUCE VOMITING. If conscious, dilute by giving two glasses of water. Call a physician immediately. INHALATION: Remove to fresh air, if not breathing; give artificial respiration preferably mouth to mouth. If breathing is difficult give oxygen. Call a physician. SKIN CONTACT: Wash affected skin area with soapy water. Remove contaminated clothing. EYE CONTACT: Immediately flush eyes with plenty of water for 15 minutes. Consult a physician.

Continued on Next Page

Section 7 - Precautions For Safe Handling And Use:

Steps To Be Taken In Case Material Is Released Or Spilled:

Eliminate sources of ignition. Absorb with sand or inert absorbing material and dispose of with solid waste according to federal, state and local regulations. Flush spill area with water, avoid flushing into confined areas.

Waste Disposal Method:

Incinerate in accordance with the federal, state and local regulations.

Precautions To Be Taken In Handling And Storing:

Store in cool place, well-ventilated area. Keep away from open flame and sources of ignition.

Other Precautions:

Use normal good personal hygiene

Section 8 - Control Measures:

Respiratory Protection:

In confined spaces or other circumstances where adequate ventilation cannot be assured use NIOSH-approved respirator, positive pressure airline mask, or self contained breathing apparatus.

Ventilation: **Local Exhaust** As required

Mechanical All ventilating devices must be located so they do not provide a source of ignition.

Special When using cements in an area of limited ventilation, use a ventilation device such as a fan or air mover to maintain a safe air concentration.

Gloves: PVA gloves.

Other: N/A

Eye Protection: Chemical safety goggles.

Other Protective Clothing: Apron, boots, eye bath, safety shower.

Work/Hygienic Practices Wash thoroughly after handling. Avoid ingestion of the cements. Do not eat or drink when using cements or in the vicinity where such cements are being used.

HERCULES® MATERIAL SAFETY INFORMATION SERVICE

FACTS faxed FAST!

For Hercules Material Safety Data Sheets by fax anytime, day or night, just call 1-800-942-INFO (1-800-942-4636) from any Touch-Tone phone. Have your fax number ready. Checking the product label for the correct MSDS # will save time.

FACTS Faxed FAST! SM

OSHA-Required Health And Safety Information!

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Section 1

MATERIAL SAFETY DATA SHEET # 95

Hercules CPVC Cement, "LOW VOC" Standard (Orange) or Gold

Date Prepared: 11/4/1996 **Last Reviewed:** 1/24/2002

Meets OSHA 29 CFR 1910.1200

HERCULES®

MATERIAL SAFETY INFORMATION SERVICE

Hercules Chemical Company Inc.
111 South Street
Passaic NJ 07055
Phone (800) 221-9330
Fax (800) 333-3456

Section 2 - Hazardous Ingredients/Identity Information

Hazardous Components (Specific Chemical Identity; Common Name(s), CAS Numbers)	OSHA PEL	ACGIH TLV	Other Limits	Upper Bound Limit if SARA Reportable
This MSDS is for LOW VOC Product (As shown on label) ONLY. For regular product see MSDS #61.				
Tetrahydrofuran (109-99-9)	200 PPM	200 PPM	N/A	–
Methyl Ethyl Ketone (78-98-3)	200 PPM	200 PPM	N/A	.35
Cyclohexanone (108-94-1)	25 PPM	25 PPM	N/A	–
Acetone (67-64-1)	750 PPM	750 PPM	N/A	–
N-Methyl Pyrrolidone (872-50-4)	None	None	N/A	15%

HMIS Hazard Rating: Health: 3 Flammability: 4 Reactivity: 1 Personal Protection: G

Section 3 - Physical/Chemical Characteristics

Boiling Point (°F):	Specific Gravity (H2O = 1):	Vapor Density (Air = 1):	Vapor Pressur (mm Hg):
133 Based on first boiling component-Acetone	0.920 ± 0.03	2.0 to 2.5	190 Based on first boiling component-Acetone

Melting Point (° F)	Evaporation Rate: (Butyl Acetate = 1)	Solubility in Water:
N/A	6-11	55% to 75%

Appearance And Color: Orange or Yellow/Gold Viscous Liquid **Odor:** Ethereal & Acetone-like

Section 4 - Fire And Explosion Hazard Data

Flash Point:	Flammable Limits	LEL:	UEL:
0-6° F (T.C.C.) (Based on Acetone)		2%	13%

Extinguishing Media: Drv chemical. Foam. Carbon dioxide

Special Firefighting Procedures:
Handle as flammable liquid. Wear self-contained breathing apparatus & chemical goggles. Water may be ineffective, but should be used to keep fire-exposed containers cool.

Unusual Fire And Explosion Hazards:
Vapor is heavier than air and travels considerable distance to source of ignition and flashback. On long standing may form peroxides which may cause violent reaction especially upon evaporation to dryness.

Continued on Next Page

Section 5 - Reactivity Data

Stability: Stable **Conditions To Avoid:** Keep in closed containers away from sparks and open flame.

Incompatability (Materials To Avoid): Strong oxidizing materials, Lithium Aluminum Hydride, Sodium Aluminum Hydroxide, Sodium and Potassium Hydroxides.

Hazardous Decomposition: CO2 and CO are formed. Irritating peroxide fumes form when heated to decomposition.

Hazardous Polymerization: Avoid excessive exposure to air and cationic initiators like Lewis Acids.

Section 6 - Health Hazard Data

Routes of Entry **Inhalation** Yes/Primary **Skin** Yes/Primary **Ingestion** Yes/Secondary

Health Hazards

Corrosive to eyes and skin irritant. Severe overexposure can cause headache, dizziness and narcosis. May cause dermatosis with prolonged repeated contact.

Carcinogenicity **NTP** NO **IARC** NO **OSHA Regulated** NO

Signs And Symptoms of Exposure:

INGESTION: No effects of exposure expected. INHALATION: Will cause irritation of mucous membranes, nose, eyes & throat, coughing, difficulty of breathing. Exposure to high vapor concentration may cause headache, dizziness, nausea, narcosis. SKIN CONTACT: Prolonged contact causes common solvent defatting effect. EYE CONTACT: Vapors slightly uncomfortable, splashes irritating. Will cause painful burning or stinging of eyes and lids, watering of eyes and inflammation of conjunctiva.

Medical Conditions Generally Aggravated By Exposure:

Emergency And First Aid Procedures:

INGESTION: Do not induce vomiting. If conscious, dilute by giving 2 glasses of water. Call a physician immediately. INHALATION: Remove to fresh air. If not breathing give artificial respiration preferably mouth-to-mouth. If breathing is difficult, give oxygen. Call a physician. SKIN CONTACT: Wash affected areas with soapy water. Remove contaminated clothing. EYE CONTACT: Immediately flush eyes with plenty of water for 15 minutes. Consult a physician.

Continued on Next Page

Section 7 - Precautions For Safe Handling And Use:

Steps To Be Taken In Case Material Is Released Or Spilled:

Eliminate sources of ignition. Absorb with sand or inert absorbing material and dispose of with solid waste according to Federal, State and local regulations. Flush spill area with water, avoid flushing into confined areas.

Waste Disposal Method:

Incinerate in accordance with Federal, State and local regulations.

Precautions To Be Taken In Handling And Storing:

Store in cool place, well-ventilated area. Keep away from open flame and sources of ignition.

Other Precautions:

Use normal good personal hygiene.

Section 8 - Control Measures:

Respiratory Protection:

In confined spaces or other circumstances where adequate ventilation cannot be assured use NIOSH-approved respirator, positive pressure airline mask, or self contained breathing apparatus.

Ventilation: **Local Exhaust** As required.

Mechanical All ventilating devices must be located so they do not provide a source of ignition.

Special When using cements in an area of limited ventilation, use a ventilation device such as a fan or air mover to maintain a safe air concentration.

Gloves: PVA gloves.

Eye Protection: Chemical safety goggles.

Other: N/A

Other Protective Clothing: Apron, boots, eye bath, safety shower.

Work/Hygienic Practice: Wash thoroughly after handling. Avoid ingestion of the cements. Do not eat or drink when using cements or in the vicinity where such cements are being used.

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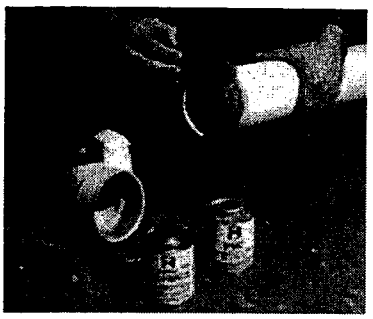
Plastic Pipe Cements



With plastic pipe use at an all-time high, professional contractors rely on Hercules plastic pipe cements, primers, and cleaners to join pipe and fittings securely and without leaks. Hercules plastic pipe cements are manufactured to very tight specifications to ensure consistently high performance.

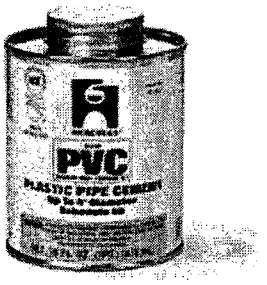
Cements for PVC

pvc cement

clear, regular body, medium set

For PVC Types I & II, potable water, DWV, and SW pipe and fittings up to 4" diameter. Schedule 40. Pink label. Meets ASTM D2564.

MSDS #53. Spec Sheet.



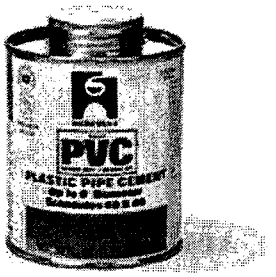
Prod. No.	Size	Pack	Note	Bar Code
60043	1/4 pt.	12	dauber in cap	032628600430
60053	1/2 pt.	12	dauber in cap	032628600539
60055	1 pt.	12	jumbo dauber in cap	032628600553
60060	1 qt.	12	jumbo dauber in cap	032628600607
60065	1 gal.	6	-	032628600652

pvc cement

clear, medium body, medium set

For PVC Types I & II, potable water, DWV, and SW pipe and fittings up to 6" diameter. Schedules 40 and 80. Blue label. Meets ASTM D2564.

MSDS #52. Spec Sheet.



Prod. No.	Size	Pack	Note	Bar Code
60003	1/4 pt.	12	dauber in cap	032628600034
60013	1/2 pt.	12	dauber in cap	032628600133
60015	1 pt.	12	jumbo dauber in cap	032628600157
60020	1 qt.	12	jumbo dauber in cap	032628600201
60025	1 gal.	6	-	032628600256

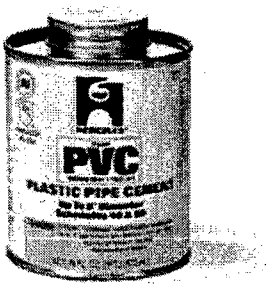
pvc cement

clear, medium body, fast set

For PVC Types I & II, potable water, DWV, and SW pipe and fittings up to 8" diameter. Schedules 40 and 80. Yellow label. Meets ASTM D2564.

MSDS #52. Spec Sheet.

Prod. No.	Size	Pack	Note	Bar Code
60103	1/4 pt.	12	dauber in cap	032628601031
60113	1/2 pt.	12	dauber in cap	032628601130
60115	1 pt.	12	jumbo dauber in cap	032628601154
60120	1 qt.	12	jumbo dauber in cap	032628601208
60125	1 gal.	6	-	032628601253



pvc cement

clear, heavy body, slow set

For PVC Types I & II, potable water, DWV, and SW pipe and fittings up to 15" diameter. Schedules 40 and 80. Tan label. Meets ASTM D2564.

MSDS #50. Spec Sheet.

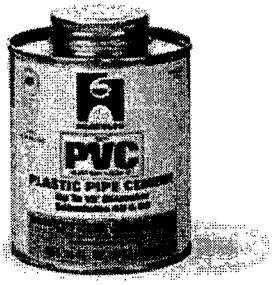
Prod. No.	Size	Pack	Note	Bar Code
60155	1/2 pt.	24	dauber in cap	032628601550
60160	1 pt.	12	jumbo dauber in cap	032628601604
60165	1 qt.	12	jumbo dauber in cap	032628601659

pvc cement

gray, heavy body, slow set

For PVC Types I & II, potable water, DWV, and SW pipe and fittings up to 15" diameter. Schedules 40 and 80. Gray label. Meets ASTM D2564.

MSDS #60. Spec Sheet.



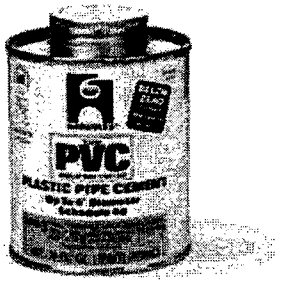
Prod. No.	Size	Pack	Note	Bar Code
60210	1/2 pt.	24	dauber in cap	032628602106
60215	1 pt.	12	jumbo dauber in cap	032628602151
60220	1 qt.	12	jumbo dauber in cap	032628602205
60225	1 gal.	6	-	032628602250

below-zero pvc cement

clear, regular body, fast set

For PVC Types I & II, potable water, DWV, and SW pipe and fittings up to 6" diameter. Schedule 40. Withstands temperatures down to -10° F (-23° C). Orange label. Meets ASTM D2564.

MSDS #51. Spec Sheet.



Prod. No.	Size	Pack	Note	Bar Code
60142	1/2 pt.	24	dauber in cap	032628601420
60145	1 pt.	12	jumbo dauber in	032628601451

60148	1 qt.	12	cap jumbo dauber in cap	032628601482

wet set pvc cement

aqua blue, medium body, fast set

For PVC Types I & II, potable water, DWV, and SW pipe and fittings up to 8" diameter. Schedules 40 and 80. Formulated for applications where conditions are very wet and/or when quick pressurization is imperative. Ideal for lawn sprinkler and swimming pool installations. Aqua label. Meets ASTM D2564.
MSDS #76. Spec Sheet.

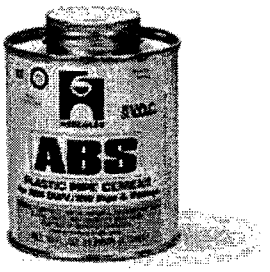
Prod. No.	Size	Pack	Note	Bar Code
60253	1/2 pt.	12	dauber in cap	032628602533
60255	1 pt.	12	jumbo dauber in cap	032628602557
60260	1 qt.	12	jumbo dauber in cap	032628602601
60265	1 gal.	6	-	032628602656

Cements for ABS

abs cement

black, medium body, fast set

For DWV and SW pipe and fittings up to 8" diameter. Schedules 40 and 80. Green label. Meets ASTM 2235.
MSDS #64. Spec Sheet.



Prod. No.	Size	Pack	Note	Bar Code
60503	1/4 pt.	12	dauber in cap	032628605039
60513	1/2 pt.	12	dauber in cap	032628605138
60515	1 pt.	12	jumbo dauber in cap	032628605152
60520	1 qt.	12	jumbo dauber in cap	032628605206
60525	1 gal.	6	-	032628605251

abs/pvc transition cement

green, medium body, fast set

For joining ABS to PVC pipe and fittings up to 6" diameter. Schedules 40 and 80. Brown label. Meets ASTM D3138.
MSDS #65. Spec Sheet.

Prod. No.	Size	Pack	Note	Bar Code
60555	1/2 pt.	24	dauber in cap	032628605558
60560	1 pt.	12	jumbo dauber in cap	032628605602

Cements for CPVC

cpvc cement

orange, medium body, fast set

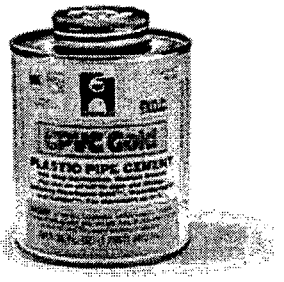
CPVC potable water pipe and fittings up to 8" diameter. All Schedules. Orange label. Meets ASTM F493.
MSDS #61. Spec Sheet.

Prod. No.	Size	Pack	Note	Bar Code
60303	1/4 pt.	12	dauber in cap	032628603035
60313	1/2 pt.	12	dauber in cap	032628603134
60315	1 pt.	12	dauber in cap	032628603158
60320	1 qt.	12	dauber in cap	032628603202

cpvc gold

gold, medium body, medium set

One step, low V.O.C. cement for use on all CPVC pipe and fittings including FlowGuard Gold (for use on specific brands of CPVC pipe, verify suitability with pipe manufacturer). Schedules 40 and 80. Yellow label. Meets ASTM F493.
MSDS #95. Spec Sheet.



Prod. No.	Size	Pack	Note	Bar Code
60353	1/4 pt.	12	dauber in cap	032628603530
60358	1/2 pt.	12	dauber in cap	032628603585
60360	1 pt.	12	dauber in cap	032628603608
60365	1 qt.	12	dauber in cap	032628603653

Specialty Cements

multi-purpose cement

milky, medium body, fast set

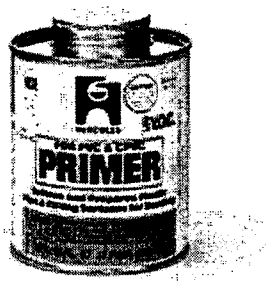
For potable water, DWV and SW pipe and fittings. For joining PVC, CPVC and ABS pipe and fittings up to 6" diameter. Schedules 40 and 80. Olive label. Meets ASTM D2564, D2235, F493.
MSDS #66. Spec Sheet.

Prod. No.	Size	Pack	Note	Bar Code
60703	1/4 pt.	12	dauber in cap	032628607033
60713	1/2 pt.	12	dauber in cap	032628607132
60715	1 pt.	12	jumbo dauber in cap	032628607156
60720	1 qt.	12	jumbo dauber in cap	032628607200
60725	1 gal.	6	-	032628607255

Primers and Cleaner

primer for pvc and cpvc

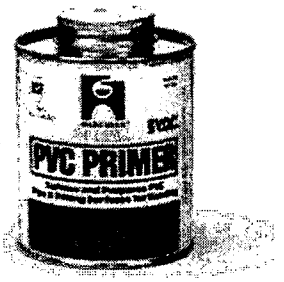
purple *[Note: For use where plumbing codes require purple, rather than clear, primers.]* Recommended method to soften and prepare surface of PVC and CPVC pipe and fittings (all sizes and Schedules except copper tube size CPVC before applying solvent cements. Purple label. Use caution: Purple primers contain a dye which is difficult or impossible to remove from many surfaces. Meets ASTM F656.
MSDS #62. Spec Sheet.



Prod. No.	Size	Pack	Note	Bar Code
60403	1/4 pt.	12	dauber in cap	032628604032
60413	1/2 pt.	12	dauber in cap	032628604131
60415	1 pt.	12	jumbo dauber in cap	032628604155
60420	1 qt.	12	jumbo dauber in cap	032628604209
60425	1 gal.	6	-	032628604254

pvc primer

clear
Recommended method to soften and prepare surface of PVC pipe and fittings (all sizes and Schedules) before applying solvent cements. Red label. Meets ASTM F656.
MSDS #63. Spec Sheet.



Prod. No.	Size	Pack	Note	Bar Code
60453	1/4 pt.	12	dauber in cap	032628604537
60458	1/2 pt.	12	dauber in cap	032628604582
60460	1 pt.	12	jumbo dauber in cap	032628604605
60465	1 qt.	12	jumbo dauber in cap	032628604650
60470	1 gal.	6	-	032628604704

pvc primer

purple *[Note: For use where plumbing codes require purple, rather than clear, primers.]* Recommended method to soften and prepare surface of PVC pipe and fittings (all sizes and Schedules) before applying solvent cements. Use caution: Purple primers contain a dye which is difficult or impossible to remove from many surfaces. Lavender label. Meets ASTM F656.
MSDS #70. Spec Sheet.

Prod. No.	Size	Pack	Note	Bar Code
60473	1/4 pt.	12	dauber in cap	032628604735
60483	1/2 pt.	12	dauber in cap	032628604834
60485	1 pt.	12	jumbo dauber in cap	032628604858
60490	1 qt.	12	jumbo	032628604902

			dauber in cap	
60495	1 gal.	6	-	032628604957

plastic pipe and fittings cleaner

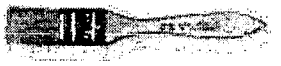
clear

For removing foreign matter and dirt from ABS, PVC, and CPVC, pipe and fittings. Yellow label.
MSDS #67. Spec Sheet.

Prod. No.	Size	Pack	Note	Bar Code
60652	1/4 pt.	12	dauber in cap	032628606524
60659	1/2 pt.	12	dauber in cap	032628606593
60664	1 pt.	12	jumbo dauber in cap	032628606647
60667	1 qt.	12	jumbo dauber in cap	032628606678
60669	1 gal.	6	-	032628606692

Accessories

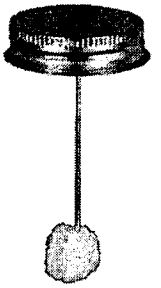
plastic pipe cement brush



One inch wide, natural bristle brush. For larger size pipe and fitting to ensure a full and even application.

Prod. No.	Size	Pack	Note	Bar Code
50200	1"	36	-	032628502000

plastic pipe cement daubers



For clean, rapid application of cements and primers. Dauber extends to the bottom of the cans for which they were designed, so there is no wasted cement and no tipping of cans.

Prod. No.	Size	Pack	Note	Bar Code
50235	1 1/2" dia. for 1 pt.	48	-	032628502352
50245	1 1/2" dia. for 1 qt.	48	-	032628502451

"We've got to take care of our customers." That's been the Hercules cre since 1915 when founder Sam Wander opened our doors.

Contact us by phone, e-mail, fax or good ole US mail.

Hercules Chemical Company, Inc.
111 South Street
Passaic, NJ 07055 USA
(973) 778-5000
TEL 800-221-9330
FAX 800-333-3456
EMail: Info@herchem.com

Stay in touch, and we'll do the same.

CONTACT

Search Our Site

FACTS Faxed FAST! SM

OSHA-Required Health And Safety Information!

This Material Safety Data Sheet (MSDS) was requested moments ago from Hercules Automated Fax Information System. Please forward it immediately to the person in charge of MSDS's, or retain it at the machine until claimed.

Section 1

MATERIAL SAFETY DATA SHEET # 67

Hercules Plastic Pipe Cleaner

HERCULES® MATERIAL SAFETY INFORMATION SERVICE

Date Prepared: 3/24/1994 **Last Reviewed:** 1/24/2002

Meets OSHA 29 CFR 1910.1200

Hercules Chemical Company Inc.
111 South Street
Passaic NJ 07055
Phone (800) 221-9330
Fax (800) 333-3456

Section 2 - Hazardous Ingredients/Identity Information

Hazardous Components (Specific Chemical Identity; Common Name(s), CAS Numbers)	OSHA PEL	ACGIH TLV	Other Limits	Upper Bound Limit if SARA Reportable
Methyl Ethyl Ketone (78-93-3)	200PPM	200PPM	N/A	99%
Acetone (67-64-1)	1000PPM	750PPM	N/A	.95

HMIS Hazard Rating: Health: 3 Flammability:4 Reactivity: 1 Personal Protection: G

Section 3 - Physical/Chemical Characteristics

Boiling Point (°C):	Specific Gravity (H2O = 1):	Vapor Density (Air = 1):	Vapor Pressure (mm Hg):
133 (Based on first boiling component-Acet	0.79 ± 0.02	2.0 to 2.5	190 Based on first boiling component-Acetone

Melting Point (° F)	Evaporation Rate: (Butyl Acetate = 1)	Solubility In Water:
N/A	7-11	60% to 95%

Appearance And Color: Clear Liquid **Odor:** Ethereal & Acetone-like

Section 4 - Fire And Explosion Hazard Data

Flash Point:	Flammable Limits: LEL:	UEL:
0° F T.C.C. (Based on Acetone)	2%	13%

Extinguishing Media: Foam, Dry chemical, Carbon Dioxide

Special Firefighting Procedures:
Handle as flammable liquid, wear self-contained breathing apparatus and chemical goggles. Water may be ineffective but should be used to keep fire exposed containers cool.

Unusual Fire And Explosion Hazards:
Vapor is heavier than air and travels considerable distance to source of ignition and flashback.

Continued on Next Page

Section 5 - Reactivity Data

Stability: Stable **Conditions To Avoid:** Keep in closed containers away from sparks and open flame.

Incompatability (Materials To Avoid): Strong oxidizing materials, Lithium Aluminum Hydride, Sodium Aluminum Hydroxide, Sodium & Potassium Hydroxides.

Hazardous Decomposition: Carbon dioxide and carbon monoxide are formed. Irritating Peroxide fumes formed when heated to decomposition.

Hazardous Polymerization: Avoid excessive exposure to air and cationic initiators like Lewis Acids.

Section 6 - Health Hazard Data

Routes of Entry: **Inhalation** YES/Primary **Skin** YES/Primary **Ingestion** YES/Secondary

Health Hazards:

Corrosive to eyes and skin irritant. Severe overexposure can cause headache, dizziness and narcosis. May cause dermatosis and dermatitis with prolonged skin contact.

Carcinogenicity: **NTP** NO **IARC** NO **OSHA Regulated** NO

Signs And Symptoms of Exposure:

INGESTION: No effects of exposure expected. INHALATION: Will cause irritation of mucous membranes, nose, eyes, and throat, coughing, difficulty in breathing. Exposure to high vapor concentration may cause headache, dizziness, nausea, narcosis. SKIN CONTACT: Prolonged contact causes common solvent defatting effect. EYE CONTACT: Vapors slightly uncomfortable, splashes irritating. Will cause painful burning or stinging of eyes and lids, watering of eyes and inflammation of conjunctiva.

Medical Conditions Generally Aggravated By Exposure:

No data found

Emergency And First Aid Procedures:

INGESTION: DO NOT INDUCE VOMITING. If conscious, dilute by giving two glasses of water. Call a physician immediately. INHALATION: Remove to fresh air. If not breathing give artificial respiration, preferably mouth to mouth. If breathing is difficult give oxygen. Call a physician. SKIN CONTACT: Wash affected skin area with soapy water. Remove contaminated clothing. EYE CONTACT: Immediately flush eyes with plenty of water for 15 minutes. Consult a physician.

Continued on Next Page

Section 7 - Precautions For Safe Handling And Use:

Steps To Be Taken In Case Material Is Released Or Spilled:

Eliminate sources of ignition. Absorb with sand or inert absorbing material and dispose of with solid waste according to federal, state and local regulations. Flush spill area with water, avoid flushing into confined areas.

Waste Disposal Method:

Incinerate in accordance with federal, state and local regulations.

Precautions To Be Taken In Handling And Storing:

Store in cool place, well-ventilated area. Keep away from open flame and sources of ignition.

Other Precautions:

Use normal good personal hygiene

Section 8 - Control Measures:

Respiratory Protection:

In confined spaces or other circumstances where adequate ventilation cannot be assured use NIOSH-approved respirator, positive pressure airline mask, or self contained breathing apparatus.

Ventilation: **Local Exhaust** As required

Mechanical All ventilating devices must be located so they do not provide a source of ignition.

Special When using cements in an area of limited ventilation, use a ventilation device such as a fan or air mover to maintain a safe air concentration.

Gloves: PVA gloves.

Other: N/A

Eye Protection: Chemical safety goggles

Other Protective Clothing: Apron, boots, eye bath, safety shower.

Work/Hygienic Practices Wash thoroughly after handling. Avoid ingestion of the cements. Do not eat or drink when using cements or in the vicinity where such cements are being used.

HERCULES® MATERIAL SAFETY INFORMATION SERVICE

FACTS faxed FAST!

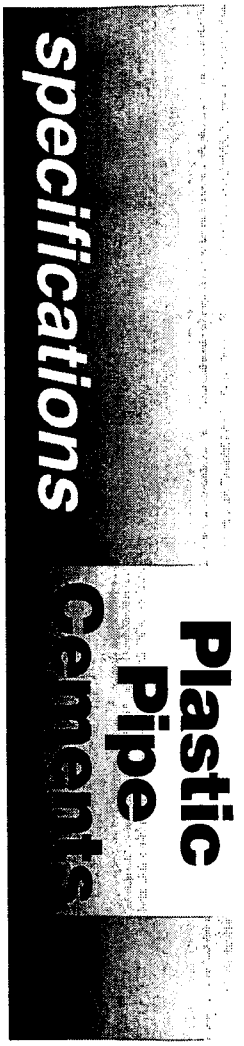
For Hercules Material Safety Data Sheets by fax anytime, day or night, just call 1-800-942-INFO (1-800-942-4636) from any Touch-Tone phone. Have your fax number ready. Checking the product label for the correct MSDS # will save time.

Plastic Pipe Cements

Spec Sheet #S00032
July 2004

HERCULES®

Primers, Cleaner & Accessories



DESCRIPTION

Cements, Primers, Cleaner & Daubers

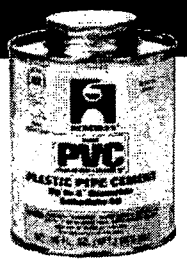
Application specific **solvent cements** for superior bonding strength on rigid or flexible PVC, CPVC and ABS plastic pipe and fittings. Regular, medium, heavy bodied cements for use on pipe and fittings up to 15" diameter. Ideal for use with hot or cold potable water pressure systems, irrigation, conduit, pool and spas, industrial piping, sewer, drain waste and vent systems. Clear and purple primers for softening and preparing surfaces of pipe and fittings before applying solvent cement and for code verification. Fast acting **Hercules cleaner** removes surface dirt, grease and grime on pipes and fittings. An assortment of daubers and a brush are also available.

Each product meets standards set by nationally recognized code-making standards and testing organizations. As designated on individual labels, these products meet standards set by the National Sanitation Foundation (NSF), the Uniform Plumbing Code of the International Association of Plumbing and Mechanical Officials (IAPMO) and the specifications of the American Society for Testing and Materials (ASTM). Cans of Hercules cements, primers and cleaner are available in sizes 1/4 pt. to 1 qt. and have dauber applicators for fast and easy installation. All Hercules cements, primers and cleaner are date-coded for shelf life and color-coded for easy selection.

CPVC/PVC Cements

Polyvinyl chloride (PVC) cements are used for solvent welding PVC pipe and socket-type fittings. Hercules offers 5 different types of pvc cements with various setting speeds and viscosities. Chlorinated polyvinyl chloride (CPVC) cements are used for solvent welding CPVC tubing, and socket-type fittings. Hercules offers 2 different types of CPVC formulations.

Cements for PVC

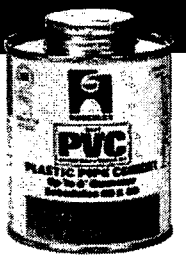


clear, regular body, medium set
For PVC Types I & II, potable water, DWV, and SW pipe and fittings up to 4" diameter. Schedule 40.
Meets ASTM D2564
MSDS #53

NSF. UPC.®

SIZES AND PACKING

STOCK NO.	SIZE	PACKING	WEIGHT/CASE
60043*	1/4 pt.	12	4.3 lbs.
60053*	1/2 pt.	12	7.8 lbs.
60055**	1 pt.	12	14.7 lbs.
60060**	1 qt.	12	27.5 lbs.
60065	1 gal.	6	53.6 lbs.



clear, medium body, medium set
For PVC Types I & II, potable water, DWV, and SW pipe and fittings up to 6" diameter. Schedules 40 and 80.
Meets ASTM D2564
MSDS #52

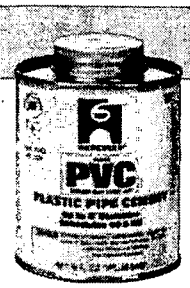
NSF. UPC.®

SIZES AND PACKING

STOCK NO.	SIZE	PACKING	WEIGHT/CASE
60003*	1/4 pt.	12	4.3 lbs.
60013*	1/2 pt.	12	7.8 lbs.
60015**	1 pt.	12	14.5 lbs.
60020**	1 qt.	12	27.5 lbs.
60025	1 gal.	6	53.2 lbs.

*Dauber in cap **Jumbo Dauber in cap

pvc cement, yellow label



clear, medium body, fast set
For PVC Types I & II, potable water, DWV, and SW pipe and fittings up to 8" diameter. Schedules 40 and 80.
Meets ASTM D2564
MSDS#52

SIZES AND PACKING

STOCK NO.	SIZE	PACKING	WEIGHT/CASE
60103*	1/4 pt.	12	4.3 lbs.
60113*	1/2 pt.	12	7.8 lbs.
60115**	1 pt.	12	14.9 lbs.
60120**	1 qt.	12	27.5 lbs.
60125	1 gal.	6	53.0 lbs.

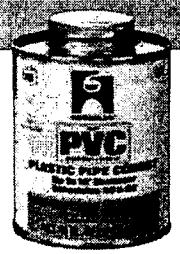
pvc cement, tan label

clear, heavy body, slow set
For PVC Types I & II, potable water, DWV, and SW pipe and fittings up to 15" diameter. Schedules 40 and 80.
Meets ASTM D2564
MSDS #50

SIZES AND PACKING

STOCK NO.	SIZE	PACKING	WEIGHT/CASE
60155*	1/2 pt.	24	15.6 lbs.
60160**	1 pt.	12	14.6 lbs.
60165**	1 qt.	12	27.6 lbs.

pvc cement, gray label

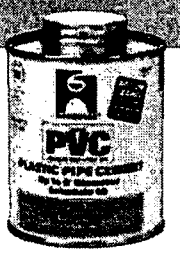


gray, heavy body, slow set
For PVC Types I & II, potable water, DWV, and SW pipe and fittings up to 15" diameter. Schedules 40 and 80.
Meets ASTM D2564
MSDS #60

SIZES AND PACKING

STOCK NO.	SIZE	PACKING	WEIGHT/CASE
60210*	1/2 pt.	24	15.9 lbs.
60215**	1 pt.	12	14.7 lbs.
60220**	1 qt.	12	27.9 lbs.
60225	1 gal.	6	54.0 lbs.

below-zero pvc cement, orange label



clear, regular body, fast set
For PVC Types I & II, potable water, DWV, and SW pipe and fittings up to 6" diameter. Schedule 40.
Withstands storage temperatures down to -10°F (-23°C).
Meets ASTM D2564
MSDS #51

SIZES AND PACKING

STOCK NO.	SIZE	PACKING	WEIGHT/CASE
60142*	1/2 pt.	24	15.4 lbs.
60145**	1 pt.	12	14.5 lbs.
60148**	1 qt.	12	27.5 lbs.

wet set pvc cement, aqua blue label

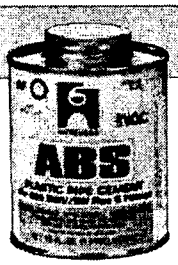
aqua blue, medium body,fast set
For PVC Types I & II, potable water, DWV, and SW pipe and fittings up to 8" diameter. Schedules 40 and 80.
Formulated for applications where conditions are very wet and/or when quick pressurization is imperative. Ideal for lawn sprinkler and swimming pool installations.
Meets ASTM D2564
MSDS#76

SIZES AND PACKING

STOCK NO.	SIZE	PACKING	WEIGHT/CASE
60253*	1/2 pt.	12	7.4 lbs.
60255**	1 pt.	12	13.7 lbs.
60260**	1 qt.	12	28.7 lbs.
60265	1 gal.	6	54.2 lbs.

Cements for ABS

abs cement, green label



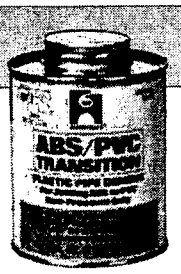
black, medium body, fast set
For ABS potable water and DWV and SW pipe and fittings up to 8" diameter. Schedules 40 and 80.
Meets ASTM 2235
MSDS #64

LOW V.O.C.

SIZES AND PACKING

STOCK NO.	SIZE	PACKING	WEIGHT/CASE
60503*	1/4 pt.	12	4.1 lbs.
60513*	1/2 pt.	12	7.4 lbs.
60515**	1 pt.	12	13.6 lbs.
60520**	1 qt.	12	25.7 lbs.
60525	1 gal.	6	49.5 lbs.

abs/pvc transition cement, brown label



green, medium body, fast set
For joining ABS to PVC pipe and fittings up to 6" diameter, non pressure only. Schedules 40 and 80.
Meets ASTM D3138
MSDS #65

SIZES AND PACKING

STOCK NO.	SIZE	PACKING	WEIGHT/CASE
60555*	1/2 pt.	24	15.5 lbs.
60560**	1 pt.	12	14.5 lbs.

*Dauber in cap **Jumbo Dauber in cap

Cements for CPVC

cpvc cement, orange label

orange, medium body, fast set
CPVC potable water pipe and fittings to 8" diameter. All schedules.
Meets ASTM F493
MSDS #61

SIZES AND PACKING

STOCK NO.	SIZE	PACKING	WEIGHT/CASE
60303*	1/4 pt.	12	4.4 lbs.
60313*	1/2 pt.	12	8.0 lbs.
60315*	1 pt.	12	14.7 lbs.
60320*	1 qt.	12	28.0 lbs.

cpvc gold, yellow label

gold, medium body, medium set
One step, low V.O.C. cement for use on all CPVC pipe and fittings including FlowGuard Gold™ (for use on specific brands of CPVC pipe, verify suitability with pipe manufacturer). Schedules 40 and 80.
Meets ASTM F493. *MSDS #95*

LOW V.O.C.

SIZES AND PACKING

STOCK NO.	SIZE	PACKING	WEIGHT/CASE
60353*	1/4 pt.	12	4.4 lbs.
60358*	1/2 pt.	12	8.0 lbs.
60360*	1 pt.	12	14.7 lbs.
60365*	1 qt.	12	28.0 lbs.

Specialty Cement

multi-purpose cement, blue label

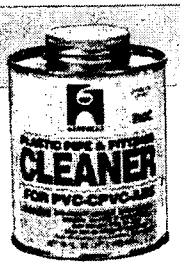
milky, medium body, fast set
For potable water, DWV and SW pipe and fittings. For joining PVC, CPVC and ABS pipe and fittings up to 6" diameter. Schedules 40 and 80.
Meets ASTM D2564, D2235, F493 performance requirements.
MSDS #66

SIZES AND PACKING

STOCK NO.	SIZE	PACKING	WEIGHT/CASE
60703*	1/4 pt.	12	4.4 lbs.
60713*	1/2 pt.	12	7.2 lbs.
60715**	1 pt.	12	13.1 lbs.
60720**	1 qt.	12	24.8 lbs.
60725	1 gal.	6	47.5 lbs.

Plastic Pipe and Fittings Cleaner

plastic pipe and fittings cleaner, yellow label



clear
For removing foreign matter and dirt from ABS, PVC, and CPVC pipe and fittings.
MSDS #67

LOW V.O.C.

SIZES AND PACKING

STOCK NO.	SIZE	PACKING	WEIGHT/CASE
60652*	1/4 pt.	12	4.0 lbs.
60659*	1/2 pt.	12	7.2 lbs.
60664**	1 pt.	12	13.1 lbs.
60667**	1 qt.	12	24.7 lbs.
60669	1 gal.	6	47.5 lbs.

Primers

primer for pvc and cpvc, purple label

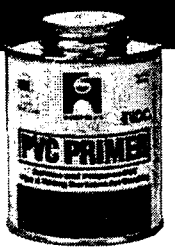
purple *[Note: For use where plumbing codes require purple, rather than clear primers.]* Recommended method to soften and prepare surface of PVC and CPVC pipe fittings (all sizes and schedules except copper tube size CPVC) before applying solvent cements. Use caution: Purple primers contain a dye which is difficult or impossible to remove from many surfaces. Meets ASTM F656. *MSDS #62*

SIZES AND PACKING

STOCK NO.	SIZE	PACKING	WEIGHT/CASE
60403*	1/4 pt.	12	4.1 lbs.
60413*	1/2 pt.	12	7.4 lbs.
60415**	1 pt.	12	13.7 lbs.
60420**	1 qt.	12	25.9 lbs.
60425	1 gal.	6	49.8 lbs.

LOW V.O.C.

pvc primer, red label



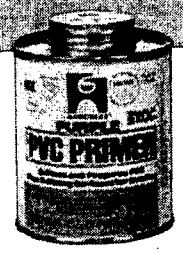
clear Recommended method to soften and prepare surface of PVC pipe and fittings (all sizes and schedules) before applying solvent cements.
Meets ASTM F656.
MSDS #63

LOW V.O.C.

SIZES AND PACKING

STOCK NO.	SIZE	PACKING	WEIGHT/CASE
60453*	1/4 pt.	12	4.1 lbs.
60458*	1/2 pt.	12	7.3 lbs.
60460**	1 pt.	12	13.4 lbs.
60465**	1 qt.	12	25.3 lbs.
60470	1 gal.	6	48.6 lbs.

pvc primer, lavender label



purple *[Note: For use where plumbing codes require purple, rather than clear primers.]* Recommended methods to soften and prepare surface of PVC pipe and fittings (all sizes and schedules) before applying solvent cements. Use caution: Purple primers contain a dye which is difficult or impossible to remove from many surfaces. Meets ASTM F656
MSDS #70

SIZES AND PACKING

STOCK NO.	SIZE	PACKING	WEIGHT/CASE
60473*	1/4 pt.	12	4.1 lbs.
60483*	1/2 pt.	12	7.3 lbs.
60485**	1 pt.	12	13.4 lbs.
60490**	1 qt.	12	25.3 lbs.
60495	1 gal.	6	48.6 lbs.

LOW V.O.C.

*Dauber in cap **Jumbo Dauber in cap

FACTS Faxed AST! SM

OSHA-Required Health And Safety Information!

This Material Safety Data Sheet (MSDS) was requested moments ago from Hercules Automated Fax Information System. Please forward it immediately to the person in charge of MSDS's, or retain it at the machine until claimed.

Section 1

MATERIAL SAFETY DATA SHEET # 70

Hercules Purple PVC Primer

HERCULES® MATERIAL SAFETY INFORMATION SERVICE

Date Prepared: 3/24/1994 **Last Reviewed:** 1/24/2002

Meets OSHA 29 CFR 1910.1200

Hercules Chemical Company Inc.
111 South Street
Passaic NJ 07055
Phone (800) 221-9330
Fax (800) 333-3456

Section 2 - Hazardous Ingredients/Identity Information

Hazardous Components (Specific Chemical Identity; Common Name(s), CAS Numbers)	OSHA PEL	ACGIH TLV	Other Limits	Upper Bound Limit if SARA Reportable
Tetrahydrofuran (109-99-9)	200PPM	200PPM	N/A	- -
Methyl Ethyl Ketone (78-93-3)	200PPM	200PPM	N/A	.40
Cyclohexanone (108-94-1)	25PPM	25PPM	N/A	- -
Acetone (CAS67-64-1)	1000 PPM	750PPM		.45

HMIS Hazard Rating: Health: 3 Flammability: 4 Reactivity: 1 Personal Protection: G

Section 3 - Physical/Chemical Characteristics

Boiling Point (°C):	Specific Gravity (H2O = 1):	Vapor Density (Air = 1):	Vapor Pressure (mm Hg):
133 Based on first boiling component-Acet	0.820 ± 0.03	2.0 to 2.5	190 Based on first boiling component-Acetone

Melting Point (° F)	Evaporation Rate: (Butyl Acetate = 1)	Solubility in Water:
N/A	7-11	50% to 75%

Appearance And Color: Purple Liquid **Odor:** Ethereal & Acetone-like

Section 4 - Fire And Explosion Hazard Data

Flash Point:	Flammable Limits: LEL:	UEL:
0° to 6.0° F (TCC) (Based on acetone)	2%	13.0%

Extinguishing Media: Foam/Dry chemical/CO2

Special Firefighting Procedures:
Handle as flammable liquid. Wear self-contained breathing apparatus & chemical goggles. Water may be ineffective, but should be used to keep fire-exposed containers cool.

Unusual Fire And Explosion Hazards:
Vapor is heavier than air and travels considerable distance to sources of ignition and flashback. On long standing may cause peroxides which may cause violent reaction especially upon evaporation to dryness.

Continued on Next Page

Section 5 - Reactivity Data

Stability: Stable **Conditions To Avoid:** Keep in closed containers away from sparks & open flame.

Incompatability (Materials To Avoid): Strong oxidizing materials, Lithium Aluminum Hydride, Sodium Aluminum Hydroxide, Sodium & Potassium Hydroxides.

Hazardous Decomposition: Carbon dioxide and carbon monoxide are formed. Irritating Peroxide fumes are formed when heated to decomposition.

Hazardous Polymerization: Avoid excessive exposure to air and cationic initiators like Lewis Acids.

Section 6 - Health Hazard Data

Routes of Entry: **Inhalation** YES/Primary **Skin** YES/Primary **Ingestion** YES/Secondary

Health Hazards:

Corrosive to eyes and skin irritant. Severe overexposure can cause headache, dizziness and narcosis. May cause dermatosis and dermatitis with prolonged repeated contact.

Carcinogenicity: **NTP** NO **IARC** NO **OSHA Regulated** NO

Signs And Symptoms of Exposure:

INGESTION: No effects expected. INHALATION: Will cause irritation of mucous membranes, nose, eyes, & throat; coughing, difficulty of breathing. Exposure to high vapor concentration may cause headache, dizziness, nausea, narcosis. SKIN CONTACT: Prolonged skin contact causes common solvent defatting effect. EYE CONTACT: Vapors slightly uncomfortable. Splashes irritating. Will cause painful burning or stinging of eyes & lids, watering of eyes and conjunctiva.

Medical Conditions Generally Aggravated By Exposure:

No data found

Emergency And First Aid Procedures:

INGESTION: DO NOT INDUCE VOMITING. If conscious, dilute by giving 2 glasses of water. Call a physician immediately. INHALATION: Remove to fresh air. If not breathing, give artificial respiration, preferably mouth-to-mouth resuscitation. If breathing is difficult, give oxygen. Call a physician. SKIN CONTACT: Wash affected area with soapy water. Remove contaminated clothing. EYE CONTACT: Immediately flush eyes with plenty of water for 15 minutes. Consult a physician.

Continued on Next Page

Section 7 - Precautions For Safe Handling And Use:

Steps To Be Taken In Case Material Is Released Or Spilled:

Eliminate sources of ignition. Absorb with sand or inert absorbing material. Dispose of with solid waste in accordance with all regulations. Flush spill area with water. Avoid flushing into confined areas.

Waste Disposal Method:

Incinerate in accordance with federal, state and local regulations.

Precautions To Be Taken In Handling And Storing:

Store in cool, well-ventilated area. Keep away from open flame and sources of ignition.

Other Precautions:

Use normal good personal hygiene.

Section 8 - Control Measures:

Respiratory Protection:

In confined spaces or other circumstances where adequate ventilation cannot be assured use NIOSH-approved respirator, positive pressure airline mask, or self contained breathing apparatus.

Ventilation: **Local Exhaust** As required

Mechanical All ventilating devices must be located so they do not provide a source of ignition.

Special When using cements in an area of limited ventilation, use a ventilation device such as a fan or air mover to maintain a safe air concentration.

Gloves: PVA gloves

Other: N/A

Eye Protection: Chemical Safety goggles.

Other Protective Clothing: Apron, boots, eye bath, safety shower

Work/Hygienic Practices Wash thoroughly after handling. Avoid ingestion of the cements. do not eat or drink when using cements or in the vicinity where such cements are being used.

HERCULES® MATERIAL SAFETY INFORMATION SERVICE

FACTS faxed FAST!

For Hercules Material Safety Data Sheets by fax anytime, day or night, just call 1-800-942-INFO (1-800-942-4636) from any Touch-Tone phone. Have your fax number ready. Checking the product label for the correct MSDS # will save time.

Household Products Database

National Institutes of Health
National Library of Medicine
Specialized Information Services

Brand Information

Brand Name: **Oatey H2O (5) Water Soluble Flux**
Form: liquid
Product Category: Home maintenance >> Plumbing >> solder flux
Home maintenance >> Solder >> flux, water soluble
Customer Service No.: 800-321-9532
Date Entered: 2001-05-30
Related Items: Products with similar usage in this database

Manufacturer

Manufacturer: Oatey
Address: 4700 West 160th Street
City: Cleveland
State: OH
Zip Code: 44135
Telephone Number: 216-267-7100
Toll Free Number: 800-321-9532
Date Info Verified: 2004-02-16
Related Items: Products by this manufacturer

Health Effects

The following information (Health Effects, Handling/Disposal, and Ingredients) is taken from the product label and/or the Material Safety Data Sheet (MSDS) prepared by the manufacturer. The National Library of Medicine does not evaluate information from the product label or the Material Safety Data Sheet.

Acute Health Effects: From MSDS:
ENTRY ROUTE INHALE – YES; INGEST - YES; SKIN - YES; EYE – YES

GENERAL Zinc Chloride is corrosive to all body tissues and can cause severe burns.
INHALATION If heated, fumes may produce respiratory irritation, fever, chills, muscular pain, headache, vomiting and sweating.
SKIN Contact may cause irritation, burns or dermatitis.
EYE May cause irritation, burns or corneal damage.
INGESTION May cause burns of mouth, throat and gastrointestinal tract, vomiting, abdominal pain, diarrhea, strictures, kidney disease, shock or death.

TARGET ORGANS Eye, Skin, Central Nervous System, kidney, respiratory system, digestive system

Chronic Health Effects: MSDS: No information provided.
Carcinogenicity: MSDS: The ingredients in this product are not identified as carcinogens

by NTP, IARC and OSHA.

First Aid: MSDS: EMERGENCY AND FIRST AID PROCEDURES - 303/623-5716 COLLECT

SKIN: Wash thoroughly with soap and water. Remove contaminated clothing and wash before re-use. Seek medical attention if irritation persists.
EYES: If fumes cause irritation, move to fresh air and irrigate eyes with water for 15 minutes. If irritation persists, seek medical attention.
INHALATION: Move to fresh air. If breathing is difficult, give oxygen. If not breathing, give artificial respiration. Keep victim quiet and warm. Call a poison control center or physician immediately.
INGESTION: Drink water. DO NOT INDUCE VOMITING and call a poison control center or physician immediately. Avoid alcoholic beverages. Never give anything by mouth to an unconscious person.

Health Rating: 2

Flammability Rating: 1

Reactivity Rating: 0

HMIS Rating Scale: 0 = Minimal; 1 = Slight; 2 = Moderate; 3 = Serious; 4 = Severe;
N = No information provided by manufacturer; * = Chronic Health Hazard

MSDS Date: 2001-04-02

Handling/Disposal

Handling: MSDS: HANDLING AND STORAGE: Do not store near heat.

Disposal: MSDS: WASTE DISPOSAL
Dispose of according to local, state, and federal regulations.

Ingredients from MSDS/Label

Chemical	CAS No / Unique ID	Percent
Surfactant(s) (unspecified)	000000-00-4	20-50
Triethanolamine hydrochloride	000637-39-8	8-15
Zinc chloride	007646-85-7	2-8
Ammonium chloride	012125-02-9	0-3
Inert ingredients (unspecified)	999999-00-2	5-25

Note: Brand names are trademarks of their respective holders.
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Customer Service: tehip@teh.nlm.nih.gov
Last updated: May 12, 2004

Melting Range
415°F - 455°F

No./No 50692

Gama de fusión
212°C - 235°C

H-20^{95}™ WATER SOLUBLE TINNING FLUX PLUMBING SOLDER KIT

WITH SAFE FLO® SILVER LEAD FREE SOLDER AND APPLICATOR BRUSH

H-20^{95}™ Water Soluble Tinning Flux is perfect for all climates, is water flushable and flux base meets ASTM B-813. H-20^{95}™ can be used for potable plumbing, copper fire sprinkler and hydronic heating systems. Safe FLo® Silver Lead Free Solder is a patented alloy of Tin, Silver, Copper and Bismuth. Safe Flo® Silver Lead Free Solder works as easy as 50 tin/50 lead solders to make joints that are even stronger. The working range of 415°-455° is easily reached and held with a standard propane torch.

DIRECTIONS: 1. Remove all corrosion, dirt and oil using Oatey abrasive cloth, utility brushes or nylon grit pads. Clean all surfaces until they are bright. **2.** Apply H-20^{95}™ Water Soluble Tinning Flux to all surfaces being soldered. Solder will not adhere to surfaces that have not been fluxed. Join parts together. **3.** Apply heat to the joint with a torch. Once flux bubbles; apply solder while maintaining heat. Allow to cool undisturbed. Remove any flux residue with a damp cloth.

SOLDER-HAZARDOUS INGREDIENTS: Tin 7440-31-5, Copper 7440-50-8, Bismuth 7440-69-9 and Silver 7440-22-4.
FLUX-HAZARDOUS INGREDIENTS: Zinc Chloride 7646-85-7 and Triethanolamine Hydrochloride 637-39-8.
FLUX-NON-HAZARDOUS INGREDIENTS: NJTSRN 80100453-5006, 5007, 5008, 5009, and 5010.

Eye/skin contact may cause intense irritation and injury. In case of eye/skin contact, flush/wash freely with water. Call physician or poison control center immediately. If swallowed, **DO NOT INDUCE VOMITING**, drink water and call a physician or poison control center immediately. Ingestion of this product could cause gastrointestinal distress. **KEEP OUT OF REACH OF CHILDREN.**

EQUIPO DE SOLDADURA PARA PLOMERÍA DE FUNDENTE PARA ESTAÑADO HIDROSOLUBLE H-20^{95}™

CON SOLDADURA DE PLATA SIN PLOMO SAFE FLO® Y CEPILLO APLICADOR

El fundente para estañado hidrosoluble H-20^{95}™ es ideal para todo tipo de clima, se enjuaga con agua y la base de fundente comple con ASTM B-813. H-20^{95}™ se puede utilizar para cañería de agua potable, cañería contra incendio de cobre y para sistemas de calefacción hidrónicos. La soldadura de plata sin plomo Safe Flo® es una aleación patentada de estaño, plata, cobre y bismuto. La soldadura de plata sin plomo Safe Flo® actúa con la facilidad de las soldaduras 50 estaño/50 plomo para hacer uniones que son aun más fuertes. La gama de fusión de 212°C - 235°C se alcanza y se mantiene fácilmente con un soplete estándar de propano.

INSTRUCCIONES: Elimine toda corrosión, polvo y aceite, utilizando tela abrasiva, cepillos utilitarios o esponjas de abrasión de nylon Oatey. Limpie hasta que las superficies estén brillantes. 2. Aplique el fundente para estañado hidrosoluble H-20^{95}™ a todas las superficies que deban soldarse. La soldadura no se adherirá a las superficies que no tengan fundente. Junte las partes. 3. Aplique calor a la junta con un soplete. Luego que el fundente burbejea, aplique la soldadura manteniendo el calor. Permita que la junta se enfríe sin interferencias. Elimine el exceso de fundente con un trapo húmedo.

INGREDIENTES PELIGROSOS DE LA SOLDADURA: Estaño 7440-31-5, cobre 7440-50-8, bismuto 7440-69-9 y plata 7440-22-4.
INGREDIENTES PELIGROSOS DEL FUNDENTE: Cloruro de zinc 7646-85-7 y hidrocloruro de trietanolamina 637-39-8.
INGREDIENTES NO PELIGROSOS DEL FUNDENTE: NJTSRN 80100453-5006, 5007, 5008, 5009 y 5010.

Contacto con los ojos y la piel puede causar irritación intensa y lesiones. En caso de contacto con los ojos y la piel, enjuague/lave con abundante cantidad de agua. Llame al médico o al centro de control de envenenanimento inmediatamente. En caso de ingestión, **NO PROVOQUE EL VOMITO**, beba agua y llame al médico o al centro de control de envenenanimento inmediatamente. La ingestión de este producto puede causar problemas gastrointestinales. **MANTENGA FUERA DEL ALCANCE DE LOS NIÑOS.**

FOR EMERGENCY FIRST AID HELP CALL 1-303-623-5716 COLLECT.
PARA PRIMEROS AUXILIOS, EN CASO DE EMERGENCIA LLAME "POR COBRAR" AL 1-303-623-5716.

MADE IN U.S.A./HECHO EN E.U.A.

Oatey
Cleveland, OH 44135
800-321-9532
www.oatey.com

Manufactured by:/Fabricado por: Oatey • Cleveland, Ohio

0 38753 50692 0

garuda chemicals

ORGANIC

Product:	**Triethanolamine Hydrochloride.**
CAS #:	637-39-8.
Synonyms:	Tris (hydroxyethyl) Amine Hydrochlorid Nitrilotriethanol Hydrochloride.
Molecular Formula:	$C_{16}H_{16}ClNO_3$.
Molecular Weight:	185.65.
Description:	Colourless to white crystalline powder,
Iron Content:	5 PPM max.
Lead Content:	5 PPM max.
Copper Content:	5 PPM max.
Cadmium Content:	5 PPM max.
Sulphated Ash:	0.01% max.
Moisture Content:	0.5% max.
Melting Point:	176.0 to 177.0°C.
Assay:	99.0% min.
Quantity Available:	30.0 MT. per month.
Packing:	25.0 kilos net, new, polylined HDPE dru
Delivery:	4 to 6 weeks from receipt of confirmat
Price:	Available on request.
Payment:	Negotiable.

AMINE

Office:
15/605-606 Mayuresh C.H.S., Majaswadi MHADA Colony, Off Mahakali Caves Road, Andheri (East), Mumbai-400 093. India.
Tel.: ++91.22.2820.1198 • ++91.22.2821.5596 Fax: ++91.22.2820.1201 Email: sales@garudachem.com

Factory:
B-46 M. I. D. C. Industrial Estate, Lote-Parshuram, Tal.: Khed, Dist.: Ratnagiri. Maharashtra. India.
Tel.: ++91.2356.27.2157 Email: factory@garudachem.com

Visit our website to find more information like MSDS, infra-red (IR), molfile, sdf file, structure, price, a catalog of over 130000 chemicals and over 150 chemical suppliers. You may also add your own catalog of chemicals for free.

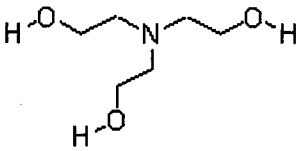
Triethanolamine hydrochloride

Synonyms: 2,2',2"-Nitrilotriethanol hydrochloride~Tris(2-hydroxyethyl)amine hydrochloride; triethanolamine hydrochloride gr; triethanolamine hcl; tris(2-hydroxyethyl) ammonium chloride; 2,2',2"-Nitrilotriethanol

Molecular Formula: $C_6H_{15}NO_3.HCl$

Formula Weight: 185.65

Registry number: 637-39-8



Registry number (RN, CAS): 637-39-8

Melting point (Mp): 177-179 °C

Safety Description

S24/25 Avoid contact with skin and eyes.

Products commercially available

Supplier	Name and purity	Qtt	Reference
abcr	Triethanolamine hydrochloride, 99%	250.00 g 1.00 kg 5.00 kg	AV15678 Get offer AV15678 Get offer AV15678 Get offer
Acros	Triethanolamine hydrochloride p.a. p.a.	5 GR 100 GR 500 GR	170050050 Get offer 170051000 Get offer 170055000 Get offer
acros	Triethanolamine hydrochloride 99% 99%	1 GR 100 GR 500 GR	421640010 Get offer 421641000 Get offer 421645000 Get offer
AlfaAesar	Triethanolamine hydrochloride, 99%	5000g 250g	A15678 Get offer A15678 Get offer
Alkemi	Triethanolamine hydrochloride, 99%	250 g 1 kg 5 kg	ALK19604 Get offer ALK19605 Get offer ALK19606 Get offer
chemos	Triethanolamine Hydrochloride	on request	FC49500 Get offer
lancaster	Triethanolamine hydrochloride 99+ 99+	250g 1kg	X03480G0250 X03480G1000
lancaster	Triethanolamine hydrochloride	250g 1kg	3480 3480
lobachem	triethanolamine hydrochloride gr	500 gm 100 gm	6362 Get offer 6362 Get offer
MatrixSwitzerland	Triethanolamine hydrochloride	semi bulk bulk	Get offer Get offer
molekula	Triethanolamine hydrochloride	100 g 100 GM	25559545 Get offer 3079T

MATERIAL SAFETY DATA SHEET

MSDS 0426

Section 1 -- PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME
Nokorode Aqua Flux

PRODUCT CODES
74044, 74046, 74047

CHEMICAL FAMILY:
Organic/Inorganic

USE
Soldering Flux

MANUFACTURER'S NAME
The RectorSeal Corporation
2601 Spenwick Drive
Houston, Texas 77055 USA

DATE OF PREPARATION
August 7, 2002

HMIS CODES

Health	1
Flammability	1
Reactivity	0
PPI	B

EMERGENCY TELEPHONE NO.
Chemtrec 24 Hours
(800) 424-9300

TECHNICAL SERVICE TELEPHONE NO.
(800) 231-3345

Section 2 -- COMPOSITION/INFORMATION ON INGREDIENTS

% by WT	CAS No.	INGREDIENT		UNITS
10-25	7646-85-7	Zinc Chloride		
			ACGIH TLV	1 mg/m3
			OSHA PEL	1 mg/m3
10-25	12125-02-9	Ammonium Chloride		
			ACGIH TLV	10 mg/m3
			OSHA PEL	10 mg/m3
<10	111-42-2	Diethanolamine		
			ACGIH TLV	0.46 mg/m3-skin-
			OSHA PEL	3 mg/m3
70-90	8009-03-8	Pertrolatum		
			ACGIH TLV	N/D
			OSHA PEL	N/D
<10	2002-24-6	Ethanolamine Hydrochloride		
			ACGIH TLV	N/D
			OSHA PEL	N/D
<10	25322-68-3	Poly(ethylene oxide)		
			ACGIH TLV	N/D
			OSHA PEL	N/D

Section 3 -- HAZARDS IDENTIFICATION

SUMMARY OF ACUTE HAZARDS
Irritation to respiratory system from fumes evolved during soldering.
Eye contact may cause intense irritation and injury.

ROUTE OF EXPOSURE, SIGNS AND SYMPTOMS

INHALATION
Irritation to respiratory system from fumes evolved during soldering.

EYE CONTACT
Contact may cause intense irritation and injury.

SKIN CONTACT
May cause skin irritation.

INGESTION
Nausea, vomiting, irritation to digestive system.

SUMMARY OF CHRONIC HAZARDS

Short term effects to liver and kidneys can occur. Chemical irritation from continued skin contact can occur. Continuous industrial use in small unventilated areas may result in sufficient inhalation of solder and flux fumes to cause lung damage and irritation of respiratory tract.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE

Individuals with pre-existing or chronic diseases of the eyes, skin, respiratory system, cardiovascular system, gastrointestinal system, liver, or kidneys may have increased susceptibility to excessive exposure.

Section 4 -- FIRST AID MEASURES

If INHALED:	If overcome by exposure, remove victim to fresh air immediately. Give oxygen or artificial respiration as needed. Obtain emergency medical attention. Prompt action is essential.
If on SKIN:	Immediately wash with soap and water. Remove and wash any contaminated clothing.
If in EYES:	Flush eyes with large amounts of water for 15 minutes. Get medical attention if irritation persists.
If SWALLOWED:	If swallowed, call a physician immediately. Only induce vomiting at the instruction of a physician. Never give anything by mouth to an unconscious person.

Section 5 -- FIRE FIGHTING MEASURES

FLASH POINT	LEL	UEL
>400 F (204 C) SETA CC	N/D	N/D

EXTINGUSING MEDIA

Foam, dry chemical, carbon dioxide or water fog.

SPECIAL FIRE FIGHTING PROCEDURES: Wear self-contained full face piece breathing apparatus and other protective clothing. Hazardous decomposition products possible (see Section 10). May release ZnO and HCl fumes.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Heat may build up pressure and rupture closed containers.

Section 6 -- ACCIDENTAL RELEASE MEASURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED: Wipe up spills to prevent footing hazard. Avoid flushing into sewers, drains, waterways and soil.Wear protective clothing during clean up.

Section 7 -- HANDLING AND STORAGE

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING: Keep container closed and upright when not in use. Store flux at ambient conditions. Wash thoroughly after handling to remove all residue.

OTHER PRECAUTIONS: Avoid prolonged or repeated contact with skin or clothing. Empty containers may contain residues; treat as if full and observe all products precautions. Do not reuse empty containers.

Section 8 -- EXPOSURE CONTROLS/PERSONAL PROTECTION

RESPIRATORY PROTECTION (SPECIFY TYPE): In confined, poorly ventilated areas, use NIOSH/MSHA approved air purifying or supplied air respirators during soldering operations until fumes have dissipated.

VENTILATION - LOCAL EXHAUST: Acceptable

SPECIAL: N/A

MECHANICAL (GENERAL): Acceptable

OTHER: N/A

PROTECTIVE GLOVES: Wear rubber gloves.
EYE PROTECTION: Safety glasses (ANSI Z-87.1 or equivalent)
OTHER PROTECTIVE CLOTHING OR EQUIPMENT: Coveralls recommended.
WORK/HYGIENIC PRACTICES: Where use can result in skin contact, wash exposed areas thoroughly before eating, drinking, smoking, or leaving work area. Launder contaminated clothing before reuse.

Section 9 -- PHYSICAL AND CHEMICAL PROPERTIES

BOILING POINT:	N/A
SPECIFIC GRAVITY (H20 = 1):	0.98
VAPOR PRESSURE (mm Hg):	< 0.01 @ 68 F (20 C)
MELTING POINT:	120-150 F (52-66 C)
VAPOR DENSITY (AIR = 1):	N/A
EVAPORATION RATE (ETHYL ACETATE = 1):	N/A
APPEARANCE/ODOR:	Tan / Petroleum Odor
SOLUBILITY IN WATER:	Insoluble

Section 10 -- STABILITY AND REACTIVITY

STABILITY: Stable
CONDITIONS TO AVOID: None
INCOMPATIBILITY (MATERIALS TO AVOID): None known
HAZARDOUS DECOMPOSITION PRODUCTS: Toxic fumes of zinc, chlorine, and HCL may be evolved during soldering.
HAZARDOUS POLYMERIZATION: Will not occur.

Section 11 -- TOXICOLOGY INFORMATION

CHRONIC HEALTH HAZARDS
No ingredient in this product is an IARC, NTP or OSHA listed carcinogen.

TOXICOLOGY DATA

Ingredient Name	
Zinc Chloride	
	Oral-Rat LD50:350 mg/kg
	Inhalation-Rat LCLo:1960 mg/m3/10M
Ammonium Chloride	
	Oral-Rat LD50:1650 mg/kg
	Inhalation-Rat LC50:N/D
Diethanolamine	
	Oral-Rat LD50:710 mg/kg
	Inhalation-Rat LC50:N/D
Petrolatum	
	Oral-Rat LD50:N/D
	Inhalation-Rat LC50:N/D
Ethanolamine Hydrochloride	
	Oral-Rat LD50:N/D
	Inhalation-Rat LC50:N/D
Poly(ethylene oxide)	
	Oral-Rat LD50:32 g/kg
	Inhalation-Rat LC50:N/D

Section 12 -- Ecological Information

ECOLOGICAL DATA

Ingredient Name
Zinc Chloride

Food Chain Concentration Potential	None
WATERFOWL TOXICITY	N/A
BOD	None
AQUATIC TOXICITY: 7.2 ppm/96 hr/medium bluegill/TLm	

Ammonium Chloride

Food Chain Concentration Potential	None
WATERFOWL TOXICITY	N/A
BOD	N/A
AQUATIC TOXICITY: 6 ppm/96 hr/sunfish TLm	

Diethanolamine

Food Chain Concentration Potential	N/D
WATERFOWL TOXICITY	N/D
BOD	10%
AQUATIC TOXICITY: 2100 ppm/24 hr/sunfish, bluegill/TLm	

Petrolatum

Food Chain Concentration Potential	None
WATERFOWL TOXICITY	N/D
BOD	N/D
AQUATIC TOXICITY:	N/D

Ethanolamine Hydrochloride

Food Chain Concentration Potential	None
WATERFOWL TOXICITY	N/D
BOD	N/D
AQUATIC TOXICITY:	N/D

Poly(ethylene oxide)

Food Chain Concentration Potential	None
WATERFOWL TOXICITY	N/D
BOD	N/D
AQUATIC TOXICITY:	N/D

Section 13 -- DISPOSAL CONSIDERATIONS

Waste Classification: Non-regulated solid waste
Disposal Method: Approved landfill
Waste from this product is not considered hazardous as defined under the Resource Conservation and Recovery Act (RCRA) 40 CFR 261. Dispose of in accordance with Federal, State, and Local regulation regarding pollution.

Section 14 -- TRANSPORTATION INFORMATION

DOT:	Non-Regulated
OCEAN (IMDG):	Non-Regulated
AIR (IATA):	Non-Regulated
WHMIS (CANADA):	Non-Regulated

Section 15 -- REGULATORY INFORMATION

REGULATORY DATA
Ingredient Name

Zinc Chloride

SARA 313	Yes
TSCA Inventory	Yes
CERCLA RQ	1000 lbs.
RCRA Code	N/A

Ammonium Chloride

SARA 313	No
TSCA Inventory	Yes
CERCLA RQ	N/A
RCRA Code	N/A

Diethanolamine

SARA 313	No
TSCA Inventory	Yes
CERCLA RQ	100 lbs.
RCRA Code	N/A

Petrolatum

SARA 313	No
TSCA Inventory	Yes
CERCLA RQ	N/A
RCRA Code	N/A

Ethanolamine Hydrochloride

SARA 313	Yes
TSCA Inventory	Yes
CERCLA RQ	N/A
RCRA Code	N/A

Poly(ethylene oxide)

SARA 313	No
TSCA Inventory	Yes
CERCLA RQ	N/A
RCRA Code	N/A

Section 16 -- OTHER INFORMATION

This document is prepared pursuant to the OSHA Hazard Communication Standard (29 CFR 1910.1200). The information herein is given in good faith, but no warranty, expressed or implied is made. Consult RectorSeal for further information: (713) 263-8001

NOKORODE® AQUA FLUX™
Water Washable Flux

Description | Characteristics | Applications | Packaging | Instructions | Precautions | Specifications | Limited Warranty

DESCRIPTION:

Nokorode® Aqua flux™ is a creamy, smooth paste formulated to meet ASTM B-813 specifications. Aqua Flux™ is water washable, so it may be flushed from the piping system and limit the corrosive effects found in other fluxes. It is lead-free and may be used with all types of soft solder, including 95/5, 60/40, 50/50 and 40/60 solders. Unlike other "gels" or liquid fluxes that meet ASTM B-813, Aqua Flux™ will not run or drip off acid brushes, pipes and fittings during application. The outstanding wetting characteristics of Aqua Flux™ assure a superior joint.

Top of Page

CHARACTERISTICS:

- Conforms to ASTM B-813 specifications
- Water washable
- Produces excellent, lead free joint
- Superior wetting ability - allows solder to flow easily and uniformly into joints
- Pre-cleans
- Resists spattering
- Smooth paste for easy application
- Will not run or drip during application

Top of Page

APPLICATIONS:

Nokorde® Aqua Flux™can be used with 95/5, 60/40, 50/50, and 40/60 solid wire solders.

Do not use on stainless steel, aluminum or for silver soldering.

Top of Page

PACKAGING:

Code	Size	Qty. Per Case	Lbs. per Case	Cu. Ft Per Case
74044	2 oz. (57 g)	48 jars	10	.42
74047	4 oz. (114 g)	24 jars	8	.25
74046	16 oz. (454 g)1	2 jars	13	.48

Top of Page

INSTRUCTIONS:

---

1. Clean surface before soldering

2. **Do not breathe vapor during soldering operations.**

3. Apply a small amount of flux evenly to both joining surfaces. Heat and apply solid wire solder in normal manner.

4. When joint has cooled, wipe outside with a wet rag, and flush inside surfaces thoroughly with water.

5. Flux paste may liquefy if stored under very hot conditions (usually greater than 120 degree F). Mix well before using.

For additional technical information, call Toll Free 1-800-231-3345.

Top of Page

PRECAUTIONS:

FOR CHEMICAL EMERGENCY, SPILL, LEAK, FIRE, EXPOSURE OR ACCIDENT,

CALL CHEMTREC - DAY OR NIGHT 1-800-424-9300

D A N G E R!

CAN CAUSE CHEMICAL BURNS - HARMFUL IF SWALLOWED OR INHALED

CONTAINS: Ammonium Chloride. PRECAUTIONS: Can cause burns to eyes, skin, digestive or respiratory system. Avoid direct contact, breathing of fumes, and ingestion. Wear adequate protective clothing and equipment. Use only with good ventilation. Wash thoroughly after use. **FIRST AID**: For any overexposure, get immediate medical attention after first aid is given. **Eyes** - Flush with clean water for 15 minutes. **Skin** - Wash with soap and water. **Inhalation** - Remove to fresh air. **Ingestion** - DO NOT INDUCE VOMITING. Only if conscious, give large amounts of water. **FIRE AND SPILLS**: For fire, use water fog, CO2, foam, or dry chemicals. Wipe up spills to prevent footing hazard. **STORAGE AND HANDLING**: Store in cool area. Keep container tightly closed. Do not reuse empty container. **KEEP OUT OF REACH OF CHILDREN.**

For additional information, refer to Material Safety Data Sheet.

Top of Page

SPECIFICATIONS:

Wt/Gal @ 77 degree F	8.18 +- .5 lbs/gal.
Flash Point SETA CC	less than 400 degree F
Color	Yellowish Paste
Shelf Life	1 year

NSF File No. 3708

Suggestions and recommendations covering the use of our products are based on our past experience and laboratory findings. However, as we have no control as to the methods and conditions of application, we only assume responsibility for the uniformity of our products within manufacturing tolerances.

Top of Page

LIMITED WARRANTY:

RectorSeal® makes the Limited Express Warranty that when the instructions for storage and handling of our products are followed we warrant our products to be free from defects. THIS LIMITED EXPRESS WARRANTY IS EXPRESSLY IN LIEU OF ANY OTHER EXPRESS OR IMPLIED WARRANTIES, INCLUDING ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, AND OF ANY OTHER OBLIGATION ON THE PART OF RECTORSEAL®. The sole remedy for breach of the Limited Express Warranty shall be the refund of the purchase price. All other liability is negated and disclaimed, and RectorSeal® shall not be liable for incidental or consequential damages.

Top of Page

MANUFACTURED IN U.S.A. BY

RectorSeal®
2601 Spenwick Drive • Houston, TX 77055 USA
713-263-8001 • Fax 713-263-7577
Toll-free 800-231-3345 • Fax 800-441-0051

Back to Soldering Products

Section 01 Identification

Info furnished by:	Fry Technology
Address:	4100 Sixth Avenue Altoona, PA 16602
Date Effective:	2/16/99
Emergency Phone:	(814) 946-1611
Chemtrec:	800-424-9300 (Use only in the event of chemical emergencies involving a spill, leak, fire, exposure, or accident involving chemicals.)
Product or Trade Name:	Water Flow 2000 Paste Flux
Person to Contact:	Daren Cuppett - Jack Wagner

Section 02 Hazardous Constituents

Chem	CAS	%WT	Carcinogen	TLV ACGIH	OSHA PEL
Octylphenoxy-polyethoxyethanol Surfactant					
	9004-87-9	10-20	No	NE	NE
Ethoxylated Aliphatic Alcohol					
	9003-11-6	30-35	No	NE	NE
Amine Hydrochloride	2002-24-6	5-8	No	NE	NE

Section 03 Physical Data

Melting Point	NA
Boiling Point	NA
Vapor Pressure	NA
Vapor Density (air is 1)	NA
Solubility in Water	>90%
Appearance & Color	Off white to pale yellow color, paste
Specific Gravity	NA
Odor	Mild
% Volatile	NA
pH (5% Aqueous solution)	2.5
Evaporation Rate (nBuAc=1)	NA

Section 04 Fire & Explosion Hazard Data

Flash Point/Method Used	C.O.C. >200
Flammable Limits	UN
Extinguishing Media	Dry chemical or carbon dioxide
Fire-fighting Equipment	None

Section 05 Reactivity Data

Stability:	Stable
Conditions to avoid:	None
Hazardous Polymerization:	Will not occur
Conditions to avoid:	None
Incompatibility:	Strong oxidizing agents
Hazardous Decomposition Products:	Burning may produce carbon monoxide, carbon dioxide and unidentified organic compounds.

Section 06 Spill, Leak and Disposal Procedures

Action to take for Spills/Leaks:	Product is in paste form. Using protective gloves, wipe up and clean with soap and water.
Disposal Method:	Must be in accordance with Federal, State and Local Laws and Regulations.

Section 07 Health Hazard Data

Eye:	May cause irritation and possible corneal damage.
Skin Contact:	Contact may cause irritation such as rash, itching or redness.
Skin Absorption:	Not classified as a skin absorbent.
Ingestion:	Liver and kidney damage if ingested in large amounts
Inhalation:	May cause irritation to respiratory system when heated.

Section 08 First Aid Procedures

Eyes:	Flush with large amounts of water lifting upper and lower lids occasionally. Get medical attention.
Skin:	Wash exposed area with soap and water.
Ingestion:	Consult a physician. Never give anything by mouth to an unconscious person.
Inhalation:	If affected, remove individual to fresh air. Get medical attention.

Section 09 Special Handling Information

Ventilation:	Required to maintain TLV's.
Respiratory Protection:	If threshold limit value is exceeded, when heated, use appropriate MSHA/NIOSH approved respirator.
Eye Protection:	Safety glasses in compliance with OSHA regulations are advised. Provide eyewash near work site.
Skin Protection:	Wear resistant gloves such as rubber, neoprene or plastic.

Section 10 Special Precautions & Additional Information

Storage:	Keep container closed when not in use. Read all container labeling. Wash skin contact with soap and water. For industrial use only. Do not take internally.

Section 11 Hazard Rating

Based on NFPA and NPCA Systems
Health - 2
Flammability - 1
Reactivity - 0
Special Hazard - ACD

The information contained herein is based on data considered accurate and is offered at no charge. No warranty is expressed or implied regarding the accuracy of this data. Liability is expressly disclaimed for loss or injury arising out of use of this information of the use of any materials designated.

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7525: CPVC 1-STEP CEMENT 8 OZ.

MSDS Last updated: 01/04/1999

MSDS SHEET FOR CPVC 1-STEP CEMENT 8 OZ. #7525

*** SECTION 1 PRODUCT IDENTIFICATION ***

Manufacturer's Name:	Oatey Corp.
Manufacturer's Address:	4700 W. 160th Street P.O. Box 35906 Cleveland, Ohio 44135
Emergency Telephone:	(303) 623-5716 Collect
Distributor's Name:	Imperial Supplies LLC
Distributor's Address:	789 Packer Drive Green Bay, WI 54304
Information Telephone:	(800) 558-2808
Product Name:	CPVC 1-STEP CEMENT 8 OZ.
Imperial No.:	7525
Manufacturer No.:	31911

*** SECTION 2 HAZARDOUS INGREDIENTS ***

Ingredients	%	Cas #	Sec 313
Tetrahydrofuran (See Section 6)	40-50	109-99-9	No
Acetone	24-34	67-64-1	No
Cyclohexanone	5-10	108-94-1	No
Methyl Ethyl Ketone	<5	78-93-3	Yes
Non-Hazardous Ingredients			
CPVC Resin	13-16	68648-82-8	No
Amorphous Silica	25-3	112945-52-5	No
Proprietary	5-25		No

*** SECTION 3 HAZARDS IDENTIFICATION ***

Hazards	Yes	No	Hazards	Yes	No
Combustible Liquid		X	Skin Hazard	X	
Flammable Liquid	X		Eye Hazard	X	
Pyrophoric Material		X	Toxic Agent	X	
Explosive Material		X	Highly Toxic Agent		X
Unstable Material		X	Sensitizer		X
Water Reactive Material		X	Kidney Toxin	X	
Oxidizer		X	Reproductive Toxin	X	
Organic Peroxide		X	Blood Toxin		X
Corrosice Material		X	Nervous System Toxin	X	
Compressed Gas		X	Lung Toxin	X	
Irritant	X		Liver Toxin	X	
Carcinogen NTP/IARC/OSHA		X			

*** SECTION 4 REGULATIONS ***

Chemical:	Tetrahydrofuran	Acetone
TLV (TWA):	200 ppm, 590 mg/cu m	750 ppm, 1800 mg/cu m
PEL (Transitional Limits):	200 ppm, 590 mg/cu m	1000 ppm, 2400 mg/cu m
STEL:	250 ppm, 735 mg/cu m	1000 ppm, 2400 mg/cu m
Hazard Action Level:	N/A	N/A

Chemical:	Cyclohexanone	Methyl Etheyl Ketone
TLV (TWA):	25 ppm, 100 mg/cu m(skin)	200 ppm, 590 mg/cu m
PEL (Transitional Limits):	50 ppm, 200 mg/cu m	200 ppm, 590 mg/cu m
STEL:	100 ppm, 400 mg/cu m	300 ppm, 885 mg/cu m
Hazard Action Level:	N/A	N/A

Chemical:	Amorphous Silica
TLV (TWA):	10 mg/cu m
PEL (Transitional Limits):	20 mppcf
STEL:	N/A
Hazard Action Level:	N/A

*** SECTION 5 REGULATED IDENTIFICATION ***

DOT Proper Shipping Name:	Consumer Commodity ORM-D
DOT Hazard Class:	N/A
Shipping ID No.:	N/A
EPA Hazardous Waste ID No.:	D-001
EPA Hazard Waste Class:	Ignitable Waste

*** SECTION 6 EFFECTS OF EXPOSURE ***

Entry Route: Inhale- Yes Ingest- Yes Skin- Yes Eye- Yes

Inhalation: May cause irritation of mucous membranes, nose & throat, headache, dizziness, nausea, numbness of the extremities and narcosis in high concentrations. Has caused CNS depression & liver damage in animals, & high concentrations have caused retardation of fetal development in rats.

Tetrahydrofuran Warning: The National Toxicology Program has reported that exposure of mice and rats to Tetrahydrofuran (THF) vapor levels up to 1800 ppm 6 hr/day, 5 days/week for their lifetime caused an increased incidence of kidney tumors in male rats and liver tumors in female mice. The significance of these findings for human health are unclear at this time, and may be related to "species specific" effects. Elevated incidences of tumors in humans have not been reported for THF. THF is not listed as a carcinogen by NTP, IARC, or OSHA. One THF vendor has recommended a reduction in the "acceptable exposure limit" from 200 ppm to 25 ppm, 8 and 12 hour time weighted average.

Skin: Chronic contact may lead to irritation & dermatitis. Chronic exposure to vapors of high concentration may cause dermatitis. May possibly be absorbed through the skin.

Eye: Vapors or direct contact may cause irritation.

Ingestion: May be aspirated into the lungs or cause systemic effects described under inhalation.

Target Organs: Eye, Skin, Kidney, Lung, Liver, Central Nervous System

*** SECTION 7 FIRST AID MEASURES- (303)623-5716 COLLECT ***

Skin: If irritation arises, wash thoroughly with soap and water. Seek medical attention if irritation persists.

Eyes: If fumes cause irritation, move to fresh air and irrigate eyes with water for 15 minutes. If irritation persists, seek medical attention.

Inhalation: Move to fresh air. If breathing is difficult, give oxygen. If not breathing, give artificial respiration. Keep victim quiet and warm. Call a poison control center or physician immediately.

Ingestion: Drink water and call a poison control center or physician immediately. Avoid alcoholic beverages. Never give anything by mouth to an unconscious person.

*** SECTION 8 PHYSICAL & CHEMICAL PROPERTIES ***

NFPA Hazard Signal:	Health 2 Stability 1 Flammability 3 Special None
Boiling Point:	151 Degrees F / 66 C
Melting Point:	N/A
Vapor Pressure:	145 mmHg @ 20 Degrees C

Vapor Density (Air=1):	2.5
Volatile Components:	70-80% WT.
Solubility in Water:	Negligible
PH:	N/A
Specific Gravity:	0.91 plus/minus 0.02
Evaporation Rate:	(BUAC=1) = 5.5-8.0
Appearance:	Gold Liquid
Odor:	Ether-Like
Will Dissolve In:	Tetrahydrofuran
Material Is:	Liquid

*** SECTION 9 FIRE & EXPLOSION HAZARD DATA ***

Flammability:	LEL=1.8 %Volume UEL=11.8 %Volume
Flashpoint & Method Used:	5-8 Degrees F. / PMCC
Stability:	Stable Conditions To Avoid: Heat, sparks and open flame. Hazardous Decomp. PDTS.: Carbon Monoxide / Carbon Dioxide / Hydrogen Chloride / Smoke.
Hazardous Polymerization:	Will Not Occur. Conditions To Avoid: None
Incompatibility/Mat. To Avoid:	Acids, oxidizing materials, alkalis, chlorinated inorganics (potassium, calcium and sodium hypochlorite), copper or copper alloys.
Special Fire Fighting Procedure:	For Small Fires: Use dry chemical, CO2, water or foam extinguisher. For Large Fires: Evacuate area and call Fire Department immediately.

*** SECTION 10 SPILL & DISPOSAL INFORMATION ***

Spill or Leak Procedures:	Ventilate area, stop leak if it can be done without risk. Take up with sand, earth, or other non-combustible absorbing material.
Waste Disposal:	Dispose of according to local, state, and Federal regulations.

*** SECTION 11 SAFE USAGE DATA ***

Protective Equipment Types:	Eyes: Safety glasses with side shields. Respiratory: NIOSH-approved cannister respirator in absence of adequate ventilation. Gloves: Rubber gloves. Other: Eye wash and safety shower should be available.
Ventilation:	General Mechanical: Exhaust ventilation capable of maintaining emissions at the point of use below PEL. Local Exhaust: Open doors & windows. If used in enclosed area, use exhaust fans.
Precautions:	Handling & Storage: Keep away from heat, sparks and flames; store in cool, dry place. Other: Containers, even empties will retain residue and vapors.

*** SECTION 12 DISCLAIMER ***

The information herein has been compiled from sources believed to be reliable, up-to-date, and is accurate to the best of our knowledge. However, Oatey cannot give any guarantees regarding information from other sources, and expressly does not make warranties, nor assumes any liability for its use.

The information contained in this MSDS was obtained from current and reliable sources, however, the data is provided without any warrenty, expressed or implied, regarding its correctness or accuracy. Since the conditions or handling, storage and disposal of this product are beyond the control of Imperial Supplies LLC, Imperial will not be responsible for loss, injury, or expense arising out of the products improper use. No warranty, expressed or inferred, regarding the product described in this MSDS shall be created or inferred by any statement in this MSDS. Various government agencies may have specific regulations regarding the transportation, handling, storage, use, or disposal of this product which may not be covered by this MSDS. The user is responsible for full compliance.

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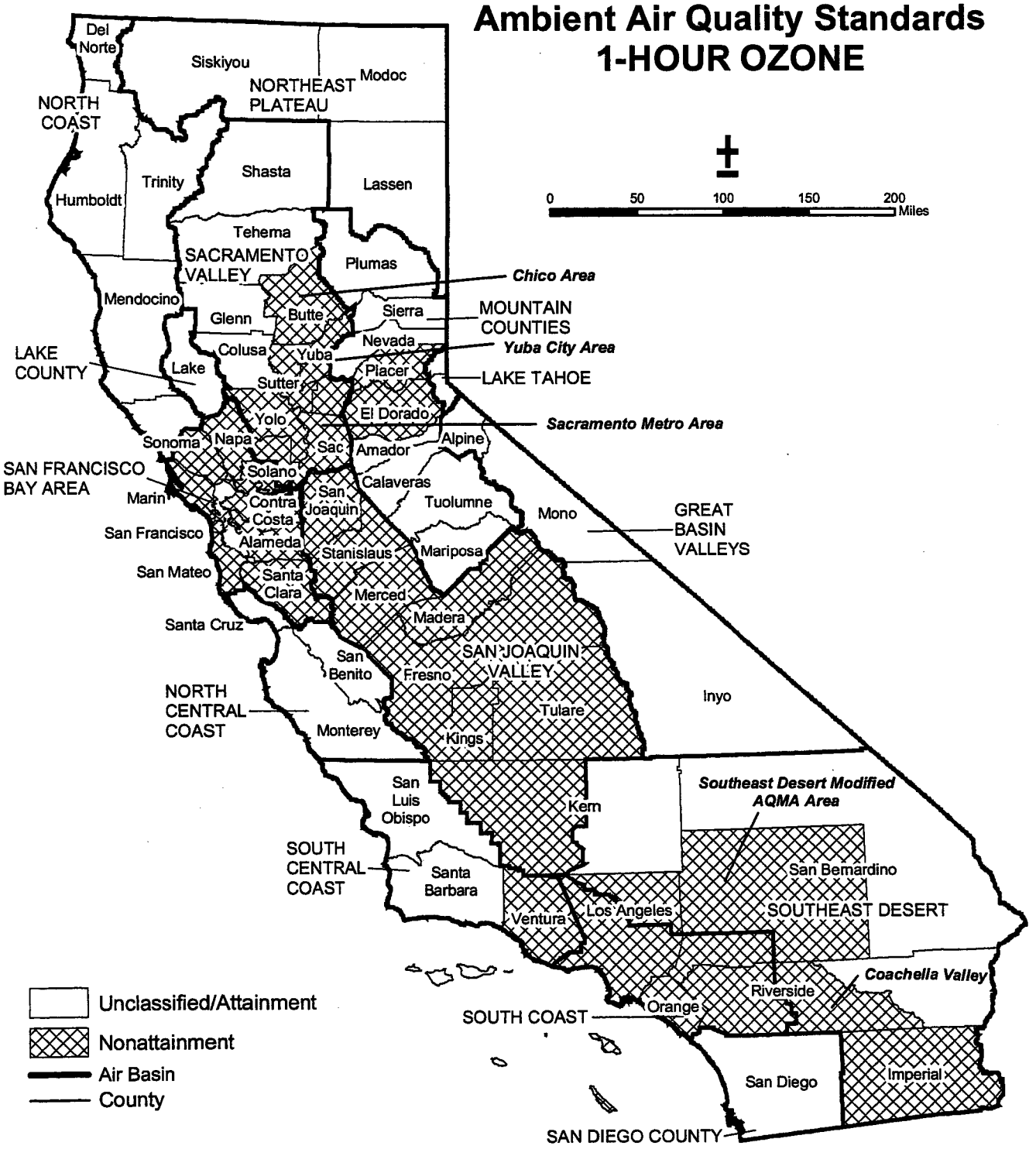
Area Designations for National Ambient Air Quality Standards 1-HOUR OZONE



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Area Designations for National Ambient Air Quality Standards 8-HOUR OZONE

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California 's Air Basins & Counties

2004
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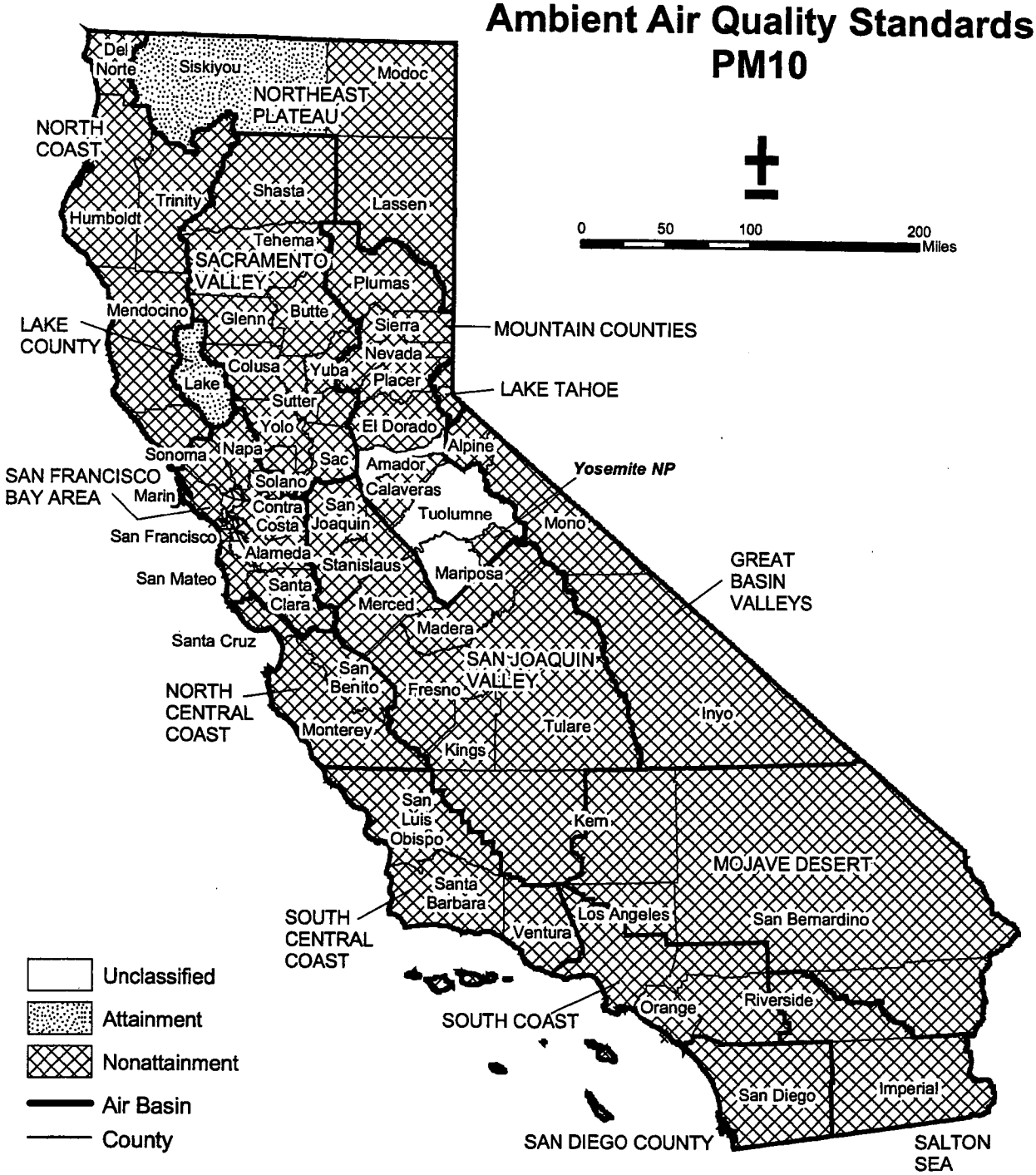

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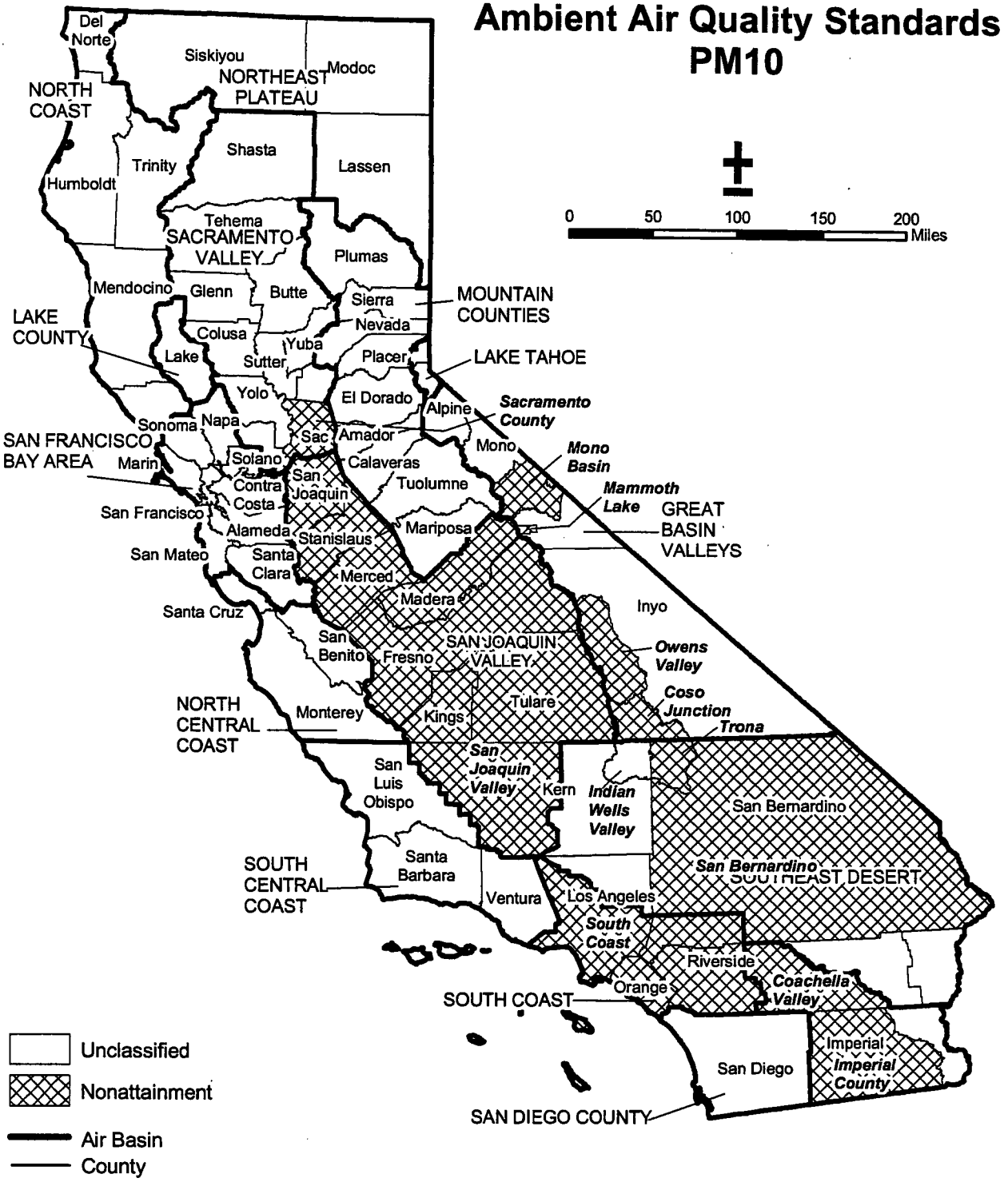
October 18, 2004

2004
Area Designations for State Ambient Air Quality Standards
NITROGEN DIOXIDE

Source Date:
October 2003
Emission Inventory Branch, PTSD

October 18, 2004

Area Designations for National Ambient Air Quality Standards PM10



Source Date:
October 2003
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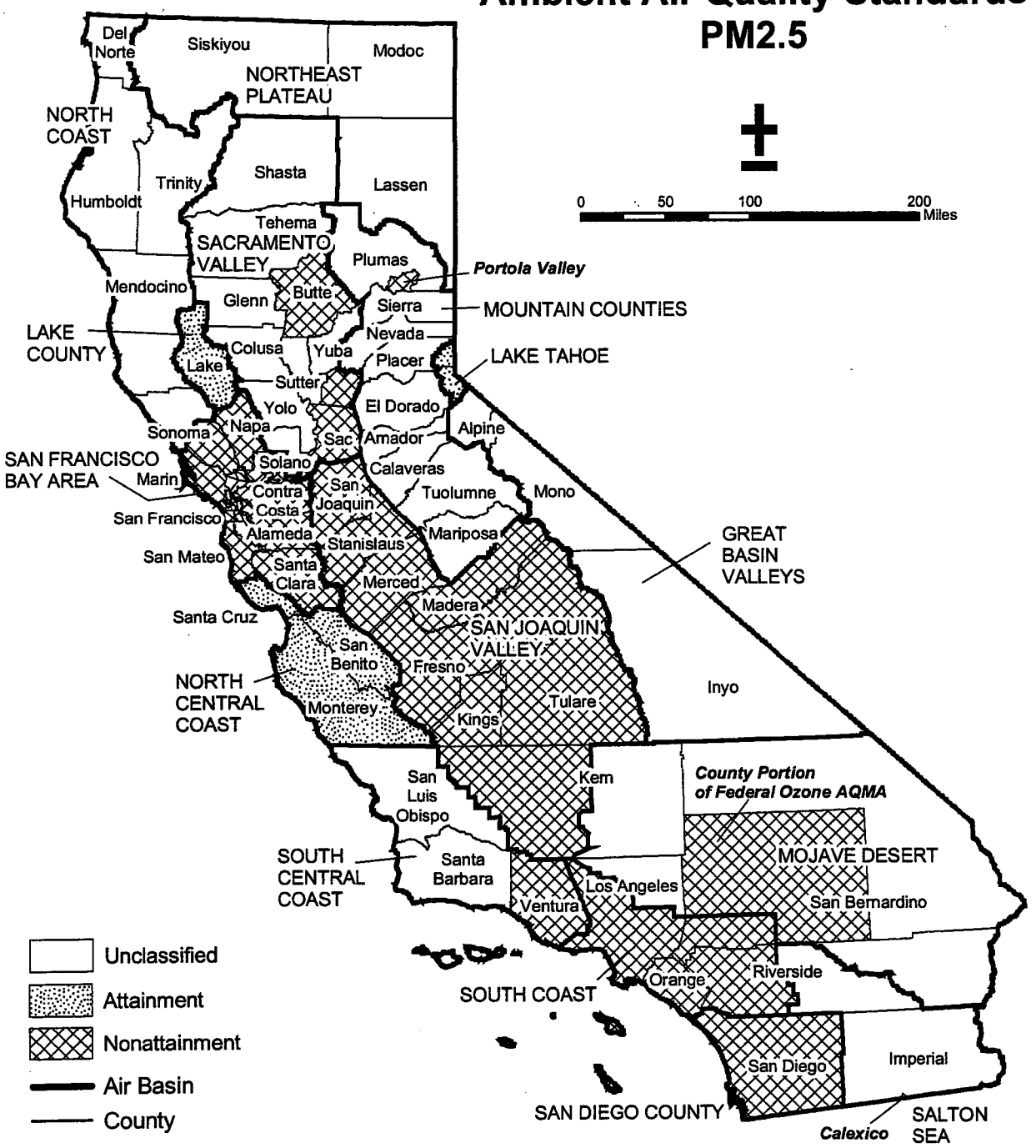
October 19, 2004

2004
Area Designations for State Ambient Air Quality Standards
PM2.5



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October 18, 2004

INCOMPLETE

HARRINGTON

Industrial Plastics, Inc

ENGINEERING HANDBOOK

For Industrial Plastic Piping Systems

TABLE OF CONTENTS

Material Descriptions 2-4
Industrial Standards 5-17
Chemical Resistance 18-38
Relative Properties 39-41
Thermoplastic Engineering 42-63
Above-Ground Installation 64-73
Below-Ground Installation 74-76
Testing 77
Installation of Thermoplastics
- Solvent Cementing 78-86
- Threading 87-89
- Flanged Joints 90

Fiberglass Reinforced Plastics (FRP) 91-92
Hydraulic Fundamentals 93-95
Conversion Charts 96-102
Pump Data 103-104
Glossary of Piping Terms 105-108

Harrington's corporate office in Chino, CA

MATERIAL DESCRIPTION

POLYVINYLS

PVC (POLYVINYL CHLORIDE) has a relatively high tensile strength and modulus of elasticity and therefore is stronger and more rigid than most other thermoplastics. The maximum service temperature is 140°F for Type 1. PVC has excellent chemical resistance to a wide range of corrosive fluids, but may be damaged by ketones, aromatics, and some chlorinated hydrocarbons. It has proved an excellent material for process piping (liquids and slurries), water service, and industrial and laboratory chemical waste drainage. Joining methods are solvent welding, threading (Schedule 80 only), or flanging.

CPVC (CHLORINATED POLYVINYL CHLORIDE) is particularly useful for handling corrosive fluids at temperatures up to 210°F. In chemical resistance, it is comparable to PVC. It weighs about one-sixth as much as copper, will not sustain combustion (self-extinguishing), and has low thermal conductivity. Suggested uses include process piping for hot, corrosive liquids; hot and cold water lines in office buildings and residences; and similar applications above the temperature range of PVC. CPVC pipe may be joined by solvent welding, threading, or flanging.

POLYOLEFINS

POLYPROPYLENE (HOMOPOLYMER) is the lightest thermoplastic piping material, yet it has considerable strength, outstanding chemical resistance, and may be used at temperatures up to 180°F in drainage applications. Polypropylene is an excellent material for laboratory and industrial drainage piping where mixtures of acids, bases, and solvents are involved. It has found wide application in the petroleum industry where its resistance to sulfur-bearing compounds is particularly useful in salt water disposal line, chill water loops, and demineralized water. Joining methods are coil fusion and socket heat welding.

COPOLYMER POLYPROPYLENE is a copolymer of propylene and polybutylene. It is made of high molecular weight copolymer polypropylene and possesses excellent dielectric and insulating properties because of its structure as a nonpolar hydrocarbon polymer. It combines high chemical resistance with toughness and strength at operating temperatures from freezing to 200°F. It has excellent abrasion resistance and good elasticity, and is joined by butt and socket fusion.

POLYETHYLENE, although its mechanical strength is comparatively low, polyethylene exhibits very good chemical resistance and is generally satisfactory when used at temperatures below 120°F. Types I and II (low and medium density) polyethylene are used frequently in tanks, tubing, and piping. Polyethylene is excellent for abrasive slurries. It is generally joined by butt fusion.

FLUOROPOLYMERS

PVDF (POLYVINYLIDENE FLUORIDE) is a strong, tough, and abrasion-resistant fluoroplastic material. It resists distortion and retains most of its strength to 280°F. As well as being ideally suited to handle wet and dry chlorine, bromine, and other halogens, it also withstands most acids, bases, and organic solvents. PVDF is not recommended for strong caustics. It is most widely recognized as the material of choice for high purity piping such as deionized water. PVDF is joined by thermal butt, socket, or electrofusion.

HALAR is a durable copolymer of ethylene and chlorofluoroethylene with excellent resistance to a wide variety of strong acids, chlorine, solvents, and aqueous caustics. Halar has excellent abrasion resistance, electric properties, low permeability, temperature capabilities from cryogenic to 340°F, and radiation resistance. Halar has excellent application for high purity hydrogen peroxide and is joined by thermal butt fusion.

TEFLON

There are three members of the Teflon family of resins.

PTFE TEFLON is the original Teflon resin developed by DuPont in 1938. This fluoropolymer offers the most unique and useful characteristics of all plastic materials. Products made from this resin handle liquids or gases up to 500°F. The unique properties of this resin prohibit extrusion or injection molding by conventional methods. When melted PTFE does not flow like other thermoplastics and it must be shaped initially by techniques similar to powder metallurgy. Normally PTFE is an opaque white material. Once sintered it is machined to the desired part.

FEP TEFLON was also invented by DuPont and became a commercial product in 1960. FEP is a true thermoplastic that can be melt-extruded and fabricated by conventional methods. This allows for more flexibility in manufacturing. The dielectric properties and chemical resistance are similar to other Teflons, but the temperature limits are -65°F to a maximum of 300°F. FEP has a glossy surface and is transparent in thin sections. It eventually becomes translucent as thickness increases. FEP Teflon is the most transparent of the three Teflons. It is widely used for its high ultraviolet light transmitting ability.

Caution: While the Teflon resin family has great mechanical properties and excellent temperature resistance, care must be taken when selecting the proper method of connections for your piping system. Generally, Teflon threaded connections will handle pressures to 120 PSIG. Loose ferrule connections are limited to 60 PSIG at ambient temperatures. Teflon loses it's ability to bear a load at elevated temperatures quicker than other thermoplastics. When working with the PTFE products shown in this catalog external ambient temperatures ranging from -60°F to 250°F (-51°C to 121°C) may be handled safely. Fluid or gas temperatures inside the product should be limited to -60 to 400°F (-51°C to 204°C) unless otherwise noted. Always use extreme care when working with chemicals at elevated temperatures.

MATERIAL DESCRIPTION

PFA TEFLON, a close cousin of PTFE, was introduced in 1972. It has excellent melt-processability and properties rivaling or exceeding those of PTFE Teflon. PFA permits conventional thermoplastic molding and extrusion processing at high rates and also has higher mechanical strength at elevated temperatures to 500°F. Premium grade PFA Teflon offers superior stress and crack resistance with good flex-life in tubing. It is generally not as permeable as PTFE.

DURAPLUS

ABS (ACRYLONITRILE-BUTADIENE-STYRENE)

There are many possibilities for polymer properties by combining these resins. For our purposes we will limit it to two products. One is the less expensive ABS resin used in drain, waste, and vent applications. The other resin for more stringent industrial applications has a different combination of the three polymers that make up the copolymer. The Duraplus product is made from this copolymer and has outstanding impact resistance even at low temperatures. The product is very tough and abrasion resistant. Temperature range is 40°F to 176°F.

RYTON (PPS) POLYPHENYLENE SULFIDE remains quite stable during both long and short term exposure to high temperatures. The high tensile strength and flexural modulus typical of PPS compounds, decrease with an increase in temperature. PPS is also highly resistant to chemical attack. Relatively few chemicals react to this material even at high temperatures. Its broad range of chemical resistance is second only to that of Teflon (PTFE). Ryton is used primarily for precision pump parts.

ELASTOMERS

VITON (FLUOROCARBON) is inherently compatible with a broad spectrum of chemicals. Because of this extensive chemical compatibility which spans considerable concentration and temperature ranges, Viton has gained wide acceptance as a sealing for valves, pumps, and instrumentation. Viton can be used in most applications involving mineral acids, salt solutions, chlorinated hydrocarbons, and petroleum oils.

EPDM (EPT) is a terpolymer elastomer made from ethylene-propylene diene monomer. EPDM has good abrasion and tear resistance and offers excellent chemical resistance to a variety of acids and alkalies. It is susceptible to attack by oils and is not recommended for applications involving petroleum oils, strong acids, or strong alkalies.

HYTREL is a multipurpose polyester elastomer similar to vulcanized thermoset rubber. Its chemical resistance is comparable to Neoprene, Buna-N and EPDM; however, it is a tougher material and does not require fabric reinforcement as do the other three materials. Temperature limits are -10°F minimum to 190°F maximum. This material is used primarily for pump diaphragms.

THERMOSETS

FIBERGLASS REINFORCED PLASTICS (FRP) including epoxy, polyester, and vinylester have become a highly valuable process engineering material for process piping.

FRP has been accepted by many industries because it offers the following significant advantages:
(a) moderate initial cost and low maintenance; (b) broad range of chemical resistance; (c) high strength-to-weight ratio; (d) ease of fabrication and flexibility of design; and (e) good electrical insulation properties.

EPOXY pipe and fittings have been used extensively by a wide variety of industries since 1960. It has good chemical resistance and excellent temperatures to pressure properties (to 300°F). Epoxy has been used extensively for fuel piping and steam condensate return lines.

POLYESTER pipe and fittings have been used by the industry since 1963. It has a proven resistance to most strong acids and oxidizing materials. It can be used in applications up to 200°F. Polyester is noted for its strength in both piping and structural shapes.

VINYLESTER resin systems are recommended for most chlorinated mixtures as well as caustic and oxidizing acids up to 200°F. Vinylester for most service has superior chemical resistance to epoxy or polyester.

NYLONS are synthetic polymers that contain an amide group. Their key characteristics are: (a) excellent resistance and low permeation to fuels, oils, and organic solvent, including aliphatic, aromatic, and halogenated hydrocarbons, esters, and ketones; (b) outstanding resistance to fatigue and repeated impact; and (c) wide temperature range from -30°F to 250°F.

Caution: Acids will cause softening, loss of strength, rigidity, and eventual failure.

POLYURETHANES

There are essentially two types of polyurethanes: polyester based and polyether based. Both are used for tubing applications.

POLYESTER based is the toughest of the two, having greater resistance to oil and chemicals. It does not harden when used with most oils, gasoline, and solvents. Polyurethane is extremely resistant to abrasives making it ideal for slurries, solids and granular material transfer. Temperature limit is 170°F.

Caution: Polyester based polyurethanes may be subject to hydrolysis under certain conditions, high relative humidity at elevated temperatures, aerated water, fungi, and bacteria. Where these potentials exist, we recommend polyether-based polyurethane.

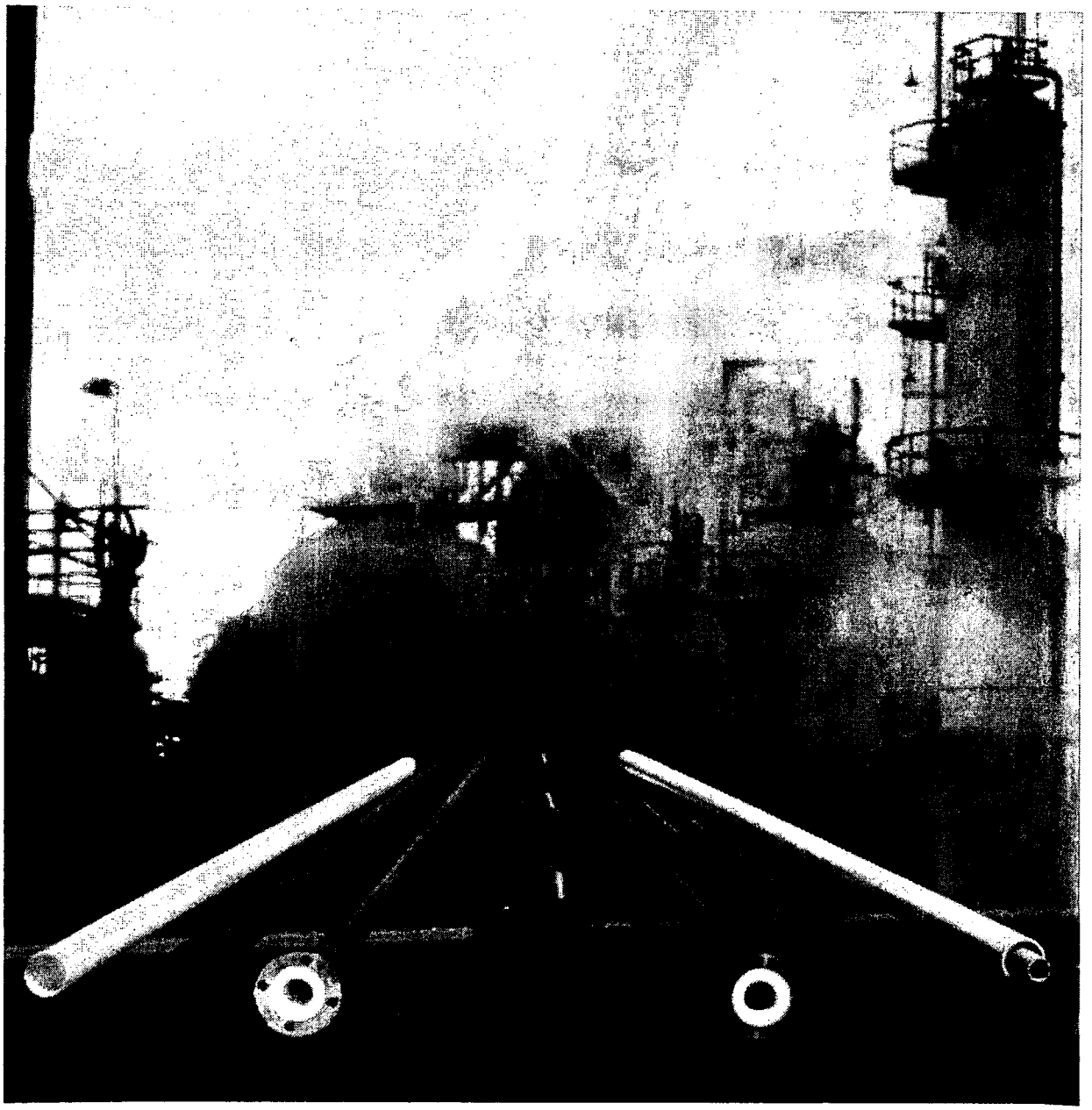
POLYETHER-based polyurethane possesses better low temperature properties, resilience and resistance to hydrolytic degradation than the polyester previously discussed.

MATERIAL DESCRIPTION

Accelerated testing indicates that polyether-based polyurethanes have superior hydrolytic stability as compared to polyester based material. Made with no plasticizers and with a low level of extractables, polyether is ideal for high purity work. It will not contaminate laboratory samples and is totally non-toxic to cell cultures. Compared with PVC tubing, polyurethanes have superior chemical resistance to fuels, oils, and some solvents. Its excellent tensile strength and toughness make it suitable for full vacuums. This tubing can withstand temperatures from -94°F to 200°F.

PTBP

Polybutylene terephthalate is a little known specialty material belonging to the polyimide group; It has excellent mechanical properties and good mechanical stress properties under corrosive environments. PTBP is used mainly for valve actuators, and bonnet assemblies.



INDUSTRY STANDARDS

The standards referenced herein, like all other standards, are of necessity minimum requirements. It should be recognized that two different plastic resin materials of the same kind, type, and grade will not exhibit identical physical and chemical properties. Therefore, the plastic pipe purchaser is advised to obtain specific values or requirements from the resin supplier to assure the best application of the material not covered by industry specifications; this suggestion assumes paramount importance.

ANSI

American National Standards Institute, Inc.
655 15th St. N.W.
300 Metropolitan Square
Washington, DC 20005
Phone (202) 639-4090

ANSI PRESSURE CLASSES
ANSI Class 125 means 175 PSIG at 100°F
ANSI Class 150 means 285 PSIG at 100°F
ANSI Class 300 means 740 PSIG at 100°F
ANSI A119.2 - 1963
ANSI B72.2 - 1967
ANSI B31.8 - 1968
ANSI Z21.30 - 1969

The following ASTM standards have been accepted by ANSI and assigned the following designations.

Table 1

ANSI Designation	ASTM Designation	ANSI Designation	ASTM Designation
B72.1	D 2239	B 72.11	D 2412
B72.2	D 2241	B 72.12	D 2446
B72.3	D 2282	B 72.13	D 2447
B72.4	D 1503	B 72.16	D 2564
B72.5	D 1527	B 72.17	D 2657
B72.6	D 1598	B 72.18	D 2661
B72.7	D 1785	B 72.19	D 2662
B72.8	D 2104	B 72.20	D 2672
B72.9	D 2152	B 72.22	D 2740
B72.10	D 2153	B 72.23	D 2235

ASTM

American Society of Testing and Materials
1916 Race Street
Philadelphia, Pennsylvania 19103

Plastic Pipe Specifications:

D	1785	Polyvinyl chloride (PVC) plastic pipe, schedules 40, 80, and 120
F	441	Chlorinated poly (vinyl chloride)(CPVC) plastic pipe, schedules 40 and 80
D	2241	Polyvinyl chloride (PVC) plastic pipe (SD - PR)
D	2513	Thermoplastic gas pressure pipe, tubing and fittings
D	2665	PVC plastic drain, waste, and vent pipe and fittings
D	2672	Bell-ended PVC pipe
D	2729	PVC sewer pipe and fittings
D	2846	Chlorinated (CPVC) plastic hot water distribution system
D	2949	3" thin wall PVC plastic drain, waste, and vent pipe and fittings
D	3034	Type PSM PVC sewer pipe and fittings

Plastic Pipe Fittings Specifications:

D	2464	Threaded PVC plastic pipe fittings, Schedule 80
F	437	Threaded chlorinated polyvinyl chloride (CPVC) plastic pipe fittings, Schedule 80
D	2466	Socket-type PVC plastic type fittings, Schedule 40
D	2467	Socket-type PVC plastic type fittings, Schedule 80
F	439	Socket-type chlorinated polyvinyl chloride (CPVC) plastic pipe fittings Schedule 80
D	3036	PVC plastic pipe lined couplings, socket type

Plastic Pipe Solvent Cement Specifications

D	2564	Solvent cements for PVC plastic pipe and fittings
F	493	CPVC solvent cement

Plastic Lined Steel Piping Specifications:

ASTM A-587	Standard specification for electric-welded low carbon steel pipe for the chemical industry
ASTM A-53	Standard specification for pipe, steel, black and hot-dipped, zinc-coated, welded and seamless
ASTM A-105	Standard specification for forgings, carbon steel, for piping components
ASTM A-125	Standard specification for steel springs, helical, heat-treated
ASTM A-126	Standard specifications for gray iron castings for valves, flanges, and pipe fittings
ASTM A-395	Standard specification for ferritic ductile iron pressure retaining castings for use at elevated temperatures
ASTM A-216	Standard specification for carbon steel castings suitable for fusion welding for high temperature service
ASTM A-234	Standard specification for piping fittings of wrought carbon steel and alloy steel for moderate and elevated temperatures
ANSI B-16.1	Cast iron pipe flanges and flanged fittings Class 25, 125, 150, 250 and 800
ANSI B-16.42	Ductile iron pipe flanges and flanged fittings Class 150 and 300

INDUSTRY STANDARDS

ANSI B-16.5	Steel pipe flanges and flanged fittings Class 150, 300, 400, 600, 900, 1500 and 2500
A-587	Standard specification for electric-welded low carbon steel pipe for the chemical industry
A-53	Standard specification for pipe, steel black and hot-dipped, zinc-coated, welded and seamless
A-105	Standard specification for forgings, carbon steel, for piping components
A-125	Standard specification for steel springs, helical, heat-treated
A-126-73	Standard specification for gray iron castings for valves, flanges, and pipe fittings
A-395-77	Standard specification for ferritic ductile iron pressure retaining castings for use at elevated temperatures
A-216-77	Standard specification for carbon steel castings suitable for fusion welding for high temperature service

Methods of Test Specifications:

D	256	Test for impact resistance of plastics and electrical insulating materials
D	543	Test for resistance of plastics to chemical reagents
D	570	Test for water absorption of plastics
D	618	Conditioning plastics and electrical insulating materials for testing
D	621	Tests for deformation of plastics under load
D	635	Test for flammability of self-supporting plastics
D	638	Test for tensile properties of plastics
D	648	Test for deflection temperature of plastics under load
D	671	Tests for repeated flexural stress of plastics
D	757	Test for flammability of plastics, self-extinguishing type
D	790	Test for flexural properties of plastics
D	883	Nomenclature relating to plastics
D	1180	Test for bursting strength of round, rigid plastic tubing
D	1598	Test for time to failure of plastic pipe under long-term hydrostatic pressure
D	1599	Test for short-time rupture strength of plastic pipe, tubing and fittings
D	2122	Determining dimensions of thermoplastic pipe and fittings
D	2152	Test for quality of extruded PVC pipe by acetone immersion
D	2412	Test for external loading properties of plastic pipe by parallel-plate loading
D	2444	Test for impact resistance of thermoplastic pipe and fittings by means of a tup (falling weight)
D	2837	Obtaining hydrostatic design basis thermoplastic pipe materials
D	2924	Test for external pressure resistance of plastic pipe

RECOMMENDED PRACTICES

D	2153	Calculating stress in plastic pipe under internal pressure
D	2321	Underground installation of flexible thermoplastic sewer pipe
D	2657	Heat joining of thermoplastic pipe and fittings
D	2749	Standard definitions of terms relating to plastic pipe fittings
D	2774	Underground installation of thermoplastic pressure pipe
D	2855	Making solvent cemented joints with PVC pipe and fittings

ASTM STANDARDS FOR PLASTIC MATERIALS REFERENCED IN PLASTIC PIPE, FITTINGS, AND CEMENT STANDARDS

D	1784	PVC compounds and CPVC compounds

BOCA

Building Officials Conference of America
1313 East 60th Street
Chicago, Illinois 60637

BOCA Basic Plumbing Code

INDUSTRY STANDARDS

Table 2

Group	Commercial Standard or Product Standard	ASTM Standard or Tentative Specification
A	PS10	D2104
B	PS11	D2238
C	PS12	D2447
D	PS18	D1527
E	PS19	D2282
F	PS21	D1785
G	PS22	D2241
H	CS228	D2852
I	CS270	D2661
J	CS272	D2665

COMMERCIAL AND PRODUCT STANDARDS
Supt. of Documents
U.S. Government Printing Office
Washington, DC 20402

CS 272	PVC-DWV pipe and fittings
PS 21	PVC plastic pipe (Schedules 40, 80, 120) supersedes CS 207-60
PS 22	PVC plastic pipe (SDR) supersedes CS 256

CSA
Canadian Standards Association
178 Rexdale Boulevard
Rexdale, Ontario, Canada

B	137.0	Defines general requirements and methods of testing for thermoplastic pressure pipe
B	137.3	Rigid polyvinyl chloride (PVC) pipe for pressure applications
B	137.4	Thermoplastic piping systems for gas service
B	137.14	Recommended practice for the installation of thermoplastic piping for gas service
B	181.2	Polyvinyl chloride drain, waste, and vent pipe and pipe fittings
B	181.12	Recommended practice for the installation of PVC drain, waste, and vent pipe fittings
B	182.1	Plastic drain and sewer pipe and pipe fittings for use underground
B	182.11	Recommended practice for the installation of plastic drain and sewer pipe and pipe fittings

DEPARTMENT OF AGRICULTURE
U.S. Department of Agriculture
Soil Conservation Service
Washington, DC 20250

SCS National Engineering Handbook, Section 2, Part 1, Engineering Practice Standards

SCS432-D	High pressure underground plastic irrigation pipelines
SCS432-E	Low head underground plastic irrigation pipelines

DEPARTMENT OF DEFENSE MILITARY STANDARDS
Commanding Officer
Naval Publications and Forms Center
5108 Tabor Avenue
Philadelphia, Pennsylvania 19120

MIL-A-22010A(1)	Adhesive solvent-type, polyvinyl chloride amendment
MIL-C-23571A(YD)	Conduit and conduit fittings, plastic, rigid
MIL-P-14529B	Pipe, extruded, thermoplastic
MIL-P-19119B(1)	Pipe, plastic, rigid, unplasticized, high impact, polyvinyl chloride
MIL-P-22011A	Pipe fittings, plastic, rigid, high impact, polyvinyl chloride, (PVC) and poly 1, 2 dichlorethylene
MIL-P-28584A	Pipe and pipe fittings, glass fiber reinforced plastic for condensate return lines
MIL-P-29206	Pipe and pipe fittings glass fiber reinforced plastic for liquid petroleum lines

DOT - OTS
Department of Transportation, Hazardous Materials Regulation Board, Office of Pipeline Safety, Title 49, Docket OPS-3 and amendments, Part 192. Transportation of Natural Gas and Other Gas by Pipeline: Minimum Federal Safety Standards, Federal Register, Vol, 35, No. 161, Wednesday, August 19, 1980. Amendments to date are 192-1, Vol. 35, No. 205, Wednesday, October 21, 1970; 19-2, Vol. 35, No. 220, Wednesday, November 11, 1970; and 192-3, Vol. 35, No. 223, Tuesday, November 17, 1970.

FEDERAL SPECIFICATIONS

Specifications Activity
Printed Materials Supply Division
Building 197, Naval Weapons Plant
Washington, DC 20407

L-P-320a	Pipe and fittings, plastic (PVC, drain, waste, and vent)
L-P-1036(1)	Plastic rod, solid, plastic tubes and tubing, heavy walled; polyvinyl chloride

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

HANDLING & STORAGE PLASTIC PIPE

Normal precautions should be taken to prevent excessive mechanical abuse. However, when unloading pipe from a truck, for example, it is unwise to drag a length off the tailgate and allow the free end to crash to the ground. Remember, too, that SCRATCHES AND GOUGES ON THE PIPE SURFACE CAN LEAD TO REDUCED PRESSURE-CARRYING CAPACITY. Standard pipe wrenches should not be used for making up threaded connections since they can deform or scar the pipe. Use strap wrenches instead. When using a pipe vise or chuck, wrap jaws with emery cloth or soft metal.

Pipe should be stored on racks that afford continuous support and prevent sagging or draping of longer lengths. Burrs and sharp edges of metal racks should be avoided. Plastic fittings and flanges should be s˚Á„Bê4˚ÁÂ'∑ «?Ëkÿ4*ùÍ◊∑3)›Ì À1ÀPÔ ¸ 0ôé≈¬.rÚ$\+›jÛ%+)qïÛ¡›&Â7Û^...$GÆ
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FIELD STACKING

During prolonged field storage of loose pipe, its stacks should not exceed two feet in height. Bundled pipe may be double-stacked providing its weight is distributed by its packaging boards.

HANDLING

Care should be exercised to avoid rough handling of pipe and fittings. They should not be pushed or pulled over sharp projections, dropped or have any objects dropped upon them. Particular care should be taken to avoid kinking or buckling the pipe. Any kinks or buckles which occur should be removed by cutting out the entire damaged section as a cylinder. All sharp edges on a pipe carrier or trailer that could come in contact with the pipe should be padded; i.e., can use old fire hose or heavy rubber strips. Only nylon or rope slings should be used for lifting bundles of pipe; chains are not to be used.

INSPECTION

Before installation, all lengths of pipe and fittings should be thoroughly inspected for cuts, scratches, gouges, buckling, and any other imperfections which may have been imparted to the pipe during shipping, unloading, storing, and stringing. Any pipe or pre-coupled fittings containing harmful or even questionable defects should be removed by cutting out the damaged section as a complete cylinder.

JOINING TECHNIQUES

FOR THERMOPLASTIC PIPE

There are six recommended methods of joining thermoplastic pipe and fittings, each with its own advantages and limitations:

SOLVENT CEMENTING

The most widely used method in Schedule 40 PVC, Schedule 80 PVC and CPVC piping systems as described in ASTM D-2855-93. The O.D. of the pipe and the I.D. of the fitting are primed, coated with special cement and joined together, as described in detail below. Knowledge of the principles of solvent cementing is essential to a good job. These are discussed in the Solvent Welding Instructions Section.

NOTE: The single most significant cause of improperly or failed solvent cement joints is lack of solvent penetration or inadequate primer application.

THREADING

Schedule 80 PVC, CPVC, PVDF, and PP can be threaded with special pipe dyes for mating with Schedule 80 fittings provided with threaded connections. Since this method makes the piping system easy to disassemble, repair, and test, it is often employed on temporary or take-down piping systems, as well as systems joining dissimilar materials. However, threaded pipe must be derated by 50 percent from solvent-cemented systems. **(Threaded joints are not recommended for PP pressure applications.)**

FLANGES

Flanges are available for joining all thermoplastic piping systems. They can be joined to the piping either with solvent-cemented or threaded connections. Flanging offers the same general advantages as threading and consequently is often employed in piping systems that must frequently be dismantled. The technique is limited to **150 psi working pressure.**

BUTT FUSION

This technique us used to connect all sizes of Polypropylene (Proline), PVDF (Super Proline) and large diameter Fuseal. Butt fusion is an easy, efficient fusion method especially in larger diameters.

SOCKET FUSION

This technique is used to assemble PVDF and polypropylene pipe and fittings for high-temperature, corrosive-service applications. (See each material Design Data section for recommended joining technique.)

FUSEAL HEAT FUSION

R & G Sloane's Fuseal is a patented method of electrically fusing pipe and fitting into a single homogenous unit. This advanced technique is used for GSR Fuseal polypropylene corrosive waste-handling systems.

FUSEAL MECHANICAL JOINT

Mechanical Joint polypropylene drainage system is used extensively for accessible smaller sized piping areas. The system, as the name implies, is a mechanical sealed joint that consists of a seal-ring, grab-ring, and nut. It is quick and easy to install and can be disconnected just as easily. You will find it most suitable for under sink and under counter piping.

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS
BASIC PRINCIPLES OF SOLVENT CEMENTING

SAFETY PRECAUTIONS

Cements contain highly volatile solvents which evaporate rapidly. Avoid breathing the vapors. If necessary, use a fan to keep the work area clear of fumes. Avoid skin or eye contact. Do not use near heat, sparks, or open flame. Do not pressure test with compressed air or gas! Severe damage or bodily injury can result.

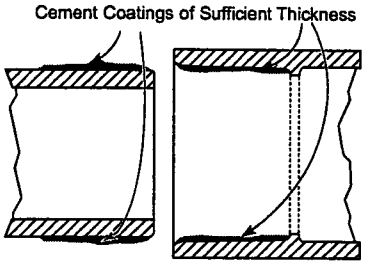
Solvent cementing is a preferred method of joining rigid PVC (Polyvinyl Chloride) and CPVC (Chlorinated Polyvinyl Chloride) pipe and fittings providing a chemically fused joint. The solvent-cemented joint is the last vital link in the installation process. It can mean the success or failure of the whole system. Accordingly, it requires the same professional care and attention that is given to the other components of the system. Experience shows that most field failures of plastic piping systems are due to improperly made solvent-cemented joints.

There are step-by-step procedures on just how to make solvent-cemented joints shown on the following pages. However, we feel that if the basic principles involved are first explained and understood, better quality installation can result with ease. To consistently make good joints, the following basics should be clearly understood by the installer.

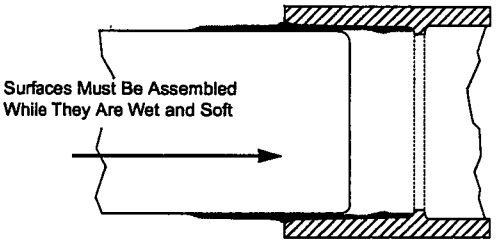
1. The joining surfaces must be clean, then softened and made semi-fluid.
2. Sufficient cement must be applied to fill the gap between pipe and fittings.
3. Assembly of pipe and fittings must be made while the surfaces are still wet and fluid.
4. Joint strength develops as the cement dries. In the tight part of the joint the surfaces will tend to fuse together. In the loose part the cement will bond to both surfaces.

Penetration and softening should be achieved with a suitable primer such as P70. Primer will penetrate and soften the surfaces more quickly than cement alone. Primer also provides a safety factor for the installer, as he can know under various temperature conditions when he has achieved sufficient softening of the material surfaces. For example, in cold weather more time and additional applications of primer will be required.

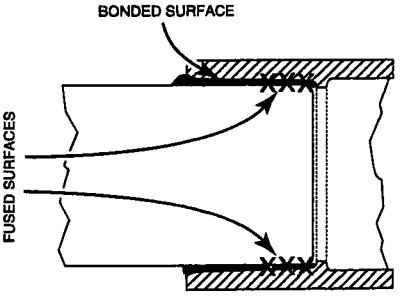
More than sufficient cement to fill the loose part of the joint must be applied. Besides filling the gap, adequate cement layers will penetrate the surface and also remain wet until the joint is assembled. Prove this for yourself. Apply on the top surface of a piece of pipe two separate layers of cement. First, flow on a heavy layer of cement, then alongside it a thin brushed out layer. Test the layers every 15 seconds or so by a gentle tap with your finger. You will note that the thin layer becomes tacky and dries quickly (probably within 15 seconds). The heavy layer will remain wet much longer. Now check for penetration a few minutes after applying these layers. Scrape them with a knife. The thin layer will have achieved little or no penetration, the heavy one much more penetration.



If the cement coating on the pipe and fittings are wet and fluid when assembly takes place, they will tend to flow together and become one cement layer. Also, if the cement is wet the surface beneath them will be soft, and these softened surfaces in the tight part of the joint will tend to fuse together.



As the solvent dissipates, the cement layer and the softened surfaces will harden with a corresponding increase in joint strength. A good joint will take the required pressure long before the joint is fully dry and final strength is obtained. In the tight (fused) part of the joint, strength will develop more quickly than in the loose (bonded) part of the joint. Information about the development of the bond strength of solvent-cemented joints is available on request.



JOINING EQUIPMENT AND MATERIALS

- **Cutting Tool (Saw or Wheel cutter)**
- **Deburring Tool (knife or file)**
- **Applicator Can or Bucket**
- **Solvent Cement**
- **Notched Boards**
- **Rags (nonsynthetic, i.e., cotton)**
- **Cement and Primer Applicators**
- **Purple Primer**
- **Tool Tray**

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

SOLVENT CEMENTING INSTRUCTIONS FOR PVC AND CPVC PIPE AND FITTINGS

Before commencing work, this entire section should be studied and thoroughly understood. It is important that workers making joints be knowledgeable of these instructions and follow them carefully. Do not take shortcuts or omit any of the detailed steps.

KNOW YOUR MATERIAL

There are two general types of rigid vinyl materials, PVC and CPVC. Fitting are made of both materials and in both Schedule 40 and Schedule 80 weights.

Because of the difference in socket dimensions between the Schedule 40 and Schedule 80 fittings, more care must be taken with the Schedule 80 fittings and the cure schedules are different. Determine before proceeding with the job which type of vinyl plastic you are working with and which weight of fitting.

HANDLING CEMENTS AND PRIMERS

Cements and primers contain highly volatile solvents which evaporate rapidly. Avoid breathing the vapors. If necessary, use a fan to keep the work area clear of fumes. Avoid skin or eye contact. Keep cans closed when not actually in use. Solvent cements are formulated to be used "as received" in the original containers. If the cement thickens much beyond its original consistency, discard it. Cement should be free flowing, not jelly-like. Do not attempt to dilute it with thinner, as this may change the character of the cement and make it ineffective. Caution: Solvent cement has limited shelf life, usually one year for CPVC and two years for PVC. Date of manufacture is usually stamped on the bottom of the can. Do not use the cement beyond the period recommended by the manufacturer. Always keep solvent cements and primers out of the reach of children.

SELECTION OF CEMENTS, PRIMERS AND APPLICATORS

1. Obtain the correct primer and solvent cement for the product being installed. (See Harrington's Catalog for detailed information on solvent cements and primers.)

PVC

(a) Use #P-70 purple primer for all sizes of PVC pipe and fittings.
(b) Use #710 clear, light-bodied cement with PVC Schedule 40 fittings having an interference fit through 2" size. Not for use on Schedule 80.
(c) Use #705 clear, medium-bodied cement with PVC Schedule 40 fittings having an interference fit though 6" size. Not for use on Schedule 80.
(d) Use #711 gray, heavy-bodied cement with PVC Schedule 80 fittings through 8" and Schedule 40 fittings 6" and 8" size.
(e) Use #719 gray, extra-heavy-bodied cement for Schedule 40, 80, and all class or schedule sizes over 8" size.

CPVC

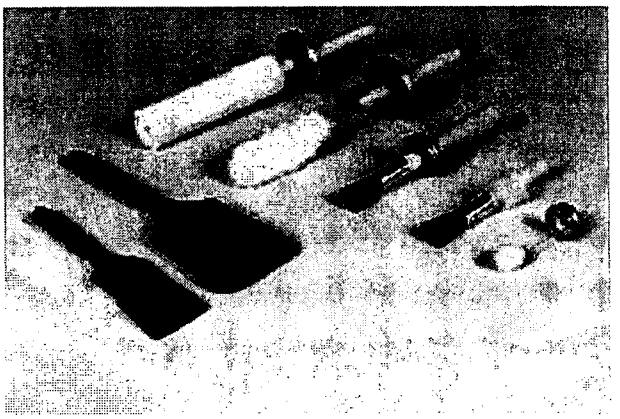
(a) Use #P-70 purple primer for all sizes of CPVC pipe and fittings except copper tube size CPVC (which requires #P-72 or 729).
(b) Use #714 orange or gray, heavy-bodied cement for all sizes of CPVC pipe and fittings.

2. Obtain the correct primer applicators. (See Harrington's Catalog for applicators.) Generally, the applicator should be about 1/2 the pipe diameter.

(a) Use #DP-75, 3/4" diameter, dauber (Supplied with pint size cans of P-70 primer.) for pipe sizes thru 1 1/4".
(b) Use #DP-150, 1 1/2" diameter, dauber for pipe sizes through 3".
(c) Use #4020 cotton string mop for pipe sizes 4" and larger.

Low VOC 724 cement for hypochlorite service.
Weld-on 724 CPVC low VOC cement is a gray, medium bodied, fast setting solvent cement used for joining CPVC industrial piping through 12" diameter, and is specially formulated for services that include caustics and hypochlorites.

3. Obtain the correct solvent cement applicators. Generally, the applicator should be about 1/2 the pipe diameter.



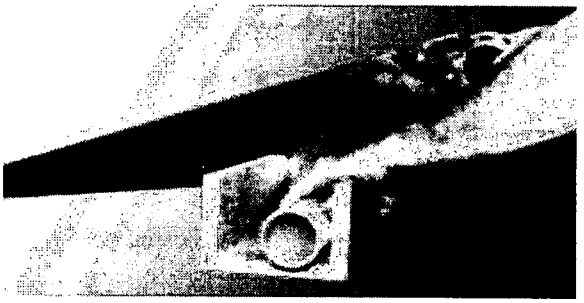
(a) Use #DP-75 3/4" diameter dauber or a natural bristle brush for pipe sizes 1/2" through 1-1/4"
(b) Use #DP-150 1-1/2" diameter dauber for pipe sizes 3/4" through 3". (1" natural bristle brush may be used for pipe sizes up to 2".).
(c) Use #3020, 2" diameter, "Roll-A-Weld" roller for 3" through 6" pipe sizes.
(d) Use #7020 7" long roller or #4020 large cotton swab for 6" through 12" pipe sizes.
(e) Use extra-large natural bristle paint brush to flow cement onto pipe larger than 12".

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

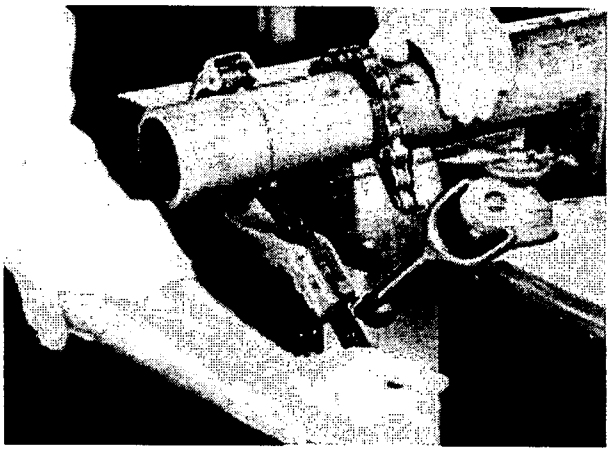
SOLVENT CEMENTING INSTRUCTIONS FOR PVC AND CPVC PIPE AND FITTINGS

PREPARATION

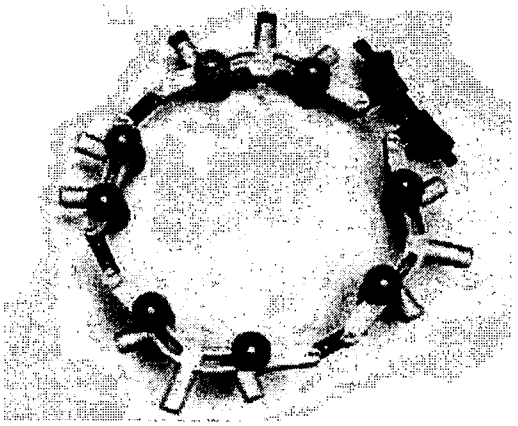
Condition pipe and fittings to the same temperature.



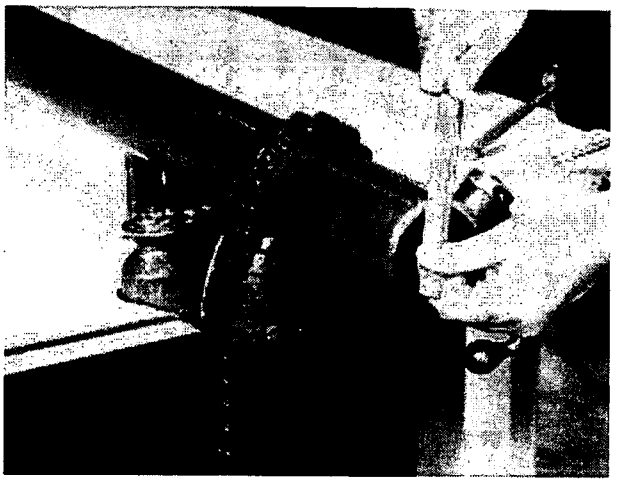
1. Cut pipe square to desired length using a hand saw and miter box or mechanical cutoff saw. A diagonal cut reduces the bonding area in the most effective part of the joint.



2. Plastic tubing cutters may also be used for cutting plastic pipe. However, most produce a raised bead at the end of the pipe. This must be removed with a file, knife, or beveling tool. A raised bead will wipe the cement away when the pipe is inserted into the fitting.

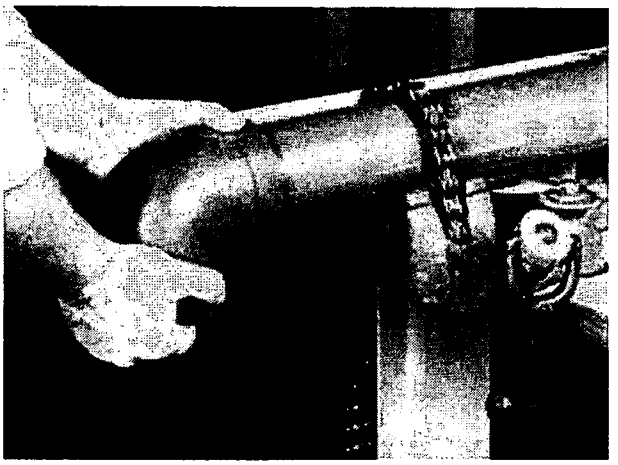


3. Large diameter pipe should be cut and chamfered with appropriate power tools. See Harrington's Products Catalog for tools.



- **For 3/8" to 8" pipe** - 1/16" to 3/32"
- **For 10" to 30" pipe** - 1/4" to 5/8"

4. Chamfer end of the pipe as shown above.



5. Clean and dry pipe and fitting socket of all dirt, moisture, and grease. Use a clean, dry rag.

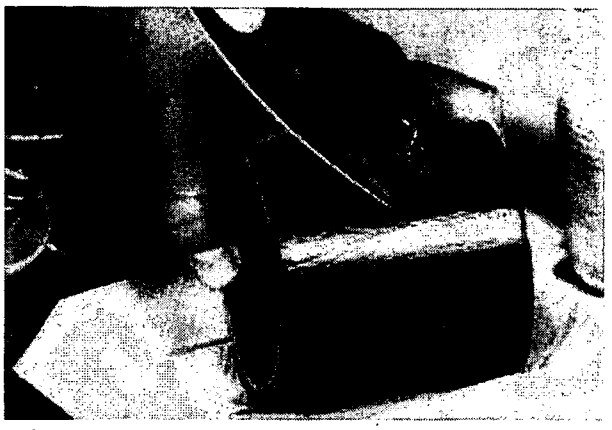
Check pipe and fitting for fit (dry) before cementing. For proper interference fit, the pipe must go into the fitting 1/3 to 3/4 of the way to the stop. Too tight of a fit is not desirable. You must be able to fully bottom the pipe into the socket after it has been softened with primer. If the pipe and fitting are not out of round, a satisfactory joint can be made if there is a "net" fit. That is, the pipe bottoms in the fitting socket with no interference, but without slop. All pipe and fitting must conform to ASTM or other standards.

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

SOLVENT CEMENTING INSTRUCTIONS FOR PVC AND CPVC PIPE AND FITTINGS

PRIMING

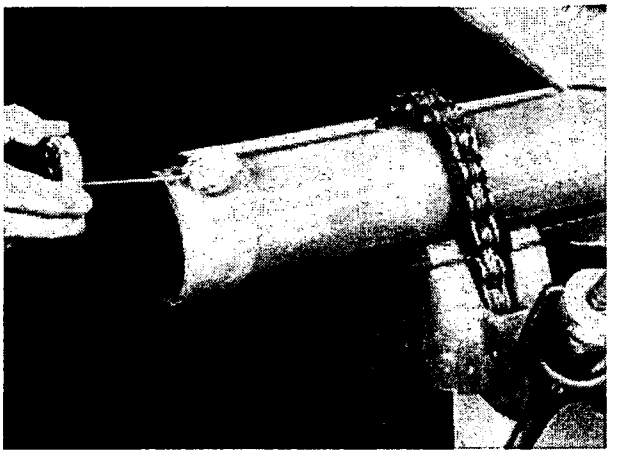
7. The purpose of the primer is to penetrate and soften the surfaces so that they can fuse together. The proper use of the primer and checking of its softening effect provides assurance that the surfaces are prepared for fusion in a wide variety of temperatures and working conditions.



Before starting the installation, we recommend checking the penetration and softening effect of the primer on a scrap piece of the material you will be working with. This should be done where the temperature and environmental conditions are the same as those where the actual installation will take place. The effect of the primer on the surface will vary with both time and temperature. To check for proper penetration and softening, apply primer as indicated in step number 9. After applying primer, use a knife or sharp scraper and draw the edge over the coated surface. Proper penetration has been made if you can scratch or scrape a few thousandths of an inch of the primed surface away.

8. Using the correct applicator as previously mentioned, apply primer freely with a scrubbing motion to the fitting socket, keeping the surface and applicator wet until the surface has been softened. This usually requires 5-15 seconds. More time is needed for hard surfaces (found in belled-end pipe and fittings made from pipe stock) and in cold weather conditions. Redip the applicator in the primer as required.

When the surface is primed, remove any puddles of primer from the socket. Puddles of primer can weaken the pipe and/or joint itself.

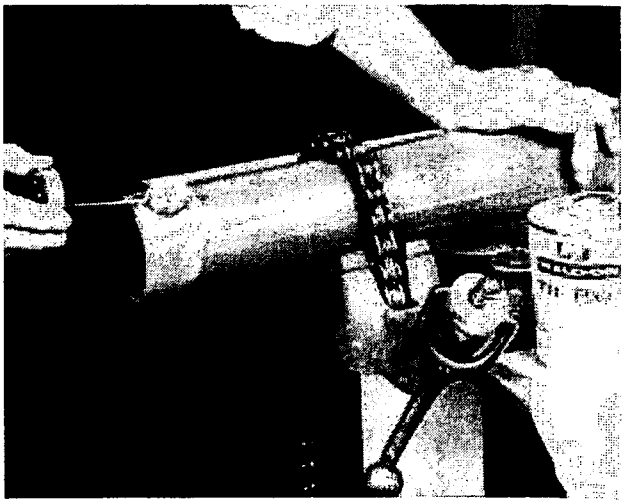


9. Apply the primer to the end of the pipe equal to the depth of the fitting socket. Application should be made in the same manner as was done to the fitting socket. Be sure the entire surface is well dissolved or softened.

10. Apply a second application of primer to the fitting socket and immediately, while the surfaces are still wet, apply the appropriate solvent cement. Time becomes important at this stage. Do not allow cement or primer to dry or start forming film on the surface.

CEMENTING

11. Apply a liberal coat of solvent cement to the male end of the pipe. Flow the cement on with the applicator. **Do not** brush cement out to a thin paint-type layer that will dry in a few seconds. The amount should be more than sufficient to fill any gap between the pipe and fitting.

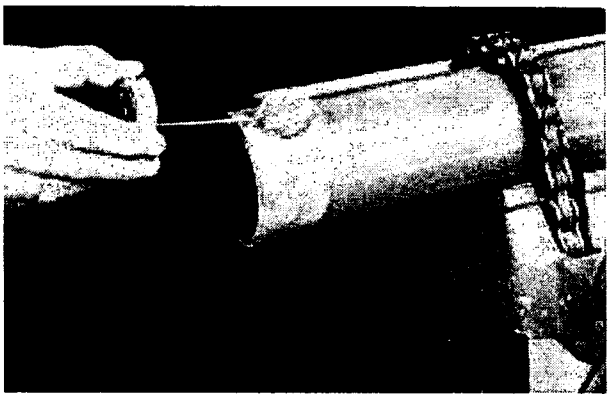


INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

SOLVENT CEMENTING INSTRUCTIONS FOR PVC AND CPVC PIPE AND FITTINGS

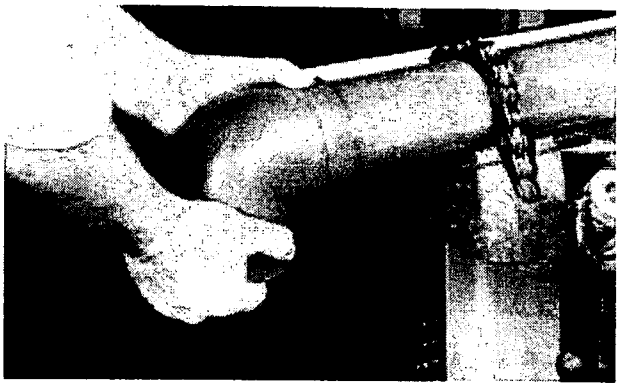
12. Apply a medium layer of solvent cement to the fitting socket; avoid puddling cement in the socket. On bell-end pipe do not coat beyond the socket depth or allow cement to run down in the pipe beyond the bell.

13. Apply a second full, even coat of solvent cement to the male end of the pipe. There must be sufficient cement to fill any gap in the joint. The cement must be applied deliberately but without delay. It may be necessary for two men to work together when cementing three inch and larger pipe.

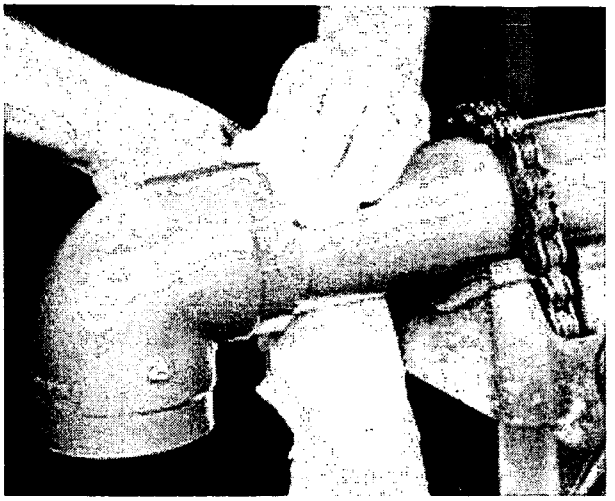


14. While both the inside of the socket and the outside surface of the male end of the pipe are soft and wet with cement, forcefully bottom the male end of the pipe into the socket. Give the male end of the pipe a one-quarter turn if possible. This will help drive any air bubbles out of the joint. The pipe must go into the bottom of the socket and stay there. Hold the joint together until both soft surfaces are firmly gripped. (Usually less than 30 seconds on small diameter piping, larger sizes will require more time.) Care must be used since the fitting sockets are tapered and the pipe will try to push out of the fitting just after assembly.

When solvent cementing large diameter (8 inch and above) pipe and fittings proper equipment should be used. We recommend using straps and come-alongs as shown. See the tool section of the Harrington catalog.



15. After assembly a properly made joint will normally show a ring or bead of cement completely around the juncture of the pipe and fitting. Any gaps at this point may indicate a defective assembly job, due to insufficient cement or the use of light bodied cement on larger diameters where heavy bodied cement should have been used.



16. Without disturbing the joint, use a rag and remove excess cement from the pipe at the end of the fitting socket. This includes the ring or bead noted earlier. This excess cement will not straighten the joint and may actually cause needless softening of the pipe and additional cure times.

17. Handle newly assembled joints carefully until initial set has taken place. Recommended setting time allowed before handling or moving is related to temperature. See initial set times (Table 70).

18. Allow the joint to cure for adequate time before pressure testing. Joint strength development is very rapid within the first 48 hours. Short cure periods are satisfactory for high ambient temperatures with low humidity, small pipe sizes, and interference-type fittings. Longer cure periods are necessary for low temperatures, large pipe sizes, loose fits, and relatively high humidity. See Table 71 for recommended cure times.

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

SOLVENT CEMENTING INSTRUCTIONS FOR PVC AND CPVC PIPE AND FITTINGS

Table 70 INITIAL SET TIMES

TEMPERATURE RANGE DURING INITIAL SET TIME	SET TIME FOR PIPE SIZES 1/2" TO 1 1/4"	SET TIME FOR PIPE SIZES 1 1/2" TO 3"	SET TIME FOR PIPE SIZES 4" TO 8"	SET TIME FOR PIPE SIZES 10" TO 14"	SET TIME FOR PIPE SIZES 16" TO 24"
60° TO 100° F	15 MIN.	30 MIN.	1 HR.	2 HR.	4 HR.
40° TO 59° F	1HR.	2 HR.	4 HR.	8 HR.	16 HR.
0° TO 39° F	3 HR.	6 HR.	12 HR.	24 HR.	48 HR.

* In damp or humid weather allow 50% more cure time.

The following cure schedules are suggested as guides. They are based on laboratory test data and should not be taken to be the recommendation of all cement manufacturers. Individual manufacturers' recommendations for their particular cement should be followed. These cure schedules are based on laboratory test data obtained on net fit joints. (Net fit—in a dry fit the pipe bottoms snugly in the fitting socket without meeting interference.) If a gap joint is encountered in the system, double the following cure times.

Table 71 JOINT CURE SCHEDULE FOR PVC/CPVC PIPE AND FITTINGS

RELATIVE HUMIDITY 60% OR LESS* TEMPERATURE RANGE DURING ASSEMBLY AND CURE TIME	CURE TIME FOR PIPE SIZES 1/2" TO 1 1/4		CURE TIME FOR PIPE SIZES 1 1/2" TO 3"		CURE TIME FOR PIPE SIZES 4" TO 8"		CURE TIME FOR PIPE SIZES 10" TO 14"	CURE TIME FOR PIPE SIZES 16" TO 24"
	Up To 180 psi	Above 180 to 370 psi	Up To 180 psi	Above 180 to 315 psi	Up To 180 psi	Above 180 to 315 psi	Up to 180 psi	Up to 100 psi
60° TO 100° F	1 Hr.	6 Hr.	2 Hr.	12 Hr.	6 Hr.	24 Hr.	24 Hr.	48-72 Hr.
40° TO 59° F	2 Hr.	12 Hr.	4 Hr.	24 Hr.	12 Hr.	48 Hr.	72 hrs	5 Days
0° TO 39° F	8 Hr.	48 Hr.	16 Hr.	96 Hr.	48 Hr.	8 Days	8 Days	10-14 Days

TROUBLESHOOTING AND TESTING SOLVENT CEMENT JOINTS

DO NOT TEST WITH AIR OR COMPRESSED GAS.

DO NOT TAKE SHORTCUTS. Experience has shown that shortcuts from the instructions given above are the cause of most field failures. Don't take a chance.

Solvent cemented joints correctly assembled with good cement under reasonable field conditions should never blow apart when tested, after the suggested cure period under recommended test pressures.

Good solvent cemented joints exhibit a complete dull surface on both surfaces **when cut in half and pried apart.** Leaky joints will show a continuous or an almost continuous series of shiny spots or channels from the bottom to the outer lip of the fitting. No bond occured at these shiny spots. The condition can increase to the point where the entire cemented area is shiny, and the fitting can blow off at this point.

Shiny areas can be attributed to one or a combination of the following causes:

1. Cementing surface not properly primed and dissolved prior to applying solvent cement.
2. Use of too small an applicator for primer or cement in comparison to pipe and fitting diameter.
3. Use of a cement which has partially or completely dried prior to bottoming the pipe into the fitting.
4. Use of jelled cement which will not bite into the pipe and fitting surface due to loss of the prime solvent.
5. Insufficient cement or cement applied only to one surface.
6. Excess gap which cannot be satisfactorily filled.
7. Excess time taken to make the joint after start of the cement application. In many of these cases, as well as condition No. 2, examination will show that it was impossible to bottom the fitting, since the lubrication effect of the cement had dissipated.
8. Cementing with pipe surfaces above 110°F has evaporated too much of the prime solvent.
9. Cementing with cement which has water added by one means or another, or excess humidity conditions coupled with low temperatures.
10. Joints that have been disturbed and the bond broken prior to the firm set, or readjusted for alignment after bottoming.

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

SOLVENT CEMENTING INSTRUCTIONS FOR PVC AND CPVC PIPE AND FITTINGS

JOINING PLASTIC PIPE IN HOT WEATHER

There are many occasions when solvent cementing plastic pipe in 95°F temperatures and over cannot be avoided. If special precautions are taken, problems can be avoided. Solvent cements for plastic pipe contain high-strength solvents which evaporate faster at elevated temperatures. This is especially true when there is a hot wind blowing. If the pipe is stored in direct sunlight, surface temperatures may be 20°F to 30°F above the air temperature. Solvents attack these hot surfaces faster and deeper, especially inside the joint. Thus it is very important to avoid puddling inside the socket and to wipe off excess cement outside the joint.

By following our standard instructions and using a little extra care as outlined below, successful solvent cemented joints can be made even in the most extreme hot weather conditions.

JOINING PLASTIC PIPE IN COLD WEATHER

Working in freezing temperatures is never easy, but sometimes the job is necessary. If that unavoidable job includes solvent cementing of plastic pipe, it can be done.

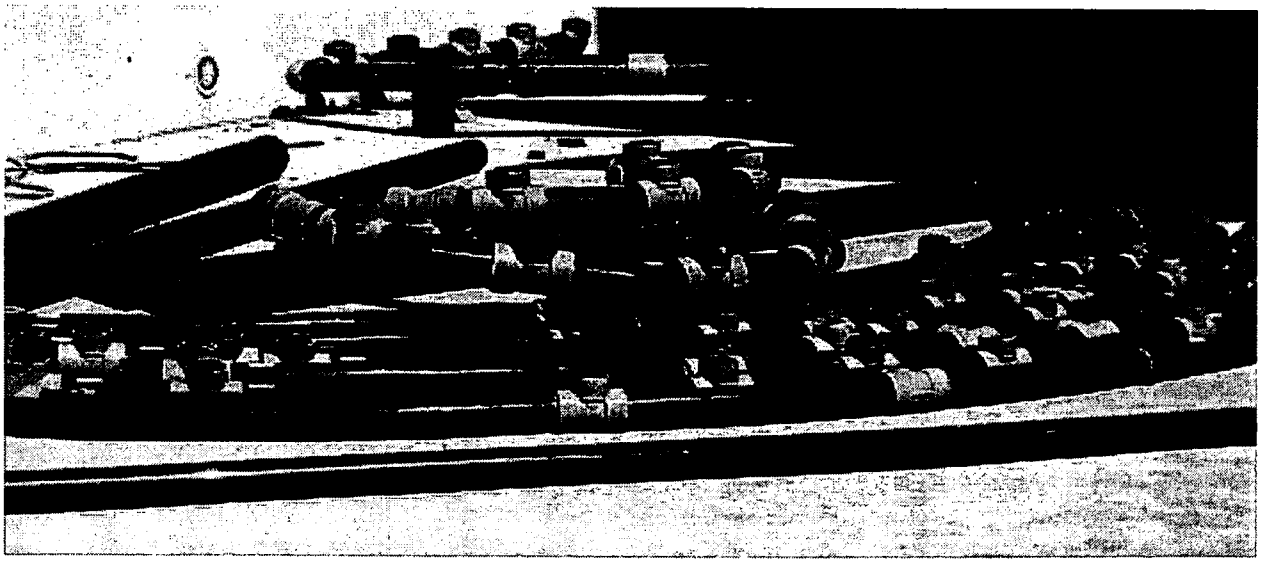
GOOD JOINTS CAN BE MADE AT SUB-ZERO TEMPERATURES

By following our standard instructions and using a little extra care and patience, successful solvent cemented joints can be made at temperatures even as low as -15°F. In cold weather solvents penetrate and soften the surfaces more slowly than in warm weather. Also, the plastic is more resistant to solvent attack. Therefore, it becomes more important to presoften surfaces with primer.

Because solvents evaporate slower in cold weather, a longer cure time will be required. The cure schedule printed in Table 71 already allows a wide margin for safety. For colder weather, simply allow more cure time.

TIPS TO FOLLOW WHEN SOLVENT CEMENTING IN HIGH TEMPERATURES:

1. Store solvent cements and primers in a cool or shaded area prior to use.
2. If possible, store fittings and pipe, or at least the ends to be solvent cemented, in a shady area before cementing.
3. Cool surfaces to be joined by wiping with a damp rag. Be sure that surface is dry prior to applying solvent cement.
4. Try to do the solvent cementing in the cooler morning hours.
5. Make sure that both surfaces to be joined are still wet with cement when putting them together. With large size pipe, more people on the crew may be necessary.
6. Use one of our heavier bodied, high viscosity cements since they will provide a little more working time.
7. Be prepared for a greater expansion-contraction factor in hot weather.



INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

SOLVENT CEMENTING INSTRUCTIONS FOR PVC AND CPVC PIPE AND FITTINGS

TIPS TO FOLLOW IN SOLVENT CEMENTING DURING COLD WEATHER:

1. Prefabricate as much of the system as is possible in a heated working area.
2. Store cements and primers in a warmer area when not in use and make sure they remain fluid.
3. Take special care to remove moisture, including ice and snow.
4. Use extra primer to soften the joining surfaces before applying cement.
5. Allow a longer initial set and cure period before the joint is moved or the system is tested.
6. Read and follow all of our directions carefully before installation.

Regular cements are formulated to have well-balanced drying characteristics and to have good stability in sub-freezing temperatures. Some manufacturers offer special cements for cold weather because their regular cements do not have that same stability.

For all practical purposes, good solvent cemented joints can be made in very cold conditions with our existing products, providing proper care and a little common sense are used.

PHYSICAL DATA
P-70 PRIMER FOR PVC AND CPVC

BOILING POINT (°F) Based on 1st boiling Comp. THF.	151°F	SPECIFIC GRAVITY (H_2O=1)	0.870 ±0.010
VAPOR PRESSURE (mm Hg.) THF @ 25	190	PERCENT, VOLATILE BY VOLUME (%)	100%
VAPOR DENSITY (AIR = 1) APPROX.	2.49	EVAPORATION RATE (BUAC = 1) APPROX.	5.5 - 8

SOLUBILITY IN WATER 100%

APPEARANCE AND ODOR - Purple Color, - Etheral Odor

FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used) (T.C.C.) 6°F	FLAMMABLE LIMITS	Left 1.8	Used 11.8

EXTINGUISHING MEDIA
Dry chemical,Carbondioxide - Foam - Ansul "Purple K" National Aero-O-Foam

SPECIAL FIREFIGHTING PROCEDURES
Close or confined quarters require self contained breathing apparatus. Positive pressure hose mask or airline masks.

UNUSUAL FIRE AND EXPLOSION HAZARDS
Fire hazard because of low flash point, high volatility and heavy vapor.

PHYSICAL DATA
705 CLEAR OR GRAY CEMENT FOR PVC

BOILING POINT (°F) Based on 1st boiling Comp. THF.	151°F	SPECIFIC GRAVITY (H_2O=1)	0.920 ±0.02
VAPOR PRESSURE (mm Hg.) THF @ 25°C	190	PERCENT, VOLATILE BY VOLUME (%) APPROX	85 to 90%
VAPOR DENSITY (AIR = 1) APPROX.	2.49	EVAPORATION RATE (BUAC = 1) APPROX.	5.5 to 8

SOLUBILITY IN WATER Solvent portion PVC resin & filler - Precipates

APPEARANCE AND ODOR - Clear,Thin syrupy liquid, Etheral odor

FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used) (T.O.C.)10°F	FLAMMABLE LIMITS	Left 1.8	Used 1.8

EXTINGUISHING MEDIA
Dry chemical,Carbondioxide - Foam - Ansul "Purple K" National Aero-O-Foam

SPECIAL FIREFIGHTING PROCEDURES
Close or confined quarters require self contained breathing apparatus. Positive pressure hose mask or airline masks.

UNUSUAL FIRE AND EXPLOSION HAZARDS
Fire hazard because of low flash point, high volatility and heavy vapor.

PHYSICAL DATA
711 GRAY CEMENT FOR PVC

BOILING POINT (°F) Based on 1st boiling Comp. THF.	151°F	SPECIFIC GRAVITY (H_2O=1)	0.958± 0.008
VAPOR PRESSURE (mm Hg.) THF @ 25°C	190	PERCENT, VOLATILE BY VOLUME (%)APPROX.	80%
VAPOR DENSITY (AIR = 1) APPROX.	2.49	EVAPORATION RATE (BUAC = 1) APPROX.	5.0 to 8

SOLUBILITY IN WATER Solvent portion PVC resin & filler - Precipates

APPEARANCE AND ODOR - Gary color, medium syrupy liquid - Etheral Odor

FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used) (T.O.C.) 8°F	FLAMMABLE LIMITS % in Air	Left 2.0	Used 11.8

EXTINGUISHING MEDIA
Dry chemical, Carbondioxide - Foam - Ansul "Purple K" National Aero-O-Foam

SPECIAL FIREFIGHTING PROCEDURES
Close or confined quarters require self contained breathing apparatus. Positive pressure hose mask or airline masks.

UNUSUAL FIRE AND EXPLOSION HAZARDS
Fire hazard because of low flash point, high volatility and heavy vapor.

PHYSICAL DATA
719 GRAY CEMENT FOR PVC

BOILING POINT (°F) Based on 1st boiling Comp. THF.	151°F	SPECIFIC GRAVITY (H_2O=1)	0.009 ±0.004
VAPOR PRESSURE (mm Hg.) THF @	190	PERCENT, VOLATILE BY VOLUME (%)	80%
VAPOR DENSITY (AIR = 1) APPROX.	2.49	EVAPORATION RATE (BUAC = 1) APPORX. Initial	5 - 8

SOLUBILITY IN WATER Solvent portion PVC resin & filler - Precipates

APPEARANCE AND ODOR - Gray color, paste like, Etheral Odor

FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used) (T.C.C.)8°F	FLAMMABLE LIMITS	Left 2	Used 11.8

EXTINGUISHING MEDIA
Carbondioxide, Dry chemicals

SPECIAL FIREFIGHTING PROCEDURES
Close or confined quarters require self-contained breathing apparatus. Positive pressure hose mask or airline masks.

UNUSUAL FIRE AND EXPLOSION HAZARDS
Fire hazard because of low flash point, high volatility and heavy vapor.

PHYSICAL DATA
714 GRAY CEMENT FOR CPVC

BOILING POINT (°F) The lowest boiling point	151°	SPECIFIC GRAVITY (H_2O=1)	
VAPOR PRESSURE (mm Hg.) THF @ 25	190	PERCENT, VOLATILE BY VOLUME (%)	85-90%
VAPOR DENSITY (AIR = 1) APPROX.	2.49	EVAPORATION RATE (BUAC = 1) Initially	8.0

SOLUBILITY IN WATER Resin precipates

APPEARANCE AND ODOR -Gray color, Medium syrupy liquid - Etheral Odor

FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used) (T.O.C.) 6°F	FLAMMABLE LIMITS	Left 1.8 %	Used 11.8%

EXTINGUISHING MEDIA
Dry chemical, Carbondioxide - Foam - Ansul "Purple K" National Aero-O-Foam

SPECIAL FIREFIGHTING PROCEDURES
Close or confined quarters require self contained breathing apparatus. Positive pressure hose mask or airline masks

UNUSUAL FIRE AND EXPLOSION HAZARDS
Fire hazard because of low flash point, high volatility and heavy vapor.

Low VOC 724 cement for hypochlorite service

weld-on 724 CPVC low VOC cement is a gray, medium bodied, fast-setting solvent cement used for joining CPVC industrial piping through 12" diameter and is specially formulated for services that include caustics and hypochlorites.

INDUSTRY STANDARDS

FHA
Architectural Standards Division
Federal Housing Administration
Washington, DC 20412

FHA UM-41	PVC plastic pipe and fittings for domestic water service
FHA UM-49	ABS and PVC plastic drainage and vent pipe and fittings, FHA 4550.49
FHA UM-53a	Polyvinyl chloride plastic drainage, waste and vent pipe and fittings
FHA MR-562	Rigid chlorinated polyvinyl chloride (CPVC) hi/temp water pipe and fittings
FHA MR-563	PVC plastic drainage and vent pipe and fittings
FHA Minimum	Property standards interim revision No. 31

IAPMO
International Association of Plumbing and Mechanical Officials
5032 Alhambra Avenue
Los Angeles, California 90032

Uniform Plumbing Code

IAPMO IS8	Solvent cemented PVC pipe for water service and yard piping
IAPMO IS9	PVC drain, waste, and vent pipe and fittings
IAPMO IS10	Polyvinyl chloride (PVC) natural gas yard piping
IAPMO PS27	Supplemental standard to ASTM D2665; polyvinyl chloride (PVC) plastic drain, waste, and vent pipe and fittings

(NOTE: IS = installation standard; PS = property standard)

NSF
National Sanitation Foundation
School of Public Health
University of Michigan
Ann Arbor, Michigan 48106

NSF
Standard No. 14: Thermoplastic Materials, Pipe, Fittings, Valves, Traps, and Joining Materials

NSF
Seal of Approval: Listing of Plastic Materials, Pipe, Fittings, and Appurtenances for Potable Water and Waste Water (NSF Testing Laboratory).

NSPI
National Swimming Pool Institute
2000 K Street, N.W.
Washington, DC 20006

T.R.-19 The Role of Corrosion-Resistant Materials in Swimming Pools, Part D, The Role of Plastics in Swimming Pools.

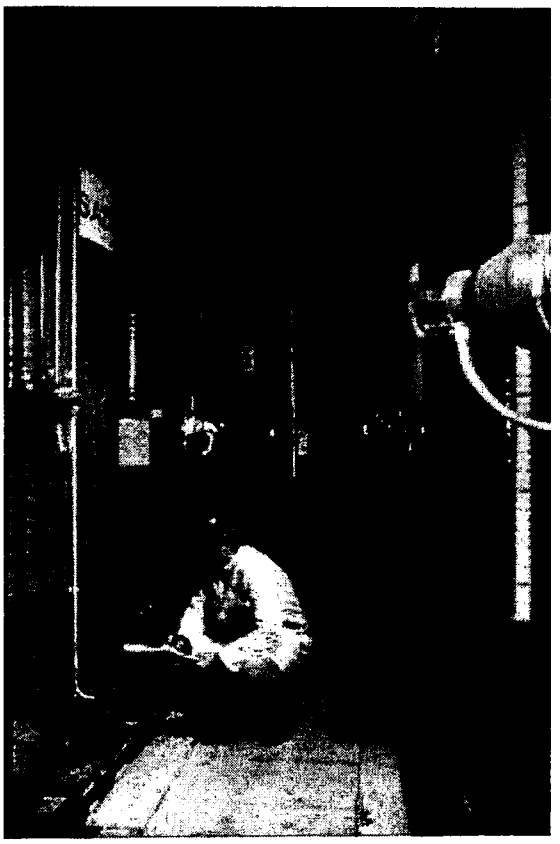
PHCC
National Association of Plumbing-Heating-Cooling Contractors
1016 20th Street, N.W.
Washington, DC 20036
National Standard Plumbing Code

SBCC
Southern Building Code Congress
1166 Brown-Marx Building
Birmingham, Alabama 35203
SBCC Southern Standard Plumbing Code

SIA
Sprinkler Irrigation Association
1028 Connecticut Avenue, N.W.
Washington, DC 20036
Minimum Standards for Irrigation Equipment

WUC
Western Underground Committee, W.H. Foote
Los Angeles Department of Water and Power
P.O. Box 111
Los Angeles, California 90054
Interim Specification 3.1: Plastic Conduit and Fittings

UL
Underwriters Laboratories, Inc.
207 East Ohio Street
Chicago, Illinois 60611
UL 651 Rigid Nonmetallic Conduit (September 1968)
UL 514 Outlet Boxes and Fittings (March 1951 with Amendments of 22-228-67)



INDUSTRY STANDARDS

NEMA
National Electrical Manufacturers' Association
2101 "L" St. N.W.
Washington, DC 20037

Type 1 — General Purpose - Indoor: This enclosure is intended for use indoors, primarily to prevent accidental contact of personnel with the enclosed equipment in areas where unusual service conditions do not exist. In addition, they provide protection against falling dirt.

Type 2 — Dripproof - Indoor: Type 2 dripproof enclosures are for use indoors to protect the enclosed equipment against falling non-corrosive liquids and dirt. These enclosures are suitable for applications where condensation may be severe such as encountered in cooling rooms and laundries.

Type 3 — Dusttight, Raintight, Sleet (Ice) Resistant Outdoor: Type 3 enclosures are intended for use outdoors to protect the enclosed equipment against windblown dust and water. They are not sleet (ice) proof.

Type 3R — Rainproof and Sleet (Ice) Resistant Outdoor: Type 3R enclosures are intended for use outdoors to protect the enclosed equipment against rain and meet the requirements of Underwriters Laboratories Inc., Publication No. UL 508, applying to "Rainproof Enclosures." They are not dust, snow, or sleet (ice) proof.

Type 3S — Dusttight, Raintight, and Sleet (Ice) Proof-Outdoor: Type 3S enclosures are intended for use outdoors to protect the enclosed equipment against windblown dust and water and to provide for its operation when the enclosure is covered by external ice or sleet. These enclosures do not protect the enclosed equipment against malfunction resulting from internal icing.

Type 4 — Watertight and Dusttight - Indoor and Outdoor: This type is for use indoors or outdoors to protect the enclosed equipment against splashing and seepage of water or streams of water from any direction. It is sleet-resistant but not sleet-proof.

Type 4X — Watertight, Dusttight and Corrosion-Resistant - Indoor and Outdoor: This type has same provisions as Type 4 and, in addition, is corrosion-resistant.

Type 5 — Superseded by Type 12 for Control Apparatus.

Type 6 — Submersible, Watertight, Dusttight, and Sleet (Ice) Resistant - Indoor and Outdoor: Type 6 enclosures are intended for use indoors and outdoors where occasional submersion is encountered, such as in quarries, mines, and manholes. They are required to protect equipment against a static head of water of 6 feet for 30 minutes and against dust, splashing or external condensation of non-corrosive liquids, falling or hose directed lint and seepage. They are not sleet (ice) proof.

Type 7 — Class I, Group A, B, C, and D-Indoor Hazardous Locations - Air-Break Equipment: Type 7 enclosures are intended for use indoors, in the atmospheres and locations defined as Class 1 and Group A, B, C or D in the National Electrical Code. Enclosures must be designed as specified in Underwriters' Laboratories, Inc. "Industrial Control Equipment for Use in Hazardous locations," UL 698. Class I locations are those in which flammable gases or vapors may be present in explosive or ignitable amounts. The group letters A, B, C, and D designate the content of the hazardous atmosphere under Class 1 as follows:

Group A
Atmospheres containing acetylene.

Group B
Atmospheres containing hydrogen or gases or vapors of equivalent hazards such as manufactured gas.

Group C
Atmospheres containing ethyl ether vapors, ethylene, or cyclopropane.

Group D
Atmospheres containing gasoline, hexane, naphtha, benzene, butane, propane, alcohols, acetone, lacquer solvent vapors and natural gas.

CTS PLUMBING
Code Approvals
Dimensions
Specifications
Testing
Water Heater Connections

Installation
Hangers and Supports
Joining Techniques
Thermal Expansion
Transition Connections
Wall Penetration

Warranty

Literature Request
Quote Request
Contact Information
Harvel Home

Copper Tube Size (CTS)

CTS Piping For Hot and Cold Water Plumbing Applications

JOINING TECHNIQUES

It is important to follow proper storage and handling, joining, assembly, and other installatio to ensure a quality system installation. A properly designed and installed CPVC plumbing s provide years of trouble-free service, lasting much longer than metallic systems due to the inherent corrosion resistance and other factors. The following information is provided as a toward that end.

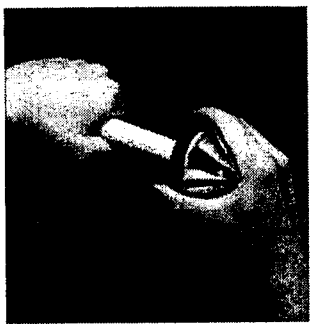
Harvel CTS CPVC pipe is joined by the solvent cementing process; a reliable joining techni proven for more than 30 years. When properly conducted, this method provides a strong, h joining area in which the mating surfaces are chemically fused together, producing a strong seal when cured. Prior to solvent cementing, appropriate safety precautions should be take

- Use only CPVC cement conforming to ASTM F493
- Follow the solvent cement manufacturer's instructions
- Avoid breathing vapors
- Use only with adequate ventilation
- Avoid frequent contact with skin
- Avoid contact with eyes
- Eliminate all ignition sources
- Store primer and solvent cement in the shade between 40°F and 110°F
- Close containers tight when not in use, and cover as much as possible during use
- Follow all manufacturer-recommended precautions when using power tools
- Flush the system for a minimum of 10 minutes after pressure testing to remove trace amo solvents or other system components

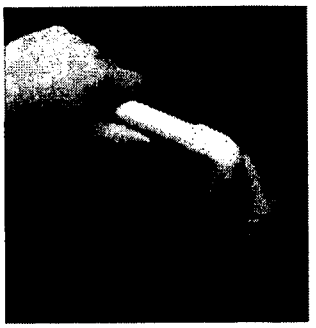
Exercise special care when assembling Harvel CTS CPVC pipe in extremely low temperatu 40°F) or extremely high temperatures (above 80°F). Extra set and handling times must be colder temperatures. Make certain cement has not "gelled" when cementing pipe and fitting temperatures. Make certain both surfaces being joined are wet with cement during assemb working in extremely hot temperatures.

1. Cutting
Harvel pipe must be cut square to obtain the proper insertior to provide the maximum bonding area for solvent cementing. pipe can easily be cut with a wheel-type plastic tubing cutter, style cutter, fine-toothed hand saw (hack saw), or power saw box should be used when working with saws to ensure a squ ratchet-style cutters are used, their blades must be sharpene The use of ratchet cutters with dull blades, or their use in col will tend to compress the pipe prior to cutting which can resu fracturing. The raised bead left on the pipe OD after cutting r removed prior to solvent cementing - see step number 2 reg beveling. Any cuts, fractures, splits, or other damaged areas removed prior to joining. Cut off at least 2" beyond any visibl

2. Beveling/Deburring



Burrs, filings, shavings etc. caused by the cutting process mı removed from the outside and inside of the pipe. Shavings a debris will prevent proper contact of the joining surfaces and joint failure. Chamfering tools are available for this purpose, pocket knives or files are also suitable. A slight bevel is requ pipe end to help ease entry into the fitting socket, and to prev cement from being pushed ahead of the pipe during the asse process. Many chamfering tools designed for use with plastic available. These tools are specifically designed to remove bu provide a proper bevel simultaneously.

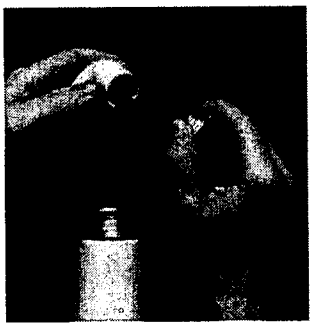


3. Fitting Preparation

Wipe dirt, debris, and moisture from the pipe end and fitting s using a clean, dry rag. Moisture will slow the cure time and re strength. Inspect piping and components for damage or irreg prior to assembly. Do not use components that appear irregu do not fit properly; contact the appropriate manufacturer of th in question to determine usability. Check the dry fit of the pip prior to assembly. The pipe should enter the fitting socket ea quarter to three-quarters of the way.

4. Solvent Cement Application

USE ONLY CPVC CEMENT that conforms to ASTM F493. T the wrong cement can result in failure. Harvel recommends t IPS 713 CPVC cement, P-68 primer or IPS Low VOC one-st cement or equivalent. Two solvent cementing processes are the two-step solvent cement and primer process, and the on process. The two-step process utilizes the application of prin outside of the pipe and the interior fitting socket prior to appl solvent cement. When using primer, it must be applied to bo and fittings using the appropriate size applicator. A dauber o brush approximately half the size of the pipe diameter is app rag must not be used. Apply primer to the fitting socket, then outside of the pipe end, re-dipping the applicator as necessa ensure the entire joining surfaces are wet; apply solvent cem immediately after primer application while primed surfaces a Cement application for one- or two-step process: Apply a he coat of cement to the outside pipe end. Apply a medium coa fitting socket. A second application of cement should be appl pipe end if there was little or no interference when the dry fit checked. Do not allow excess cement to puddle in the pipe c

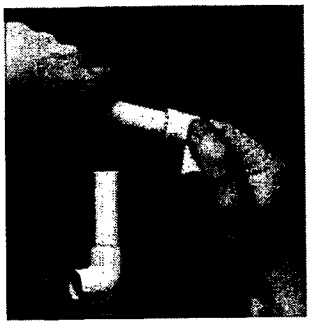


5. Assembly

Immediately insert the pipe into the fitting while rotating the p quarter turn to help distribute cement. Properly align the fittin installation at this time. Pipe must bottom completely to the s fitting. Hold the assembly for 10 to 15 seconds to ensure initi A continuous bead of cement should be evident around the p fitting juncture. If the bead is not continuous, it may indicate t insufficient cement was applied. If insufficient cement is appl fitting must be cut out, discarded and begun again. Cement i the bead should be wiped off with a rag.

6. Set and Cure Times

Assembled joints must be allowed to set and cure properly p testing the system. Set and cure times are a function of type used, pipe size, temperature, humidity, and tightness of fit. D is faster for drier environments, smaller sizes, higher temper



tighter fits. The assembly must be allowed to set without any the joint for one to five minutes depending on the pipe size a temperature. Following the initial set period, the assembly ca handled carefully. FOLLOW THE CEMENT MANUFACTURE RECOMMENDED CURE TIMES PRIOR TO PRESSURE TE FAILURE TO DO SO WILL RESULT IN JOINT FAILURE.

Minimum Cure Time Prior to Testing at 150 psi with Cold Water (based on use of IPS one CPVC cement and 713 two-step cement)

Pipe Size (in)	Ambient Temperature During Cure Time	
	>60°F	40°F - 60°F
3/8	1 hr	2 hrs
1/2	1 hr	2 hrs
3/4	1 hr	2 hrs
1	1 hr	2 hrs
1 1/4	2 hrs	4 hrs
1 1/2	2 hrs	4 hrs
2	2 hrs	4 hrs

Note: Wait 24 hours prior to putting system into hot water service when installed at cure te above 60°F; wait 48 hours prior to putting system into hot water service when installed at c temperatures below 40°F

Harvel Plastics, Inc., Easton, Pennsylvania, USA • 610-252-7355 • 610-253-4436 (fax) • Privacy Policy |

ATTACHMENT IV

CONTAINS NO CI

MRI REPORT

Polychlorinated Dibenzo-*p*-Dioxins (PCDDs) and Polychlorinated Dibenzofurans (PCDFs) Analysis of Chlorinated PVC Samples

For The BF Goodrich Company
Technical Center
Moore and Walker Road
P.O. Box 122
Avon Lake, OH 44012

Attn: Dr. John Nikora

MRI Project No. 6415-A

December 17, 1991

18

MIDWEST RESEARCH INSTITUTE 425 Volker Boulevard, Kansas City, MO 64110-2299 • (816) 753-7600

PREFACE

This report provides the polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) results from the analysis of five chlorinated PVC samples. The results for corresponding quality control samples including a laboratory method blank and duplicate matrix spikes are also presented.

The samples were prepared for analysis by Mr. Mark Clapp under the direction of Ms. Kathy Boggess, and the HRGC/HRMS analyses were performed by Mr. Mark Horrigan. Ms. Boggess performed the data reduction and prepared this report.

MIDWEST RESEARCH INSTITUTE

Kathy E. Boggess

Kathy E. Boggess
Chemist

John S. Stanley, Ph.D.
Head
Analytical Chemistry Section

Approved:

John E. Going, Ph.D.
Director
Chemical Sciences Department

19

MRI-AVR641S

CONTENTS

Preface ii
Tables iv

1. Introduction 1
2. Sample Receipt 2
3. Experimental Approach 3
   - Particle size reduction 3
   - Solvent compatibility studies 3
   - Sample preparation 4
   - HRGC/HRMS analysis 5
   - Data reduction 5
4. Results 7

20

LIST OF TABLES

Number		Page
1	Internal quantitation standard spiking solution	8
2	Native standard spiking solution	9
3	PCDD and PCDF calibration standards	10
4	Concentrations (pg/g) of PCDDs and PCDFs in chlorinated PVC samples	11
5	Quality control sample results	12
6	Absolute recoveries (%) of $^{13}C_{12}$- internal quantitation standards	13

21

Attachment 2 - 23 pp

SECTION 1

INTRODUCTION

Midwest Research Institute (MRI) was contracted by the BF Goodrich Company to determine the levels of 2,3,7,8-substituted tetra- through octachlorinated polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) in five chlorinated PVC samples. The samples included bar stock, compound cubes, pipe, and two chlorinated PVC resins.

This report presents the sample receipt, experimental approach, and results of the PCDDs and PCDFs analysis of the chlorinated PVC samples and corresponding quality control samples.

SECTION 2

SAMPLE RECEIPT

MRI received the five chlorinated PVC samples on August 27, 1991, enclosed in a cardboard shipping container at ambient temperature. The samples were stored at room temperature in a locked facility until sample preparation was initiated.

The samples were designated as follows, as described in a letter to Kathy Boggess from Dr. John Nikora, dated August 22, 1991.

Sample Code	Description
163-90-86-1	Bar Stock (grey color)
163-90-86-2	Compound Cubes (grey color)
163-90-86-3	Chlorinated PVC Resin (white)
163-90-86-4	Pipe (ivory color)
163-90-86-5	Chlorinated PVC Resin (white)

SECTION 3

EXPERIMENTAL APPROACH

This section of the report describes the experimental approach used to prepare and analyze the samples for PCDDs and PCDFs. The analytical procedures used for sample preparation included particle size reduction of the bar stock and pipe samples. Solvent compatibility studies were conducted to determine the most appropriate solvent for extracting the PCDDs and PCDFs from the various matrices.

Hexane was chosen as the most appropriate solvent and the five chlorinated PVC samples were Soxhlet-extracted with hexane. The subsequent extract cleanup procedures and high resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS) analysis procedures were modifications of EPA Method 8290.

PARTICLE SIZE REDUCTION

Particle size reduction of the bar stock (163-90-86-1) and pipe (163-90-82-4) samples was necessary before the samples were extracted. These samples were received in three sections with lengths from 3 to 4 in. The resin samples (163-90-86-3 and 163-90-86-5) were a powder consistency and required no further size reduction prior to their extraction. The particle sizes of the compound cubes (163-90-86-2) were approximately 3 mm x 3 mm x 3 mm, and further particle size reduction was not necessary.

The bar stock and pipe samples were reduced on a lathe and shaved particles were collected in a plastic bag. The metal parts of the lathe were precleaned with hexane before contact with the samples. The approximate size of the shaved particles was 1 mm x 5 mm.

SOLVENT COMPATIBILITY STUDIES

Before samples were prepared for PCDDs and PCDFs analyses, solvent compatibility studies were conducted. The objective of these studies was to identify an extraction solvent that would accomplish a slight swelling of the

material without dissolving the material in the sample extract. Ideally, a solvent that met this objective would accomplish a more exhaustive extraction than if only the surface areas of the various materials were extracted.

At ambient temperatures, methylene chloride and toluene appeared to be appropriate extraction solvents. However, initial attempts to extract the five chlorinated PVC samples with a mixture of toluene and methylene chloride proved unsuccessful. The resins were partially dissolved by the solvent, and attempts to solvent-exchange the extracts to hexane for extract cleanup resulted in precipitation of a white solid mass. This observation was attributed to the presence of methylene chloride which was used to promote swelling of the materials. Subsequent attempts to extract the resin samples with toluene and with hexane/methylene chloride mixtures were also unsuccessful. The resin material fused into a solid mass in the extraction thimble.

The first steps of the cleanup procedures, including partitioning with concentrated sulfuric acid and concentrated base solutions, did not remove the precipitated material from the sample extracts.

Extraction of the samples with hexane was then evaluated and no problems were encountered with the matrix. MRI's plans to extract the samples with hexane were discussed with Dr. John Nikora on October 24, 1991. Dr. Nikora suggested an evaluation of a mixture of isopropyl alcohol and hexane. The swelling potential of a hexane and isopropyl alcohol mixture was evaluated with a cube of sample 163-90-86-2 and no swelling was observed. Because the hexane/isopropyl mixture appeared to have no advantages over hexane, the samples were prepared for analysis using hexane as the extraction solvent.

SAMPLE PREPARATION

Sample aliquots (10 g weighed to the nearest 0.0001 g) of the bar stock and pipe- shaved particles, the compound cubes, and the resin samples were mixed with 10 g quartz sand and transferred to Soxhlet extraction thimbles. The samples were spiked with an internal quantitation standard (IQS) spiking solution containing 15 $^{13}C_{12}$-labeled PCDDs and PCDFs at the concentrations shown in Table 1. For matrix spike samples, duplicate aliquots of resin sample 163-90-86-3 were prepared and spiked with native 2,3,7,8-substituted PCDDs and PCDFs at the concentrations shown in Table 2 in addition to the IQS spiking solution.

The samples were Soxhlet-extracted for 24 hr with hexane. The hexane extracts were concentrated, and matrix interferences were removed by partitioning against 20% (w/v) aqueous KOH and concentrated sulfuric acid followed by

elution through a series of chromatography columns including acid/neutral silica gel, neutral alumina, and Carbopack C/Celite.

After the final cleanup, each extract was concentrated under prepurified nitrogen to 100 µl, and 10 µl of a recovery standard (RS) was added that contained $^{13}C_{12}$-1,2,3,4-TCDD and 1,2,3,7,8,9-HxCDD at concentrations of 10 pg/µl in tridecane. The evaporation was continued until a final volume of 10 µl was reached. The extracts were transferred to refrigerated storage until ready for HRGC/HRMS analysis.

Matrix interferences were observed during the preliminary analysis of the bar stock sample and additional cleanup was necessary. The sample extract was put through a second Carbopack C/Celite column cleanup for reanalysis by HRGC/HRMS.

HRGC/HRMS ANALYSIS

The sample extracts were analyzed using a 60-m DB-5 fused silica chromatography column and VG70 250S HRMS with mass resolution > 10,000. The day that samples were analyzed began with mass calibration of the mass spectrometer followed by the analysis of a window-defining mix which was used to set appropriate retention times for the PCDD and PCDF analytes and to calculate the separation of the 2,3,7,8-TCDD isomer from other closely eluting TCDD isomers. The 2,3,7,8 isomer was resolved from other TCDD isomers with a valley of < 25%.

The initial calibration of the instrument consisted of a series of seven standards over the concentration ranges shown in Table 3. The criterion for an acceptable calibration curve was a relative standard deviation of < 20%. The criterion for continuing daily calibration was that the daily response factor (RF) must be within ±20% of the mean from the initial calibration curve. The initial calibration curve and continuing calibration criteria were met.

After the analysis of the daily calibration standard, a tridecane solvent blank was analyzed to ensure a clean system. The chlorinated PVC samples and quality control samples were then analyzed followed by an end-of-the-day calibration standard to ensure instrument stability.

DATA REDUCTION

The data reduction procedures for the analysis of the chlorinated PVC samples included qualitative criteria for identification of a peak as a 2,3,7,8-substituted PCDD or PCDF isomer and quantitation procedures for peaks positively

identified. The quantitation ions, theoretical ion abundance ratio criteria, and calculation formulas are specified in EPA Method 8290.

An automatic data reduction program was used to calculate the responses of analytes in the appropriate mass windows with ion abundance ratios within ±15% of the theoretical ratios. Detected peaks were also required to be within relative retention time windows established from the analysis of the calibration standards. The retention times of the native 2,3,7,8-substituted PCDD or PCDF analytes were required to be within ±3 sec of the corresponding $^{13}C_{12}$-2,3,7,8 substituted internal quantitation standards.

For peaks that passed the qualitative criteria, the computer program calculated an extract concentration, and then sample weights and extract volumes were taken into account to arrive at a final sample concentration.

For compounds not positively identified, a calculated detection limit (cdl) was determined based on the concentration of the lowest instrument calibration standard. In some cases responses were noted at retention times characteristic of 2,3,7,8- substituted PCDDs or PCDFs, but the qualitative ratio criteria were not met. For these situations, a detection limit was determined based on the maximum possible concentration (MPC) for the observed peak.

SECTION 4

RESULTS

The preliminary results from the analysis of the resin samples, the compound cubes, and the pipe samples were discussed with Dr. John Nikora on November 12, 1991. During that discussion, the results for the bar stock sample were not available because the bar stock sample required additional cleanup. Additional cleanup was performed for the bar stock sample, and the results for this sample and the other chlorinated PVC samples are summarized in Table 4. The 2,3,7,8-substituted PCDDs and PCDFs are presented first followed by the total homolog concentrations. Resin sample 163-099-86-3 contained higher concentrations of PCDFs than the other samples, and concentrations of PCDDs were much lower than the PCDFs.

Quality control (QC) samples prepared and analyzed with the chlorinated PVC samples including a laboratory method blank and duplicate resin matrix spikes samples are summarized in Table 5. Background levels of 1,2,3,4,6,7,8-HpCDD and OCDD were detected in the method blank at concentrations slightly above the calculated detection limits.

The accuracy and precision of the duplicate matrix spike samples are also summarized in Table 5. The spike levels, concentrations in unspiked samples, and concentrations found in matrix spike samples are shown followed by the percent accuracy and relative percent difference precision. The accuracy of the matrix spike was determined by subtracting the amount found in the unspiked sample from the amount found in the spiked sample and then dividing the difference by the theoretical amount spiked. For some of the analytes, including 2,3,7,8-TCDF, 1,2,3,7,8-PeCDF, 2,3,4,7,8-PeCDF, and 1,2,3,6,7,8-HxCDF, the amounts found in the unspiked sample were significantly higher than the amount spiked by a factor ranging from 3 to 30 and these results are footnoted. For the remaining analytes, the accuracy and precision results were very good.

An additional quality control activity included monitoring the absolute method recoveries of the $^{13}C_{12}$-labeled IQSs that were added to the samples before extraction. The IQS recoveries shown in Table 6 indicate very good precision for the analytical method (14% to 27% relative standard deviation), and recoveries were generally within the Method 8290 suggested range of 40% to 120%. Some recoveries were slightly outside the 40% to 120% range, and these data are footnoted in Table 6.

Table 1. INTERNAL QUANTITATION STANDARD SPIKING SOLUTION

Compound	Concentration[a] (pg/µL)	Amount spiked (total pg)
$^{13}C_{12}$-2,3,7,8-TCDF	0.5	100
$^{13}C_{12}$-2,3,7,8-TCDD	0.5	100
$^{13}C_{12}$-1,2,3,7,8-PeCDF	0.5	100
$^{13}C_{12}$-2,3,4,7,8-PeCDF	0.5	100
$^{13}C_{12}$-1,2,3,7,8-PeCDD	0.5	100
$^{13}C_{12}$-1,2,3,4,7,8-HxCDF	0.5	100
$^{13}C_{12}$-1,2,3,6,7,8-HxCDF	0.5	100
$^{13}C_{12}$-2,3,4,6,7,8-HxCDF	0.5	100
$^{13}C_{12}$-1,2,3,7,8,9-HxCDF	0.5	100
$^{13}C_{12}$-1,2,3,4,7,8-HxCDD	0.5	100
$^{13}C_{12}$-1,2,3,6,7,8-HxCDD	0.5	100
$^{13}C_{12}$-1,2,3,4,6,7,8-HpCDF	0.5	100
$^{13}C_{12}$-1,2,3,4,7,8,9-HpCDF	0.5	100
$^{13}C_{12}$-1,2,3,4,6,7,8-HpCDD	0.5	100
$^{13}C_{12}$-OCDD	1.0	200

[a] Prepared in isooctane, 200 µL was added to each sample before extraction.

MRI-AVR415

Table 2. NATIVE STANDARD SPIKING SOLUTION

Compound	Concentration[a] (pg/µL)	Amount spiked (total pg)
2,3,7,8-TCDF	0.77	31
2,3,7,8-TCDD	0.76	30
1,2,3,7,8-PeCDF	0.70	28
2,3,4,7,8-PeCDF	0.57	23
1,2,3,7,8-PeCDD	0.75	30
1,2,3,4,7,8-HxCDF	1.9	76
1,2,3,6,7,8-HxCDF	1.7	66
2,3,4,6,7,8-HxCDF	1.8	73
1,2,3,7,8,9-HxCDF	2.0	79
1,2,3,4,7,8-HxCDD	2.0	79
1,2,3,6,7,8-HxCDD	1.8	71
1,2,3,7,8,9-HxCDD	1.9	75
1,2,3,4,6,7,8-HpCDF	1.8	74
1,2,3,4,7,8,9-HpCDF	1.9	75
1,2,3,4,6,7,8-HpCDD	1.8	71
1,2,3,4,6,7,8,9-OCDF	3.5	140
1,2,3,4,6,7,8,9-OCDD	3.6	145

[a] Prepared in isooctane, 40 µL was added to method spike sample before extraction.

Table 3. PCDD AND PCDF CALIBRATION STANDARDS

Compound	Concentration (pg/µL)						
Native analytes							
2,3,7,8-TCDF	0.1	0.25	0.5	2.5	10	25	50
2,3,7,8-TCDD	0.1	0.25	0.5	2.5	10	25	50
1,2,3,7,8-PeCDF	0.1	0.25	0.5	2.5	10	25	50
2,3,4,7,8-PeCDF	0.1	0.25	0.5	2.5	10	25	50
1,2,3,7,8-PeCDD	0.1	0.25	0.5	2.5	10	25	50
1,2,3,4,7,8-HxCDF	0.25	0.625	1.25	6.25	25	62.5	125
1,2,3,6,7,8-HxCDF	0.25	0.625	1.25	6.25	25	62.5	125
2,3,4,6,7,8-HxCDF	0.25	0.625	1.25	6.25	25	62.5	125
1,2,3,7,8,9-HxCDF	0.25	0.625	1.25	6.25	25	62.5	125
1,2,3,4,7,8-HxCDD	0.25	0.625	1.25	6.25	25	62.5	125
1,2,3,6,7,8-HxCDD	0.25	0.625	1.25	6.25	25	62.5	125
1,2,3,7,8,9-HxCDD	0.25	0.625	1.25	6.25	25	62.5	125
1,2,3,4,6,7,8-HpCDF	0.25	0.625	1.25	6.25	25	62.5	125
1,2,3,4,7,8,9-HpCDF	0.25	0.625	1.25	6.25	25	62.5	125
1,2,3,4,6,7,8-HpCDD	0.25	0.625	1.25	6.25	25	62.5	125
OCDF	0.5	1.25	2.5	12.5	50	125	250
OCDD	0.5	1.25	2.5	12.5	50	125	250
Internal Quantitation Standards							
^{13}C-2,3,7,8-TCDF	10	10	10	10	10	10	10
^{13}C-2,3,7,8-TCDD	10	10	10	10	10	10	10
^{13}C-1,2,3,7,8-PeCDF	10	10	10	10	10	10	10
^{13}C-2,3,4,7,8-PeCDF	10	10	10	10	10	10	10
^{13}C-1,2,3,7,8-PeCDD	10	10	10	10	10	10	10
^{13}C-1,2,3,4,7,8-HxCDF	10	10	10	10	10	10	10
^{13}C-1,2,3,6,7,8-HxCDF	10	10	10	10	10	10	10
^{13}C-2,3,4,6,7,8-HxCDF	10	10	10	10	10	10	10
^{13}C-1,2,3,7,8,9-HxCDF	10	10	10	10	10	10	10
^{13}C-1,2,3,4,7,8-HxCDD	10	10	10	10	10	10	10
^{13}C-1,2,3,6,7,8-HxCDD	10	10	10	10	10	10	10
^{13}C-1,2,3,4,6,7,8-HpCDF	10	10	10	10	10	10	10
^{13}C-1,2,3,4,7,8,9-HpCDF	10	10	10	10	10	10	10
^{13}C-1,2,3,4,6,7,8-HpCDD	10	10	10	10	10	10	10
^{13}C-OCDD	20	20	20	20	20	20	20
Recovery Standards							
^{13}C-1,2,3,4-TCDD	10	10	10	10	10	10	10
^{13}C-1,2,3,7,8,9-HxCDD	10	10	10	10	10	10	10

Table 4. CONCENTRATIONS (PG/G) OF PCDDs AND PCDFs IN CHLORINATED PVC SAMPLES

COMPOUND	Sample ID Matrix	Method Blank a	163-90-86-1 Barstock	163-90-86-2 Compound cubes	163-90-86-3 Resin	163-90-86-4 Pipe	163-90-86-5 Resin
2378TCDF		ND(.10 cdl) b	14.2	0.725	91.7	ND(.10 cdl)	ND(.10 cdl)
2378TCDD		ND(.11 cdl)	5.31	ND(.093 cdl)	ND(.11 cdl)	ND(.12)	ND(.14 mpc)
12378PECDF		ND(.093 cdl)	8.42	0.215	24.7	ND(.25 mpc)	ND(.098 cdl)
23478PECDF		ND(.089cdl)	5.10	ND(.14 mpc) c	16.2	0.356	2.9
12378PECDD		ND(.11 cdl)	ND(.28 cdl)	ND(.10 cdl)	ND(.11 cdl)	ND(.15)	0.14
123478HXCDF		ND(.25 cdl)	14.1	ND(.23 cdl)	19.1	0.661	8.11
23678HXCDF		ND(.25 cdl)	3.32	ND(.24 cdl)	3.72	ND(.21cdl)	2.1
234678HXCDF		ND(.25 cdl)	ND(.97 cdl)	ND(.24 cdl)	2.52	ND(.23 cdl)	2.3
128789HXCDF		ND(.25cdl)	ND(1.05 cdl)	ND(.25 cdl)	ND(.25 cdl)	ND(.29 mpc)	ND(.26 cdl)
123478HXCDD		ND(.22 cdl)	ND(.90 cdl)	ND(.22 cdl)	ND(.22 cdl)	ND(.26 cdl)	ND(.24 cdl)
123678HXCDD		ND(.26 cdl)	ND(.85cdl)	ND(.25 cdl)	ND(.25 cdl)	ND(.22 cdl)	ND(.26 cdl)
123789HXCDD		ND(.22 cdl)	ND(.90 cdl)	ND(.22 cdl)	ND(.22 cdl)	ND(.26 cdl)	ND(.24cdl)
1234678HPCDF		ND(.30 cdl)	3.26	ND(.30 cdl)	4.00	0.454	11.6
1234789HPCDF		ND(.28 cdl)	2.20	ND(.30 cdl)	1.61	ND(.28 cdl)	2.29
1234678HPCDD		0.373	1.65	0.39	0.404	0.781	ND(.50 mpc)
12346789OCDF		ND(.60 cdl)	7.65	ND(.66 cdl)	2.85	1.2	13.3
12346789OCDD		1.70	10.9	1.91	3.60	ND(3.62 mpc)	2.15
Homologs							
TCDF		ND(.10 cdl)	52.0	1.35	133	4.24	2.73
TCDD		ND(.11 cdl)	6.24	ND(.093 cdl)	0.223	ND(.12)	0.136
PeCDF		ND(.093 cdl)	48.3	0.713	110	2.42	49.6
PeCDD		ND(.089 cdl)	0.372	ND(.10cdl)	ND(.11 cdl)	ND(.15)	0.14
HxCDF		ND(.25 cdl)	30.2	ND(.23 cdl)	35.8	0.976	34.7
HxCDD		ND(.26 cdl)	1.97	ND(.25 cdl)	ND(.25cdl)	ND(.22 cdl)	ND(.26cdl)
HpCDF		ND(.30 cdl)	8.37	ND(.30 cdl)	9.86	0.911	25.9
HpCDD		0.373	3.09	0.646	0.695	1.32	0.326

a- For comparison to samples concentrations in method blank were based on a10 g sample size.
b- Compound not detected. Value in parenthesis is calculated detection limit (cdl) based on lowest calibration standard.
c- Compound not detected. Value in parenthesis is maximum possible concentration (mpc) for a peak that did not meet the qualitative ratio criteria.

Table 5. QUALITY CONTROL SAMPLE RESULTS

COMPOUND	Field ID Extract ID	Blank pg/g (a)	163-90-86-3 Unspiked Resin pg/g	Nominal Spike Level pg/g	163-90-86-3 Resin Matrix Spike pg/g	163-90-86-3 Resin Matrix Spike Duplicate pg/g	163-90-86-3 Resin Matrix Spike % Accuracy (c)	163-90-86-3 Resin Matrix Spike Duplicate % Accuracy	RPD (e)
2378TCDF		ND(.10 cdl) b	91.7	3.1	95.0	71.2	NC(d)	NC(d)	29
2378TCDD		ND(.11 cdl)	ND(.11 cdl)	3.1	2.57	2.79	88.8	93.2	4.8
12378PECDF		ND(.093 cdl)	24.7	2.8	26.4	25.4	NC(d)	NC(d)	3.9
23478PECDF		ND(.089 cdl)	16.2	2.3	18.2	17.4	NC(d)	NC(d)	4.5
12378PECDD		ND(.11 cdl)	ND(.11 cdl)	3.0	2.38	3.16	83.1	107	25
123478HXCDF		ND(.25 cdl)	19.1	7.6	24.0	22.0	NC(d)	NC(d)	8.7
23678HXCDF		ND(.25 cdl)	3.72	6.6	10.2	9.94	103	95.4	7.5
234678HXCDF		ND(.25 cdl)	2.52	7.3	8.89	8.91	91.6	88.9	3.0
123789HXCDF		ND(.26cdl)	ND(.25 cdl)	7.9	5.89	6.23	78.0	79.8	2.3
123478HXCDD		ND(.22 cdl)	ND(.22 cdl)	7.9	6.47	7.38	86.5	95.5	9.9
123678HXCDD		ND(.26 cdl)	ND(.25 cdl)	7.1	6.07	6.62	89.6	94.5	5.3
123789HXCDD		ND(.22 cdl)	ND(.22 cdl)	7.5	5.70	6.28	80.1	85.3	6.3
1234678HPCDF		ND(.30 cdl)	4.00	7.4	10.9	10.4	98.7	88.6	11
1234789HPCDF		ND(.28 cdl)	1.61	7.5	7.72	7.75	85.6	83.2	2.8
1234678HPCDD		0.373	0.404	7.1	6.59	7.03	91.4	94.7	3.5
12346789OCDF		ND(.60 cdl)	2.85	14	14.0	14.6	83.8	85.4	1.9
12346789OCDD		1.70	3.60	15	13.7	14.6	73.2	77.1	5.2

a- For comparison to samples concentrations in method blank were based on 10 g sample size.
b- Compound not detected. Value in parenthesis is calculated detection limit based on lowest calibration standard.
c- % Accuracy = ((Amount found in spiked sample- amount in unspiked resin)/Amount Spiked) X 100 %
d-Not calculated. The accuracy of the matrix spike sample was affected by high concentrations in the unspiked sample
RPD= Relative Percent Difference of Duplicate Matrix Spike Samples. Where accuracy was not calculated
e to high concentrations in the unspiked sample, the precision was calculated based on the the total amount found.

CECATS\TRIAGE TRACKING DBASE ENTRY FORM

CECATS DATA:
Submission # 8EHQ-0292-2291 SEQ. A

TYPE: INT SUPP FLWP

SUBMITTER NAME: B. F. Goodrich Company

INFORMATION REQUESTED: FLWP DATE:
0501 NO INFO REQUESTED
0502 INFO REQUESTED (TECH)
0503 INFO REQUESTED (VOL ACTIONS)
0504 INFO REQUESTED (REPORTING RATIONALE)
DISPOSITION:
0639 REFER TO CHEMICAL SCREENING
0678 CAP NOTICE

VOLUNTARY ACTIONS:
0401 NO ACTION REPORTED
0402 STUDIES PLANNED/UNDERWAY
0403 NOTIFICATION OF WORKER/OTHERS
0404 LABEL/MSDS CHANGES
0405 PROCESS/HANDLING CHANGES
0406 APP./USE DISCONTINUED
0407 PRODUCTION DISCONTINUED
0408 CONFIDENTIAL

BFG CPVC Compound #88998

SUB. DATE: 2/25/92 OTS DATE: 2/26/92 CSB DATE: 3/3/92

CHEMICAL NAME:	CAS#
Dioxins, chlorinated	none
~~Dioxins, Dibenzo-para~~	~~none~~
Dibenzofurans, chlorinated	none
misc. chemicals	none

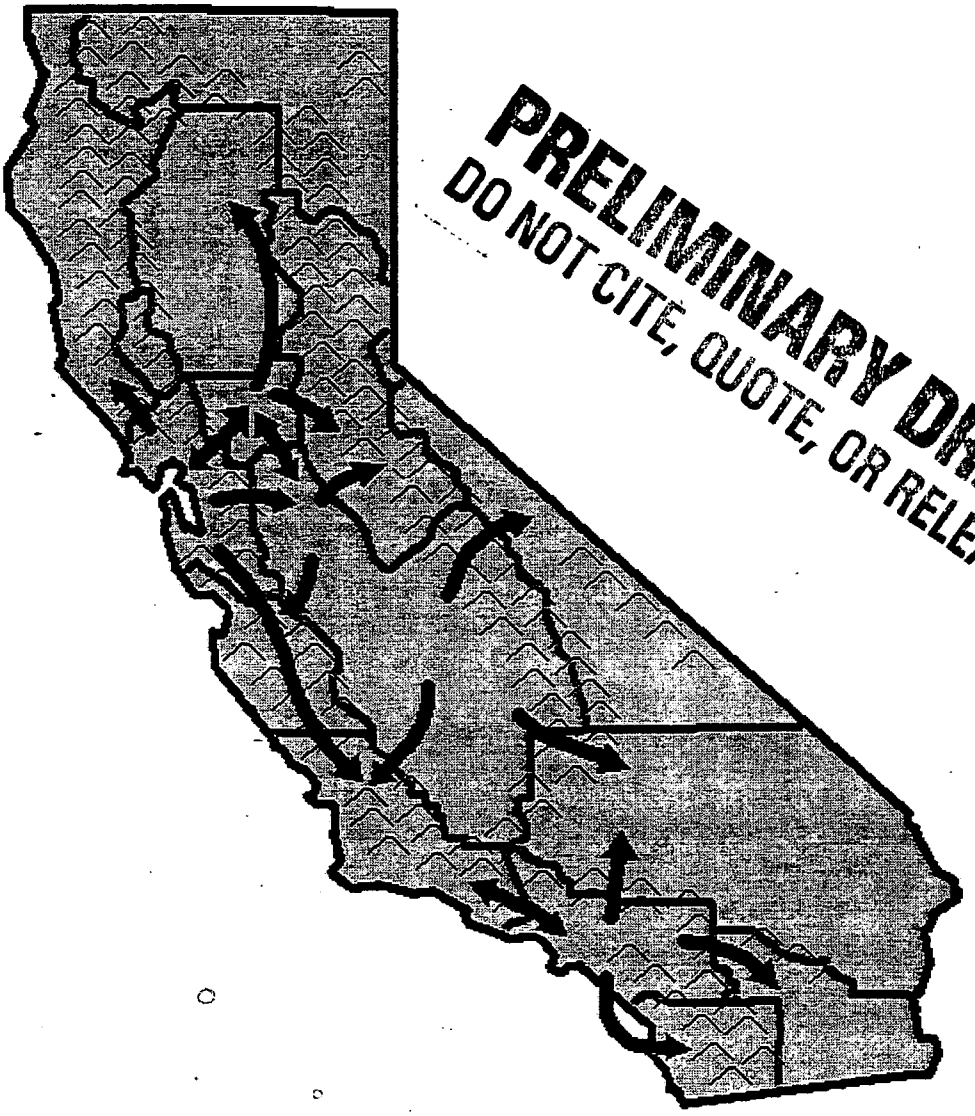
9002-86-2 POLYVINYL CHLORID
polyvinyl chloride, pastic
~~Compound 88998~~ no.

INFORMATION TYPE:		P F C	INFORMATION TYPE:		P F C	INFORMATION TYPE:		P F C
0201	ONCO (HUMAN)	01 02 04	0216	EPI/CLIN	01 02 04	0241	IMMUNO (ANIMAL)	01 02 04
0202	ONCO (ANIMAL)	01 02 04	0217	HUMAN EXPOS (PROD CONTAM)	01 02 04	0242	IMMUNO (HUMAN)	01 02 04
0203	CELL TRANS (IN VITRO)	01 02 04	0218	HUMAN EXPOS (ACCIDENTAL)	01 02 04	0243	CHEM/PHYS PROP	01 02 04
0204	MUTA (IN VITRO)	01 02 04	0219	HUMAN EXPOS (MONITORING)	01 02 04	0244	CLASTO (IN VITRO)	01 02 04
0205	MUTA (IN VIVO)	01 02 04	0220	ECO/AQUA TOX	01 02 04	0245	CLASTO (ANIMAL)	01 02 04
0206	REPRO/TERATO (HUMAN)	01 02 04	0221	ENV. OCCC/REL/FATE	01 02 04	0246	CLASTO (HUMAN)	01 02 04
0207	REPRO/TERATO (ANIMAL)	01 02 04	0222	EMER INCI OF ENV CONTAM	01 02 04	0247	DNA DAM/REPAIR	01 02 04
0208	NEURO (HUMAN)	01 02 04	0223	RESPONSE REQEST DELAY	01 02 04	0248	PROD/USE/PROC	01 02 04
0209	NEURO (ANIMAL)	01 02 04	0224	PROD/COMP/CHEM ID	01 02 04	0251	MSDS	01 02 04
0210	ACUTE TOX. (HUMAN)	01 02 04	0225	REPORTING RATIONALE	01 02 04	0299	OTHER	01 02 04
0211	CHR. TOX. (HUMAN)	01 02 04	0226	CONFIDENTIAL	01 02 04			
0212	ACUTE TOX. (ANIMAL)	01 02 04	0227	ALLERG (HUMAN)	01 02 04			
0213	SUB ACUTE TOX (ANIMAL)	01 02 04	0228	ALLERG (ANIMAL)	01 02 04			
0214	SUB CHRONIC TOX (ANIMAL)	01 02 04	0239	METAB/PHARMACO (ANIMAL)	01 02 04			
0215	CHRONIC TOX (ANIMAL)	01 02 04	0240	METAB/PHARMACO (HUMAN)	01 02 04			

TRIAGE DATA: NON-CBI INVENTORY	ONGOING REVIEW	SPECIES	TOXICOLOGICAL CONCERN:	USE:	PRODUCTION:
YES (CONTINUE)	YES (DROP/REFER)		LOW	Plastic	
NO (DROP)	NO (CONTINUE)		MED		
DETERMINE	REFER:		HIGH		

COMMENTS:

Ozone Transport:
2001 Review



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California Environmental Protection Agency

Air Resources Board

April 2001

State of California
California Environmental Protection Agency
Air Resources Board

Ozone Transport: 2001 Review

April 2001
Staff Report
For consideration on
April 26, 2001

Prepared by
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The energy challenge facing California is real. Every Californian needs to take immediate action to reduce energy consumption. For a list of simple ways you can reduce demand and cut your energy costs, see our Web-site at www.arb.ca.gov.

Contents

Introduction 1

How the ARB Assesses Transport 2

How Responsibility for Reducing Pollution is Shared 3

Transport Impacts in the Future 4

Regional Transport Assessments 9

Mojave Desert Air Basin 11
Kern County (eastern portion)
Los Angeles County (northern portion)
Riverside County (far eastern portion)
San Bernardino County (eastern portion)

Mountain Counties Air Basin 15
Amador County
Calaveras County
El Dorado County (middle portion)
Mariposa County
Nevada County
Placer County (middle portion)
Plumas County
Sierra County
Tuolumne County

North Central Coast Air Basin 19
Monterey County
San Benito County
Santa Cruz County

Sacramento Valley Air Basin

Broader Sacramento Area 23
El Dorado County (western portion)
Placer County (western portion)
Sacramento County
Solano County (eastern portion)
Sutter County (southern portion)
Yolo County

Upper Sacramento Valley 27
Butte County
Colusa County
Glenn County
Shasta County
Tehama County
Yuba County

Salton Sea Air Basin 31
Imperial County
Riverside County (Coachella Valley portion)

San Diego Air Basin 33

San Francisco Bay Area Air Basin 35
Alameda County
Contra Costa County
Marin County
Napa County
San Francisco County
San Mateo County
Santa Clara County
Solano County (western portion)
Sonoma County (southern portion)

San Joaquin Valley Air Basin 39
Fresno County
Kern County
Kings County
Madera County
Merced County
San Joaquin County
Stanislaus County
Tulare County

South Central Coast Air Basin 45
San Luis Obispo County
Santa Barbara County
Ventura County

South Coast Air Basin 49
Los Angeles County (non-desert portion)
Orange County
Riverside County (non-desert portion)
San Bernardino County (non-desert portion)

References 53

Introduction

State law gives the California Air Resources Board (ARB) the responsibility to assess how the movement of air pollutants from one air basin to another (referred to as "transport") impacts ozone concentrations. The movement of air pollutants between areas can increase the ozone levels in downwind areas. Over the last decade, ARB has done a series of technical assessments of transport relationships between air basins in California.

The analyses done over the last decade have given us a good understanding of pollutant transport statewide – including the fundamental transport relationships between air basins. We have learned that urbanized areas largely cause their own air pollution and reducing local emissions needs to be the cornerstone of their clean air efforts.

We have also learned that under certain weather conditions, these urban areas can transport pollution to their downwind neighbors or receive pollution from their upwind neighbors. The assessments show that most urbanized areas contribute to air pollution in neighboring air basins under certain weather conditions. These same urbanized areas may be transport recipients at other times. In order to meet health-based air quality standards under all weather conditions, emission reductions are needed in both upwind and downwind areas. At the same time, emission reductions from upwind areas do provide benefits to the extent that transport occurs.

These benefits are taken into account as areas prepare the air quality plans required by the California Clean Air Act and Federal Clean Air Act. The next round of ozone plans will be developed in 2003 to meet the requirements of the California Clean Air Act. These plans will update our current control strategies for achieving the State ozone standard.

From a statewide perspective, areas downwind of the Los Angeles region (South Coast Air Basin) are the most severely impacted by ozone transport. The magnitude of pollution transport from the South Coast Air Basin sometimes overwhelms the impact of local emissions in downwind desert areas and San Diego.

In other parts of California, transport impacts are more variable – mostly ranging from inconsequential to significant depending upon the weather. However, overwhelming transport also occurs in the Mountain Counties Air Basin, North Coast Air Basin, Upper Sacramento Valley, and the North Central Coast Air Basin under some circumstances. This report summarizes the nature of ozone transport for each area.

While this report focuses on ozone, the transport of fine particles or particle-forming pollutants is also of concern. Many of the emissions that contribute to high levels of ozone also contribute to high levels of particles in the air. As we continue our efforts to understand and reduce particle pollution, we will apply what we have learned from our ozone transport assessments.

How the ARB Assesses Transport

The ARB staff assesses transport impacts by first identifying "transport couples" which consist of an upwind area and a corresponding downwind area. These areas are generally defined using air basin boundaries. California is divided by the ARB into 15 air basins (see Figure 1) consistent with State law. Areas with similar geographic and meteorological conditions are within the same air basin. Air basins are often separated by geographic boundaries like mountain ranges. Transport does occur, however, through mountain passes and over geographic boundaries at higher altitudes (referred to as "aloft" transport).

Some air basins consist of a single, multi-county air district – such as the San Francisco Bay Area Air Quality Management District, the San Joaquin Valley Air Quality Management District, and the San Diego County Air Pollution Control District. Other air basins span more than one air district. An air district is the local governing body responsible for control emissions from industrial pollution sources and adoption of local air quality plans and rules. Figure 2 shows a map of the local air pollution districts.

The Sacramento Valley Air Basin is further subdivided into two planning areas: the Broader Sacramento Area (where the population is most concentrated) and the Upper Sacramento Valley (more rural in nature).

This report includes a transport summary for each air basin or transport area. The summary describes the area, its air quality problems, and the nature of transport into and out of the region. In addition to identifying upwind and downwind relationships between air basins, the ARB assesses the degree of impact. State law directs the ARB to determine if the contribution of transported pollution is overwhelming, significant, inconsequential, or some combination.

These three labels are applied according to whether violations of the ozone standard are predominantly caused by transport, local emissions, or a mixture of both. A transport couple can have more than one label, meaning that the degree of impact varies from day to day depending on weather conditions. For instance, if a transport couple is characterized as both "shared" and "local", it means that on some days violations are caused by a mixture of transported and local emissions, while on other days they are caused primarily by local emissions.

The identification and characterization of transport couples is based on detailed analyses of one or more specific days when the State ozone standard was violated. The assessments are based on modeling and analyses of meteorological data, ozone monitoring data, and emissions data. Certain extreme ozone concentrations are excluded from the analyses if they are the result of rare circumstances beyond reasonable regulatory control.

Pollutant transport is a complex phenomenon. Sometimes transport is a straightforward matter of wind blowing from one area to another at ground level, carrying ozone with it, but usually it is not that simple. Transport is three-dimensional; it can take place at the ground surface, or high above the ground. Meteorologists use the terms "surface" and "aloft" to distinguish these two cases.

Often winds can blow in different directions at different heights above the ground. For example, the surface wind may be blowing down a valley while the winds overhead, above the

surrounding hills, blow across the valley. To further complicate matters, winds can shift during the day, pushing a polluted air mass first one way, then another. To accurately determine the impacts of pollution transported from a source area upon ozone concentrations in a downwind area requires detailed scientific analyses and modeling studies.

Transport may have a significant impact on other pollutants such as fine particles. Although ozone and fine particles derive largely from similar pollution sources, ozone is primarily a summer problem while fine particles are usually more of a winter problem. Since wind patterns are different from season to season, the transport relationships may be different for ozone and fine particles. Transport of fine particles and their precursors is a subject of ongoing research.

The relative impact of transport can change over time. Economic and population growth, the benefits of air quality programs, and changes in regional climate can all act to increase or decrease one region's transport impact upon another. Furthermore, new monitoring, higher resolution data and improved air quality models can shed new light on transport impacts. The ARB will continue to assess transport impacts as new information becomes available.

How Responsibility for Reducing Pollution is Shared

Under the California Clean Air Act, when emissions from one region contribute to ozone violations in a downwind area, the upwind area shares responsibility for controlling those emission sources. The State and Federal government also share in this responsibility for reducing emissions. The ARB's State Clean Air Plan targets statewide sources, such as fuels, consumer products, and motor vehicles. This plan provides emission reductions in all upwind and downwind areas. Federal measures are also necessary to address sources such as interstate trucks and federally preempted emissions sources. The ARB is now developing an updated 2001 Clean Air Plan.

The next round of ozone plans for most of the State will be developed in 2003 to meet the requirements of the California Clean Air Act. To support this significant effort, the ARB will be updating its prior planning guidance next year to reflect current circumstances and available technical data. A critical element of this guidance will define how transport should be considered in determining the appropriate mix of State, upwind, and local control programs to attain in each region. We expect to use the same transport approach for future plans to meet the Federal eight-hour ozone standard.

The clean air plans will reflect our best understanding of pollution transport to ensure all areas of the State reach attainment. The ARB will define the core State and Federal measures that each region can rely on. All regions that continue to violate health-based standards (see Figure 3) will need to assess and reduce the local emissions contribution.

Rural areas that are dominated by an upwind area should ensure the local area has a strong and effective program to address growth and prevent degradation of air quality. Upwind areas must address their share of responsibility for ozone levels in downwind areas; the ARB will work with the upwind and downwind areas to determine how to achieve any additional reductions needed for attainment in each region.

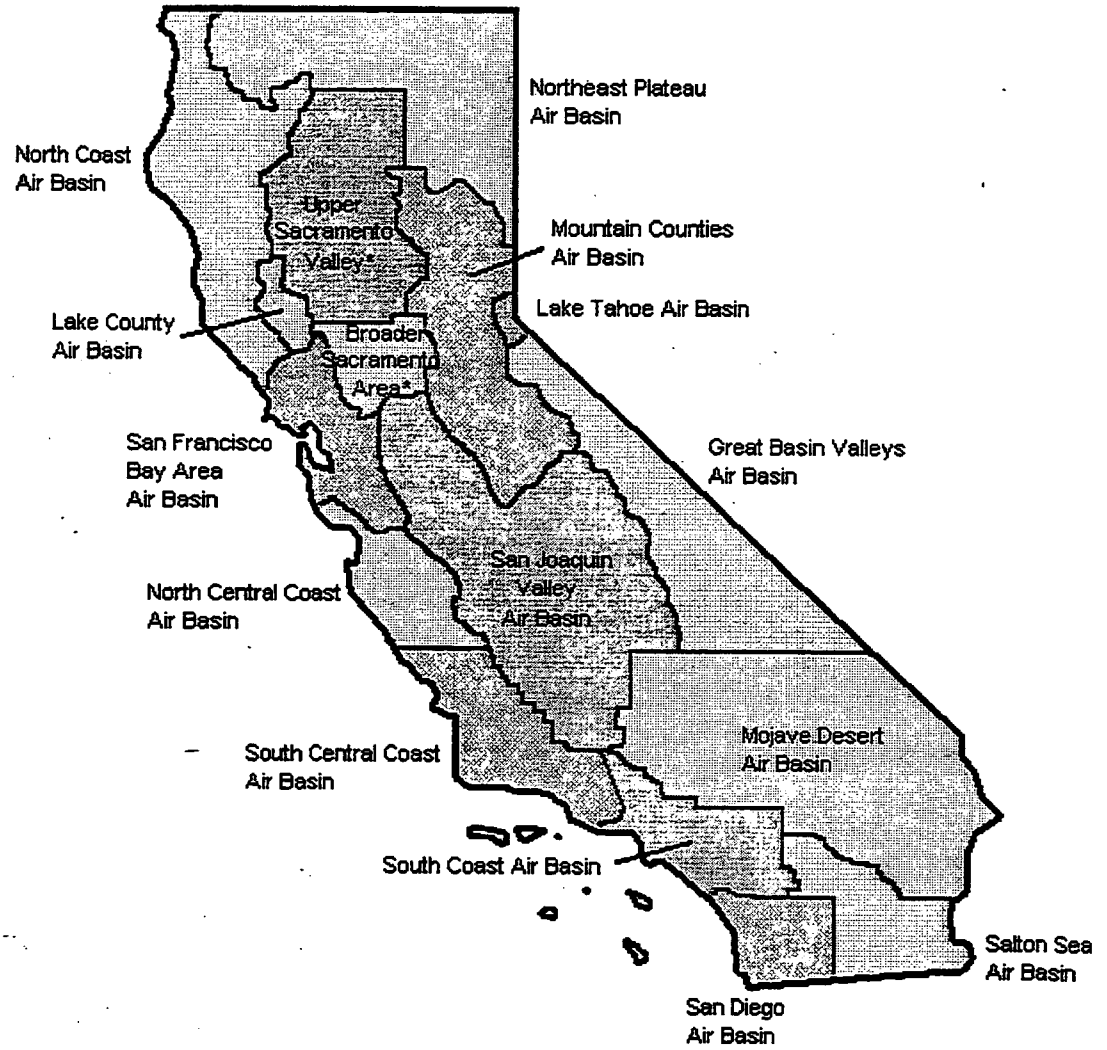
In the last several years, major field studies have been performed in Northern/Central and Southern California (see Figure 4). We will use the results from these field studies to develop

regional modeling tools that reflect a more refined understanding of ozone formation and transport. These regional models, combined with our transport assessments, will be used in preparing upcoming clean air plans. The tools will be used to project the level of control need to attain the standard and assess the benefits of existing and new control strategies.

Transport Impacts in the Future

As California's population continues to grow, traditionally rural areas are becoming more urbanized, and are generating more emissions. As this occurs, local emissions will become more significant in areas whose air quality has historically been dominated by transport from outside. Large urban areas are already required to implement stringent emission-reduction measures to improve their air quality. Newly emerging urban areas will need to take similar measures to maintain good air quality in the face of population and economic growth.

Figure 1. California Air Basins*



* *The Broader Sacramento Planning Area and the Upper Sacramento Valley planning areas together make up the Sacramento Valley Air Basin. The Sacramento Valley Air Basin has been split into two planning areas.*

Figure 2. California Air Pollution Districts

Figure 3. State Ozone Standard Attainment Status

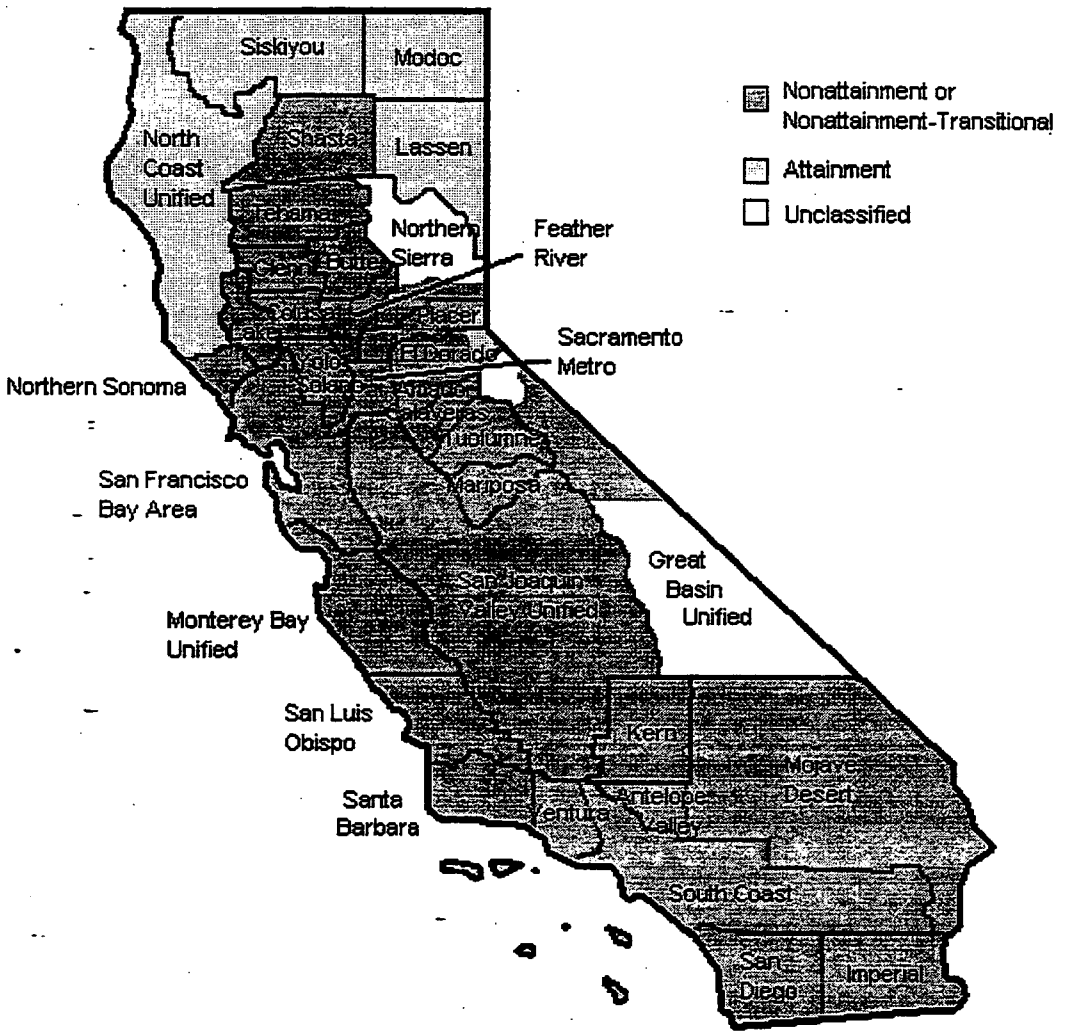
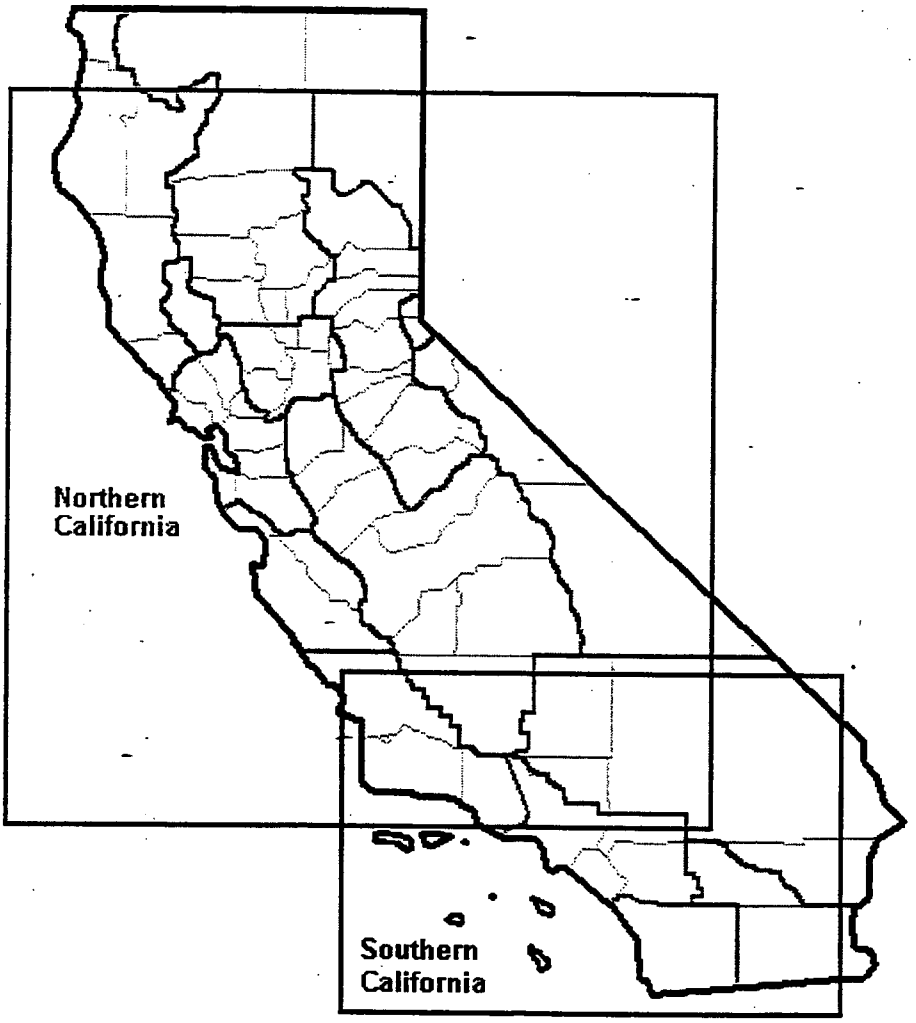


Figure 4. The Northern California and Southern California Modeling Domains

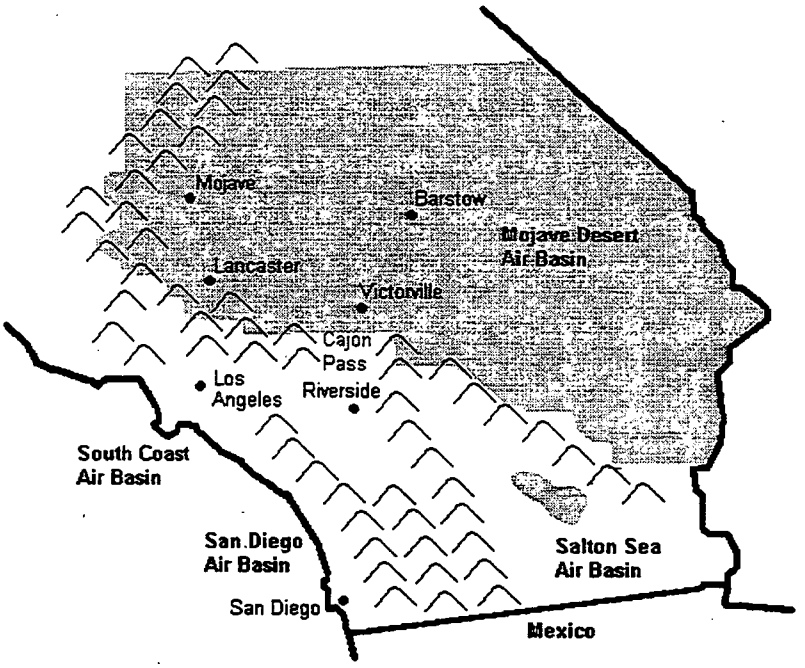


Regional Transport Summaries

The following sections summarize our knowledge of transport in the major regions of California. Not all regions have their own sections: the North Coast and Great Basin Valleys are discussed briefly in the sections on the San Francisco Bay Area and the San Joaquin Valley, respectively. Northeast Plateau (Lassen, Modoc, and Siskiyou counties), Lake County, and the Lake Tahoe Air Basin attain the State ozone standard, and are therefore not included in the discussion.

For each region, we describe the area and its current air quality status, and characterize its transport relationships with other areas. We also include a table of some important statistics compared to statewide totals, and tables summarizing its transport relationships.

Mojave Desert Air Basin



The Mojave Desert Air Basin violates both State and Federal ozone standards. Continued reductions in air pollutant emissions are needed in order to meet the 2007 deadline for attainment of the Federal one-hour standard, and make progress towards the State standard. Although the air basin is impacted by emissions from the San Joaquin Valley and the South Coast, on some days local emissions alone are primarily responsible for poor air quality. The air basin's population is substantial and growing. As air quality continues to improve in the South Coast, local emissions from the Mojave Desert Air Basin will become a more significant factor in its air quality.

Area Description

The Mojave Desert Air Basin covers a large part of the California's high desert. It includes the eastern half of Kern County, the northern part of Los Angeles County, most of San Bernardino County except for the southwest corner, and the eastern edge of Riverside County. It is separated from the South Coast Air Basin, to its south, by the San Gabriel and San Bernardino Mountains. It is separated from the San Joaquin Valley, to the northwest, by the Tehachapi Mountains and the south end of the Sierra Nevada. The Antelope Valley APCD, the Kern County APCD, and the Mojave Desert AQMD manage distinct portions of the air basin.

Although the eastern part of the basin is sparsely populated, the area just north of the San Gabriel and San Bernardino Mountains supports a large population. The Lancaster-Palmdale area has a population of over 250,000, while the Victorville-Hesperia-Apple Valley area has over 180,000. Apart from these urban areas the largest is Barstow with approximately 23,000. Military bases, highways and railroad facilities, cement manufacturing and mineral processing contribute to the region's ozone precursor emissions.

Transport Characterization

The portion of the Mojave Desert immediately to the north of the San Gabriel and San Bernardino Mountains is heavily impacted by transport from the South Coast. Air monitoring stations at Hesperia and Phelan show the impact of surface transport through the Cajon Pass.

In addition, transport aloft carries pollutants over the mountains to impact a broad area including Twentynine Palms and Lancaster-Palmdale. Despite the importance of transport from the South Coast, previous analyses have demonstrated that local emissions play a significant role in causing ozone violations in this area.

The air basin receives pollutants from the San Joaquin Valley as well. The area immediately downwind of Tehachapi Pass receives pollutants from the southern San Joaquin Valley. Violations in the town of Mojave in the eastern portion of Kern County are attributed entirely to this transport. The influence of pollutants from the San Joaquin Valley extends as far as Lancaster.

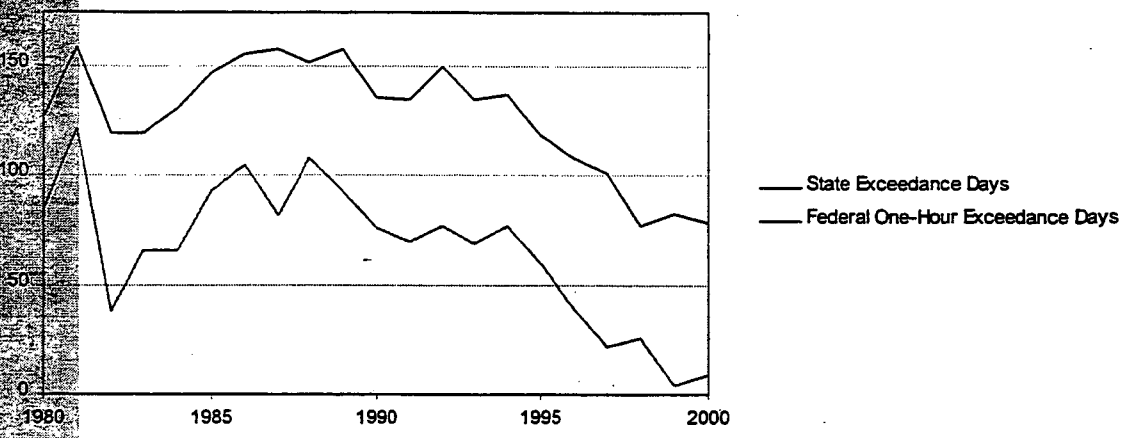
Mojave Desert Air Basin Facts

		Percent of State total
Estimated 2000 Population	860,000	2%
Vehicle Miles Traveled	26 million miles/day	3%
Est. 2000 NOx Emissions	220 tons/day	6%
Est. 2000 ROG Emissions	84 tons/day	3%

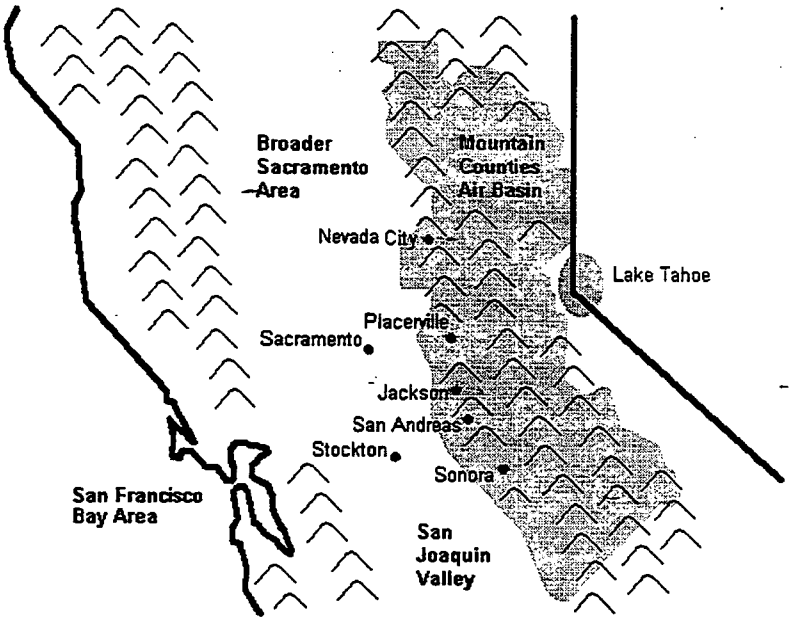
Other areas' impact on the Mojave Desert Air Basin

Area	*Day Specific Findings*
San Joaquin Valley	Overwhelming
South Coast	Overwhelming Significant

Mojave Desert Air Basin
Ozone Exceedance Trends



Mountain Counties Air Basin



The Mountain Counties Air Basin violates the State ozone standard due to transport from the Sacramento Valley, the San Joaquin Valley and the San Francisco Bay Area. The region attains the Federal one-hour standard, except for the western portions of El Dorado and Placer counties which are part of the Sacramento Federal nonattainment area. Because the region's ozone violations are the result of transport, the Mountain Counties' air quality planning process was not triggered by the California Clean Air Act. Instead the region is relying principally on emission reductions from the upwind areas. However, in the future, local pollution emissions are expected to contribute significantly to ozone concentrations as the population continues to grow.

Area Description

The Mountain Counties Air Basin covers the central and northern parts of the Sierra Nevada, from Plumas County in the north to Mariposa County in the south. The basin comprises all or portions of seven air quality control districts: the Northern Sierra AQMD, and the Placer, El Dorado, Amador, Calaveras, Tuolumne and Mariposa County APCDs. The air basin is thinly populated, its communities separated from one another by the basin's complex terrain.

Logging and mining, historically the economic basis of Sierra Nevada communities, have given way to tourism and recreational activities in recent years. A substantial number of people living in the air basin commute to jobs in the Central Valley. The largest source of pollutant emissions is motor vehicles. Vehicles travelling on transportation corridors such as Highway 50 and Interstate 80 account for a significant portion of motor vehicle emissions.

Transport Characterization

Topographically, the basin consists largely of a succession of east-west canyons and intervening ridges. The elevation ranges from several hundred feet in the foothills near the Central Valley, to over 10,000 feet at the crest of the Sierra. Surface winds are generally restricted to flowing in an east-west direction, uphill during the day and downhill at night. Pollutant transport is predominantly from the Central Valley up the canyons during the day, then back down at night.

Because much more pollution is emitted in the large urban areas of the Central Valley and San Francisco Bay Area than in the sparsely populated Sierra Nevada, pollutants transported from those urban areas have a dominant effect on ozone concentrations in the Mountain Counties. All State ozone violations have been attributed to transport from the Broader Sacramento Area, the San Joaquin Valley and the San Francisco Bay Area.

The Mountain Counties regularly experiences violation of the State ozone standard. The northern and central parts of the region (Grass Valley, Placerville, Jackson, and San Andreas) can receive pollutants from the Broader Sacramento Area, the Bay Area, or the San Joaquin Valley, or a combination of areas depending on the weather. For the southern part of the region (Sonora and Yosemite National Park), the primary source of pollutants is the San Joaquin Valley. On other days, the San Joaquin Valley and the San Francisco Bay Area contribute to the violations.

Today, ozone violations in the Mountain Counties are caused entirely by emissions from the San Joaquin Valley, the San Francisco Bay Area and the Broader Sacramento Area. However, in the future, local pollutant emissions are expected to contribute significantly to ozone concentrations in the Mountain Counties as population continues to grow. Moreover, the region has a close economic relationship with the Central Valley and San Francisco Bay Area. People from the region commute to work in the cities, and people from the cities travel to and from the mountains for recreational activities.

This transportation activity contributes to ozone problems both in the Mountain Counties and in the more heavily populated areas. The region can contribute to needed reductions in pollutant levels and offset the impacts of growth by implementing all cost-effective and technologically feasible measures. For more urban or industrial areas of the region, such as El Dorado and Placer Counties, local emission reductions are critical to attaining health-based standards.

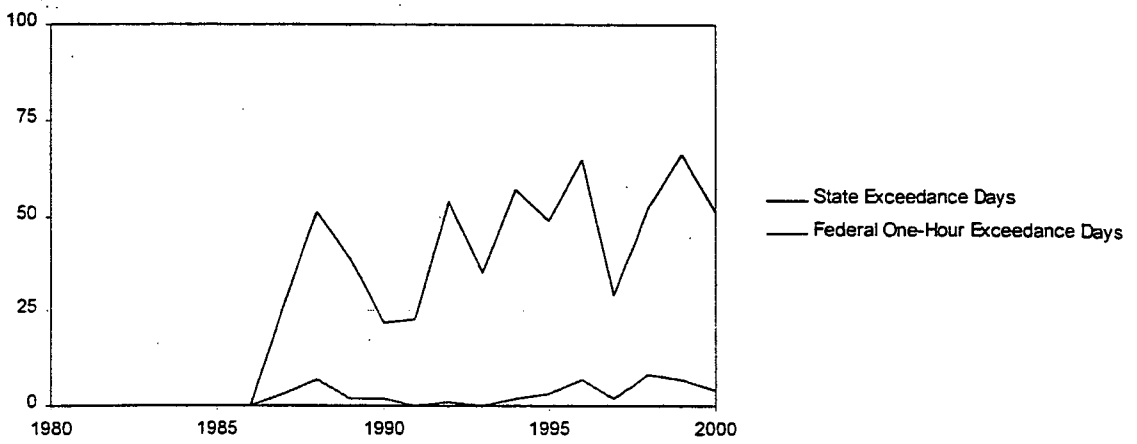
Mountain Counties Air Basin Facts

		Percent of State total
Estimated 2000 Population	424,000	1%
Vehicle Miles Traveled	12.3 million miles/day	2%
Est. 2000 NOx Emissions	62 tons/day	2%
Est. 2000 ROG Emissions	106 tons/day	3%

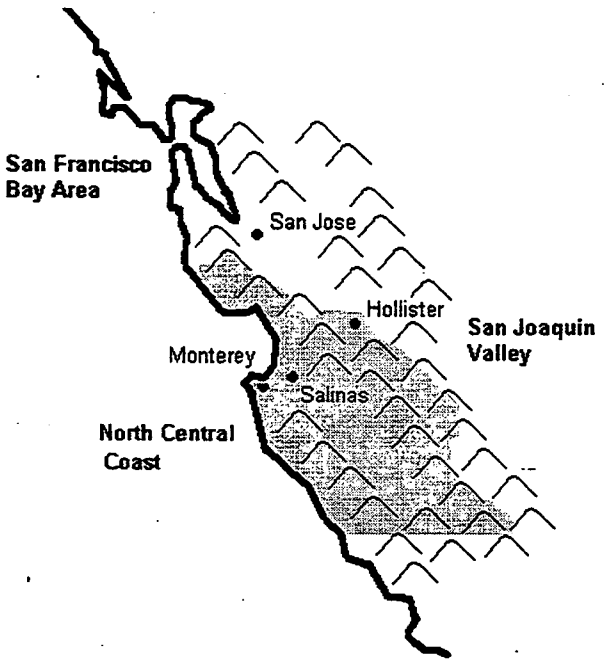
Other areas' impact on the Mountain Counties Air Basin

Area	*Day Specific Findings*
Broader Sacramento Area	Overwhelming
San Joaquin Valley	Overwhelming
San Francisco Bay Area	Significant

Mountain Counties Air Basin
Ozone Exceedance Trends



North Central Coast Air Basin



The North Central Coast Air Basin continues to violate the State ozone standard at a few locations. The region now attains the Federal one-hour standard. Although most exceedances are caused by transport, the area's growing population could begin to cause more local exceedances unless there are continued local efforts to reduce emissions from local sources. While improved air quality in the North Central Coast area relies on emission reductions in upwind areas, local measures are needed to help offset the emissions from growth and to assure attainment and maintenance of all health-based standards.

Area Description

The North Central Coast Air Basin consists of Santa Cruz, San Benito and Monterey Counties, and is synonymous with the Monterey Bay Unified Air Quality Management District. The largest population centers are Santa Cruz, Salinas, and Monterey and its surrounding communities. The estimated 2000 population of the region is roughly 700,000.

The largest urban area in the air basin is Salinas, with a population of 130,000, followed by the Monterey area, with a population of roughly 100,000. The region has significant sources of ozone precursors in the form of a large cement plant at Davenport, the Moss Landing power plant, agricultural activities, and Highway 101.

While emissions from urban areas in the region contribute to ozone violations in Hollister, its air quality is dominated by pollutants transported from the San Francisco Bay Area. The air basin adjoins the San Francisco Bay Area to the north but is physically separated by the Santa Cruz Mountains and the coast ranges. However, the valley of the San Benito River, where Hollister is situated, forms a southern extension of the Santa Clara Valley. The region is also

adjacent to the San Joaquin Valley Air Basin, separated by the Diablo Range with gaps such as the Pacheco Pass.

Transport Characterization

The North Central Coast Air Basin enjoys relatively clean air, experiencing only several exceedances of the State ozone standard per year. All of these exceedances have a transport contribution. The amount of transport can vary from significant to overwhelming and the source of the emissions can vary depending on the day.

The region can receive surface transport from the Bay Area which impacts Hollister and Scotts Valley. Violations at Scotts Valley, on the Highway 17 corridor in the mountains north of Santa Cruz, are mainly due to surface transport from the San Jose area, while transport aloft from the Bay Area can impact Pinnacles National Monument in the mountains south of Hollister. Transport aloft from the northern San Joaquin Valley mixed with pollutants from the Bay Area infrequently impacts Hollister's air quality as well.

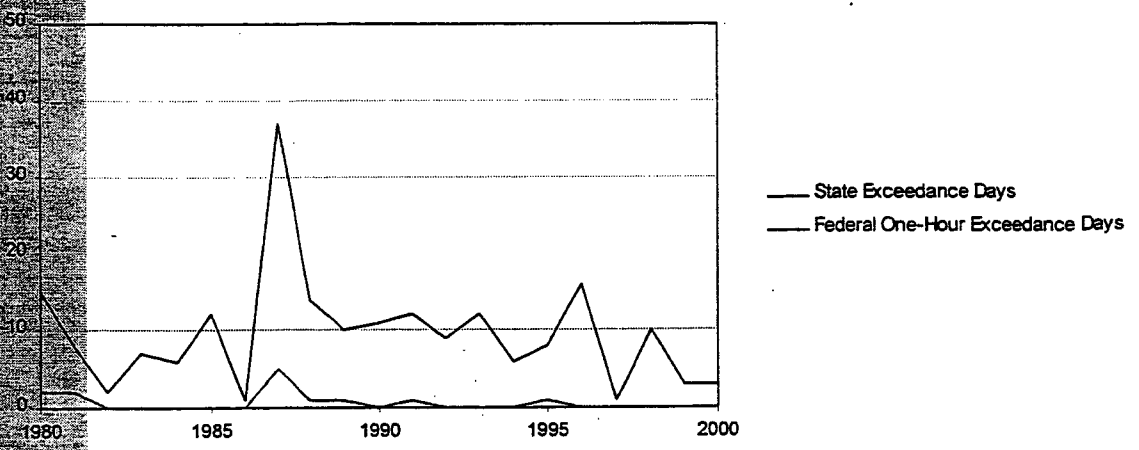
North Central Coast Air Basin Facts

		Percent of State total
Estimated 2000 Population	714,000	2%
Vehicle Miles Traveled	16.6 million miles/day	2%
Est. 2000 NOx Emissions	78 tons/day	2%
Est. 2000 ROG Emissions	79 tons/day	2%

Other areas' impact on the North Central Coast Air Basin

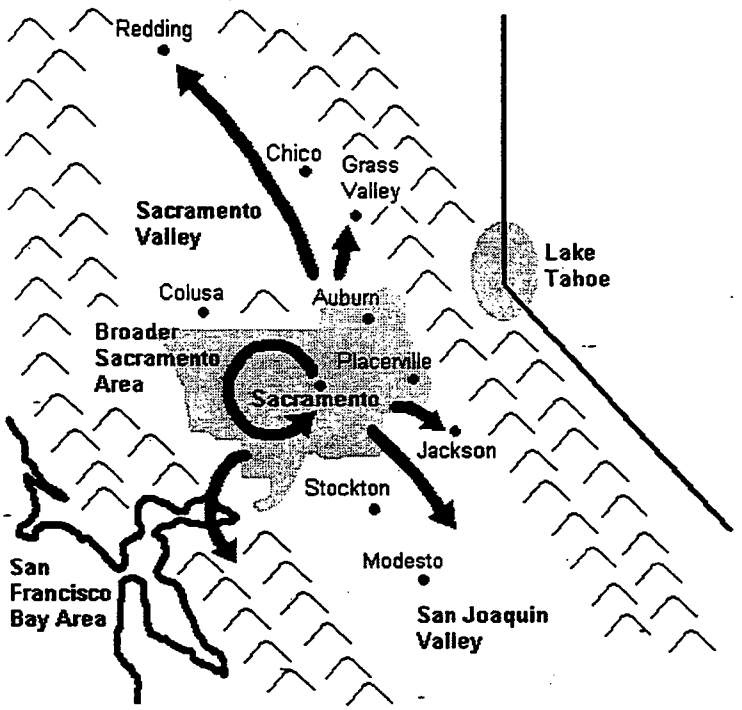
Area	*Day Specific Findings*
San Joaquin Valley	Significant
San Francisco Bay Area	Overwhelming Significant

North Central Coast Air Basin
Ozone Exceedance Trends



Sacramento Valley Air Basin:

Broader Sacramento Area



The Broader Sacramento Area continues to violate the State and Federal air quality standards for ozone. Although the air quality in the area is impacted to some degree by transport, the emissions from within the region are responsible for some of the region's smoggiest days. Continued reductions of pollutant emissions are needed in order to meet the 2005 deadline for attainment of the Federal one-hour ozone standard and make progress towards attaining the State standard.

Area Description

The Broader Sacramento Area encompasses the city of Sacramento and surrounding areas. It includes all of Sacramento and Yolo Counties, the southern part of Sutter County, the western portion of Placer and El Dorado counties, and the eastern part of Solano County. Distinct portions of the BSA are administered by the Sacramento Metropolitan AQMD, the Yolo-Solano AQMD, the Feather River AQMD, and the Placer and El Dorado County APCDs. The cities of Davis, Woodland, Rocklin, Auburn, and Placerville, among others, all lie within this region.

Geographically, the Broader Sacramento Area occupies the southern part of the Sacramento Valley. East-west, it extends from the foothills of the Coastal Range to the foothills of the Sierra Nevada. These mountain ranges form natural barriers to air movement. North-south, the area extends from the southern part of Sutter and Placer Counties to the Sacramento River delta. There are no significant barriers to north-south air movement in the Sacramento-San Joaquin Valley. The Sutter Buttes, to the north, are not wide enough to present a major obstacle to airflow into the northern Sacramento Valley.

Motor vehicles are by far the largest source of ozone precursor emissions in the area. Between 1980 and 2000, the number of vehicle miles traveled doubled. However, the increase in vehicle usage was offset by increasingly stringent motor vehicle emission controls and cleaner burning gasoline. The peak ozone concentration and number of violation days in the area have decreased slightly during the last decade, but progress has been slower than in some other parts of the State such as the South Coast.

Transport Characterization

On most summer mornings, the so-called "delta breeze" blows from the Carquinez Strait northeast towards Sacramento. Reaching Sacramento, the delta breeze turns northward and continues into the northern Sacramento Valley and the foothills of the northern Sierra Nevada. Transport from the Broader Sacramento Area into the Upper Sacramento Valley has been documented repeatedly over the last two decades.

Transport from the Broader Sacramento Area dominates the air quality in the Upper Sacramento Valley, as far north as Butte and Tehama County. However, violations in Shasta County, at the northern end of the Sacramento Valley, are occasionally entirely due to local emissions, sometimes entirely due to transport, and sometimes a mixture of both.

Another characteristic wind pattern of the southern Sacramento Valley is a counterclockwise circular eddy which carries pollutants from Sacramento to the northwest, then south to Woodland and Davis, then eastward, back to Sacramento. This circulation carries ozone and precursors from Sacramento to Colusa and Arbuckle in the Upper Sacramento Valley.

On some summer days, winds sweep down the Sacramento Valley from the north. This wind carries pollutants into the northern San Joaquin Valley, where they impact communities such as Stockton, Turlock and Modesto. Because it is located downwind of both the Broader Sacramento Area and the San Francisco Bay Area, the northern San Joaquin Valley is subject to a complex mixture of influences.

Infrequently, a north wind blowing through the Broader Sacramento Area can turn westward and carry pollutants to the eastern part of the San Francisco Bay Area. Under such conditions, violations at Fairfield and Pittsburg can be significantly impacted by pollutants transported from the Broader Sacramento Area. This influence is confined to the Sacramento-San Joaquin River delta. Violations at Livermore, Fremont, Hayward and San Jose on the same days are not affected by transport from the Broader Sacramento Area.

On days when the north wind carries pollutants from the Broader Sacramento Area into the northern San Joaquin Valley, afternoon breezes from the west may then push polluted air from the valley into the Sierra Nevada foothills. Under these conditions foothill communities such as

San Andreas, in Calaveras County, and Jackson, in Amador County, can be impacted by Broader Sacramento Area emissions. On such days, the transport contribution is usually shared between the BSA, the northern San Joaquin Valley and the San Francisco Bay Area.

In the northern Sierra Nevada foothills, Grass Valley, in Nevada County, and Colfax, in Placer County, have violated the State ozone standard almost every summer for the last decade. These violations are considered to be entirely due to transport from the Broader Sacramento Area.

Air quality in the Broader Sacramento Area is impacted to some degree by transport from the San Francisco Bay Area and, infrequently, from the San Joaquin Valley. On some days when the State standard is violated, the Sacramento area is impacted by transport of pollutants from the Bay Area. This occurs when there is a slight to moderate delta breeze in the morning which can carry commute hour emissions into the Sacramento area to mix with local emissions and react with the summer sun to produce ozone. This meteorological scenario typically leads to peak daily ozone concentrations above the State ozone standard of 0.09 but below the Federal one-hour standard of 0.12 ppm.

However, on very hot summer days when the temperature in Sacramento climbs into the high 90's and above, stagnant wind conditions allow a buildup of local emissions, and the ozone concentration can violate the both the State and Federal standards. Only when a strong evening delta breeze disperses these accumulated pollutants does the ozone concentration decrease.

Broader Sacramento Area Facts

		Percent of State total
Estimated 2000 Population	1.8 million	5%
Vehicle Miles Traveled	45 million miles/day	6%
Est. 2000 NOx Emissions	184 tons/day	6%
Est. 2000 ROG Emissions	185 tons/day	5%

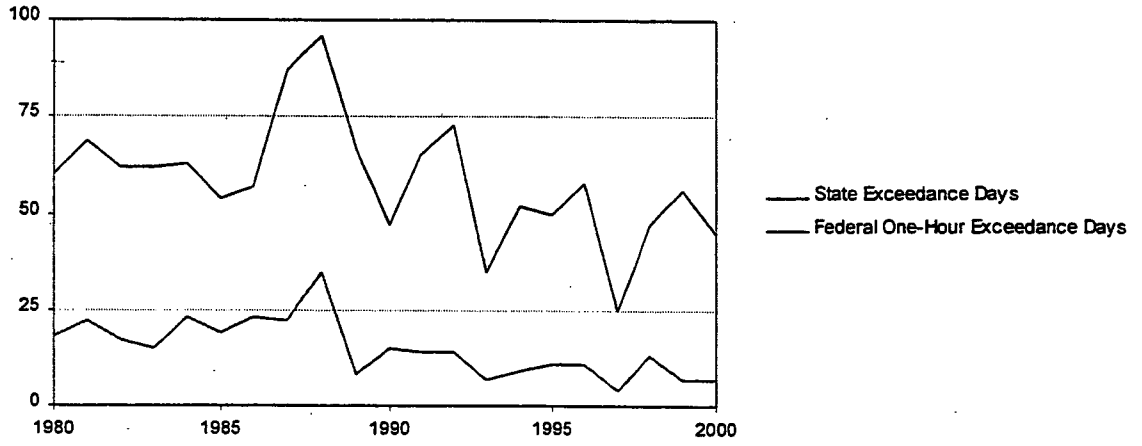
The Broader Sacramento Area's impact on other areas

Area	*Day Specific Findings*
Mountain Counties	Overwhelming
San Joaquin Valley	Significant Inconsequential
San Francisco Bay Area	Significant Inconsequential
Upper Sacramento Valley	Overwhelming Significant Inconsequential

Other areas' impact on the Broader Sacramento Area

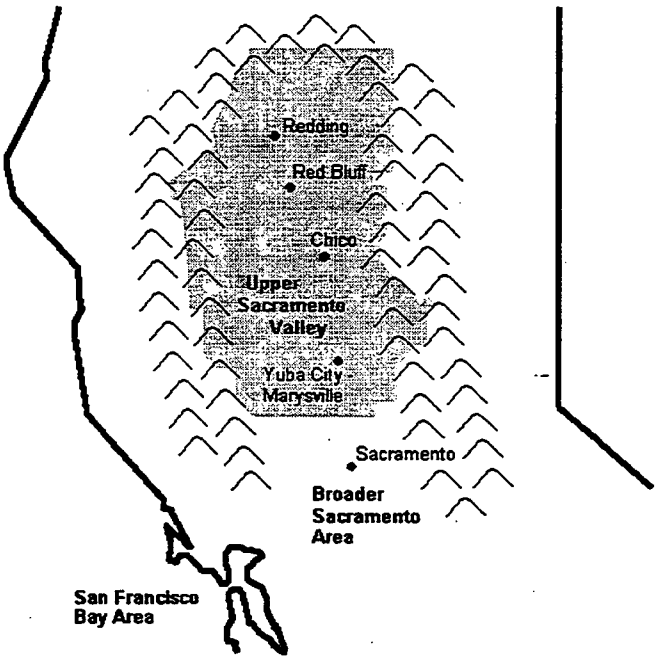
Area	*Day Specific Findings*
San Francisco Bay Area	Overwhelming Significant Inconsequential
San Joaquin Valley	Significant Inconsequential

Broader Sacramento Area
Ozone Exceedance Trends



Sacramento Valley Air Basin:

Upper Sacramento Valley



The Upper Sacramento Valley continues to violate the State ozone standard. The region attains the Federal one-hour ozone standard. Most of the State ozone exceedances are caused by the transport of pollutants from the Sacramento urban area. Although the region is primarily rural, the population and vehicle miles traveled are growing, and many sources contribute emissions. The Upper Sacramento Valley counties can achieve needed reductions in pollutant levels and offset the impacts of growth by implementing all cost-effective and technologically feasible measures. For more urban or industrial areas such as Redding in Shasta County, local emission reductions are critical to attaining health-based standards.

Area Description

The Upper Sacramento Valley comprises the seven northern counties in the Sacramento Valley Air Basin, from Sutter and Colusa counties northward to Shasta County. Its largest population centers are Redding, Chico, and Yuba City-Marysville. Smaller towns are scattered throughout the region, mostly on major transportation corridors such as Interstate 5.

Redding, the seat of Shasta County, lies approximately 150 miles north of Sacramento. While Redding is influenced by transport from Sacramento, Shasta County is also a significant source of pollutant emissions in its own right. With an estimated 2000 population of roughly 176,000, Shasta County has substantial motor vehicle emissions. Shasta County also contains numerous industrial facilities, including wood and paper processing plants, cement plants, and power

generating facilities. Three of the four largest oxides of nitrogen sources in the Sacramento Valley are located within Shasta County.

Transport Characterization

Topographical and meteorological conditions in Shasta County contribute to its local ozone problem. Bowl-shaped local topography tends to trap pollutants at the north end of the valley. Winds in the region sometimes blow simultaneously from opposite directions, southward from the Cascade Mountains and northward from the Broader Sacramento Area, to meet in the northern Sacramento Valley.

When this takes place, the winds usually meet south of Shasta County, meteorologically isolating Shasta County from the southern valley. When ozone violations occur under these conditions, as they did on two occasions in August 1998, they are entirely due to local emissions. In addition to contributing to high local ozone concentrations, it is possible that pollutants from the Redding area may contribute to ozone formation in neighboring counties to the south under such conditions.

Air quality in the portion of the region south of Chico is strongly influenced by transport from the Broader Sacramento Area. Much of the region is sparsely populated. When the occasional ozone violation takes place it is considered to be largely the result of transport from the Broader Sacramento Area.

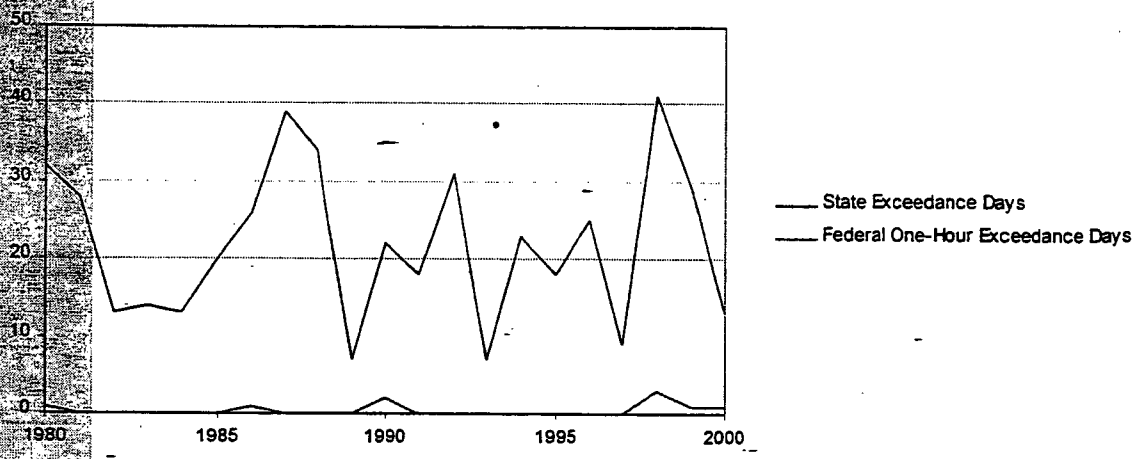
Upper Sacramento Valley Facts

		Percent of State total
Estimated 2000 Population	630,000	2%
Vehicle Miles Traveled	18.5 million miles/day	2%
Est. 2000 NOx Emissions	108 tons/day	3%
Est. 2000 ROG Emissions	116 tons/day	4%

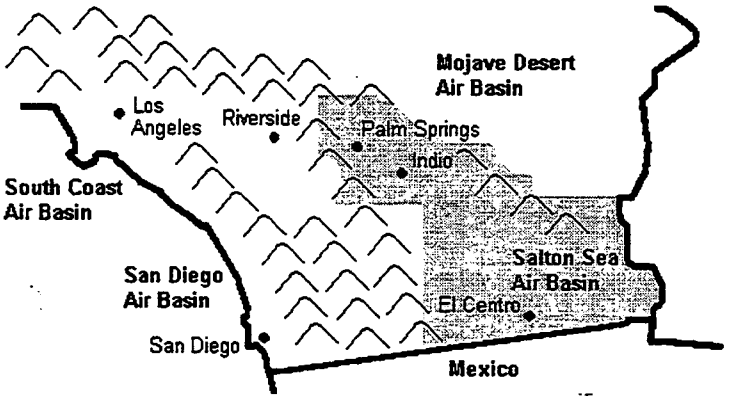
Other areas' impact on the Upper Sacramento Valley

Area	*Day Specific Findings*
Broader Sacramento Area	Overwhelming Significant Inconsequential

Upper Sacramento Valley
Ozone Exceedance Trends



Salton Sea Air Basin



The air quality in the Salton Sea Air Basin is strongly impacted by the South Coast, and by Mexico communities to the south. The region violates the State and both the Federal one-hour and eight-hour ozone standards. All of these exceedances are partly caused by transport. However, the local population of almost one-half million people also contributes to local exceedances. Cities in the Coachella Valley are experiencing some of most rapid population growth rates in the State. As a result, local controls are important in planning for improved air quality in this region.

Area Description

The Salton Sea Air Basin occupies the southeast corner of the State, east of the South Coast and San Diego Air Basins and south of the Mojave Desert. Most of the population resides in the Coachella Valley, which runs northwest-southeast from San Gorgonio Pass to the Salton Sea, and in the Imperial Valley, south of the Salton Sea. There are no large cities in the region, but modest-sized communities are scattered through the Coachella and Imperial Valleys. These include Palm Springs, Indio, El Centro, and Calexico. Local sources of ozone precursor emissions include motor vehicles and agricultural equipment.

Transport Characterization

The mouth of the Coachella Valley, at San Gorgonio Pass, is one of the major outlets for air pollution from the South Coast. Prevailing winds blow pollutants from the South Coast into the Coachella Valley on most days in summer. Ozone violations in the Coachella Valley are predominantly due to this transport. Pollutants from the South Coast occasionally penetrate as far as the Imperial Valley to contribute to ozone violations there, but local sources of ozone precursors also contribute.

In addition, the city of Mexicali lies just across the U.S. - Mexico border from Calexico. Mexicali's population of 750,000 far outnumbers that of Calexico, and Mexicali's emissions sometimes overwhelmingly impact air quality in Calexico.

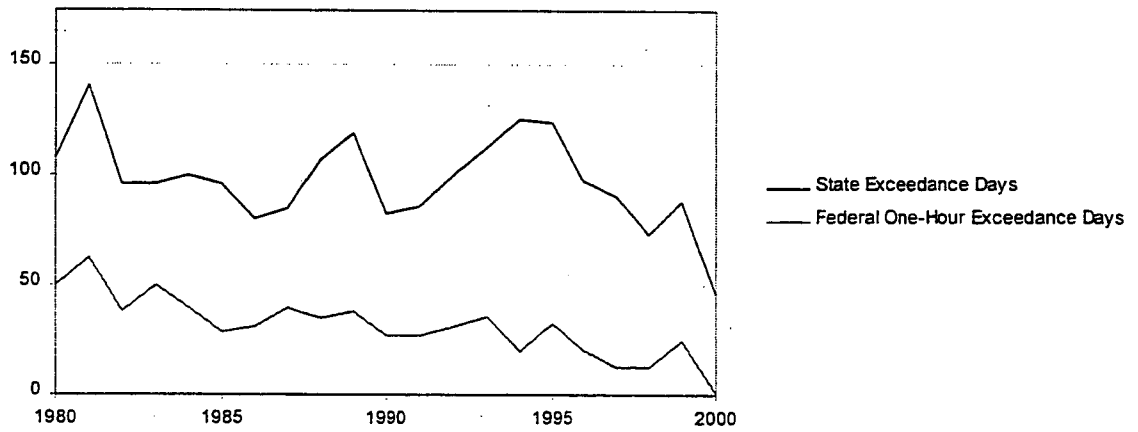
Salton Sea Air Basin Facts

		Percent of State total
Estimated 2000 Population	460,000	1%
Vehicle Miles Traveled	21.1 million miles/day	3%
Est. 2000 NOx Emissions	62 tons/day	2%
Est. 2000 ROG Emissions	52 tons/day	1%

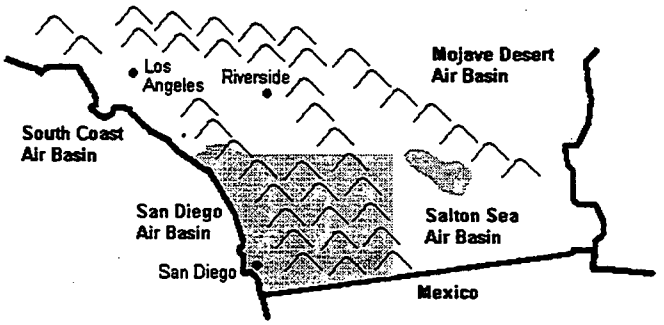
Other areas' impact on the Salton Sea Air Basin

Area	*Day Specific Findings*
Mexico	Overwhelming Significant
South Coast	Overwhelming Significant

Salton Sea Air Basin
Ozone Exceedance Trends



San Diego Air Basin



The San Diego Air Basin continues to violate the State ozone standard. The air basin is impacted by emissions from the South Coast and Mexico, but local emissions play a significant role in air quality. On some days, local emissions are solely responsible for violations of the State ozone standard. Although the San Diego Air Basin has not exceeded the Federal 1-hour ozone standard since 1998, as a large urban area, San Diego must reduce its emissions in order to maintain the Federal one-hour standard and to attain the State Standard.

Area Description

San Diego and its environs constitute the third largest urbanized area in the State after the South Coast and the San Francisco Bay Area. The county of San Diego has roughly 2.9 million inhabitants. Located on the coast 100 miles south of Los Angeles, San Diego is home to numerous industrial and transportation facilities, military installations, an international airport and a shipping port.

The city of San Diego is situated on a hilly coastal plain roughly 15 miles wide, bounded on the east by the peninsular ranges. The southern part of the urban area borders Mexico.

Transport Characterization

San Diego has also been shown to be impacted by transport from the South Coast. However, given its large population, numerous stationary sources, its climate, and its topography, San Diego County emissions can also result in local ozone violations. Prevailing daytime winds tend to carry pollutants from San Diego and El Cajon toward the east. Thus, some of the violations at Alpine, in the mountains east of San Diego, can be caused by emissions from within San Diego County.

Tijuana, a city of 1.2 million people, lies immediately across the border, forming essentially one continuous urban area with San Diego. The air above the two cities is one single mass;

emissions from Tijuana have been demonstrated to impact air quality in San Diego, and San Diego's emissions can have an impact upon Tijuana's air quality.

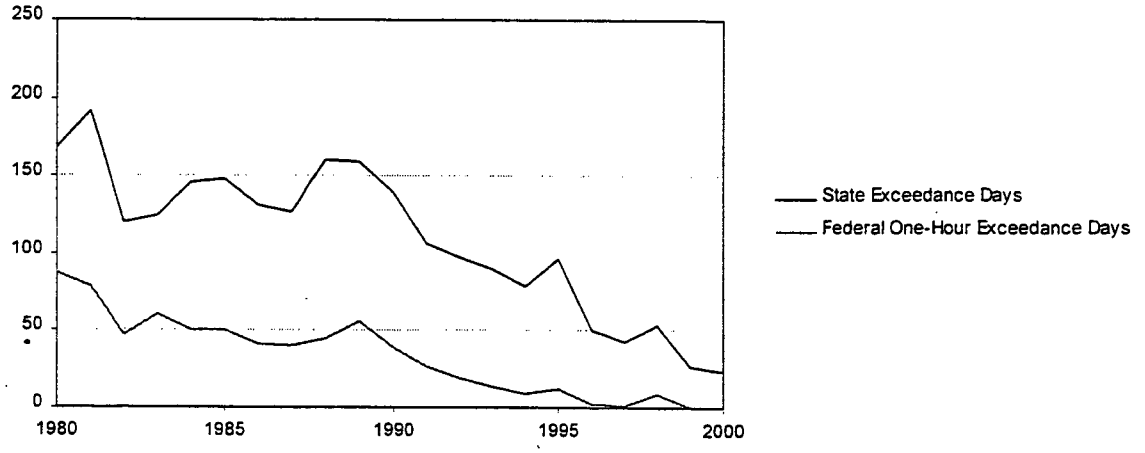
San Diego Air Basin Facts

		Percent of State total
Estimated 2000 Population	2.9 million	8%
Vehicle Miles Traveled	71.5 million miles/day	9%
Est. 2000 NOx Emissions	234 tons/day	7%
Est. 2000 ROG Emissions	239 tons/day	7%

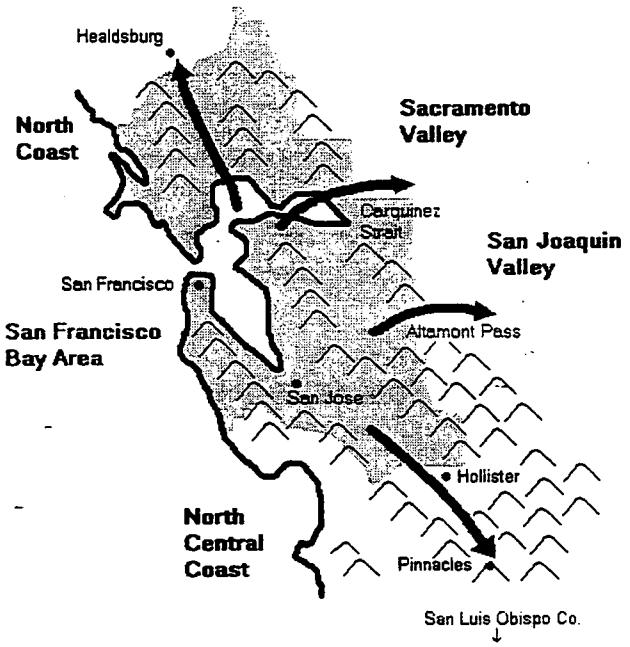
Other areas' impact on the San Diego Air Basin

Area	*Day Specific Findings*
Mexico	Overwhelming Significant Inconsequential
South Coast	Overwhelming Significant Inconsequential

San Diego Air Basin
Ozone Exceedance Trends



San Francisco Bay Area Air Basin



Emissions from the San Francisco Bay Area contribute to poor air quality throughout Northern California, including the San Joaquin Valley, Broader Sacramento Area, and the coastal areas from Sonoma County to San Luis Obispo County. The Bay Area has violated the State and Federal health-based standards many times over the last several years, and has contributed to air pollution problems in all of the surrounding air basins. The Bay Area must continue to reduce local emissions to achieve healthful air locally and downwind.

Area Description

The San Francisco Bay Area occupies a central location on California's coast. Home to nearly seven million people, the Bay Area is the second largest urban area in the State after the South Coast. It has a heavy concentration of industrial facilities, several airports, a major international port, and a dense freeway and surface street network. These air pollution sources result in high concentrations of ozone and ozone precursors. Pollutants carried by the wind from the Bay Area to surrounding areas have a major impact on air quality in those areas.

During the summer, winds usually blow from west to east, off the Pacific Ocean. Swept by sea breezes, much of the Bay Area enjoys relatively good air quality. However, interior valleys such as Livermore Valley and Santa Clara Valley experience ozone violations in summer. Since the Bay Area is upwind of much of central California, pollutants transported from the Bay Area affect a large part of central California.

Transport Characterization

Mountains surround the Bay Area to the north, east and south. Air pollution escaping the area flows mainly through a small number of gaps in these mountains. Toward the east, air flows predominantly through two natural passageways: the mouth of the Sacramento River at the Carquinez Strait, and Altamont Pass, east of Livermore. Through the Carquinez Strait the so-called "delta breeze" blows steadily towards the Central Valley in the summer, carrying ozone and precursors far into the Sacramento and San Joaquin Valleys.

At the Altamont Pass, electricity-generating windmills lining the hillcrests attest to the strong, steady winds blowing eastward into the San Joaquin Valley. Areas in the path of these natural inland air currents, such as Vacaville in the Sacramento Valley, and Tracy in the San Joaquin Valley, are strongly influenced by pollutants transported from the Bay Area. Areas farther downwind, such as the cities of Sacramento and Stockton, are also impacted by transport from the Bay Area, but to a lesser degree.

On some days when the State standard is violated in the Sacramento area, pollutants from the Bay Area are carried in by the delta breeze. However, on hot summer days when the temperature in Sacramento climbs into the high 90's and above, stagnant wind conditions allow a buildup of local emissions, and the ozone concentration can violate the State or Federal standards. Only when a strong evening delta breeze disperses these accumulated pollutants do the ozone concentrations decrease.

On some days, pollutants transported from the Bay Area also impact the northern San Joaquin Valley, mixing with local emissions to contribute to State and Federal violations at Stockton and Modesto. On other days, violations of the State standard are due entirely to local emissions. The impact of Bay Area transport diminishes with distance, so metropolitan areas such as Fresno and Bakersfield to the south are less affected. In those areas, ozone concentrations are dominated by local emissions.

Even as far east as the Sierra Nevada foothills, air quality in communities such as Jackson, San Andreas and Angels Camp in Amador and Calaveras Counties is sometimes affected by pollution originating in the Bay Area. Because winds blowing from the Bay Area to the Sierra Nevada pass over the northern San Joaquin Valley, emissions from the San Joaquin Valley also contribute to violations in the foothills.

To the south, winds funnel pollutants into the Santa Clara Valley. Surface winds can carry these pollutants southeast to Hollister in the North Central Coast Air Basin. Most ozone violations in Hollister are largely caused by this transport, with transport aloft from the northern San Joaquin Valley occasionally making a shared contribution. Winds aloft can also carry pollutants over the hills south of Hollister, as far as northern San Luis Obispo County.

Southward transport from the Bay Area offers a striking example of the three-dimensional nature of pollutant transport. On days when ozone levels stay well below the standard in Hollister, the southward-blowing wind several hundred feet overhead may be heavily laden with pollutants from the Bay Area. This can cause violations at Pinnacles National Monument at an elevation of 1,100 feet.

The pollutants can continue south, occasionally combining with pollutants transported from the San Joaquin Valley, to cause violations in the Paso Robles area of San Luis Obispo County. Gathering local emissions from Paso Robles, the polluted air mass may then be blown farther

south to cause violations in Atascadero. Thus, violations at Paso Robles can be caused by transported pollutants, while violations on the same day at Atascadero are caused by a mixture of local and transported emissions.

The northern portion of Sonoma County has only recently experienced violations of the State ozone standard. Summer prevailing winds blow across the Sonoma Plain from the southern portion of Sonoma County, which lies within the Bay Area, to the northern part, which lies within the North Coast Air Basin. The Bay Area portion of Sonoma County, comprising the urban areas of Santa Rosa and Petaluma, is a substantial source of ozone precursor emissions. High ozone concentrations at Healdsburg, in the North Coast, are entirely due to emissions transported from the Bay Area.

San Francisco Bay Area Air Basin Facts

		Percent of State total
Estimated 2000 Population	6.8 million	20%
Vehicle Miles Traveled	130 million miles/day	16%
Est. 2000 NOx Emissions	558 tons/day	16%
Est. 2000 ROG Emissions	535 tons/day	16%

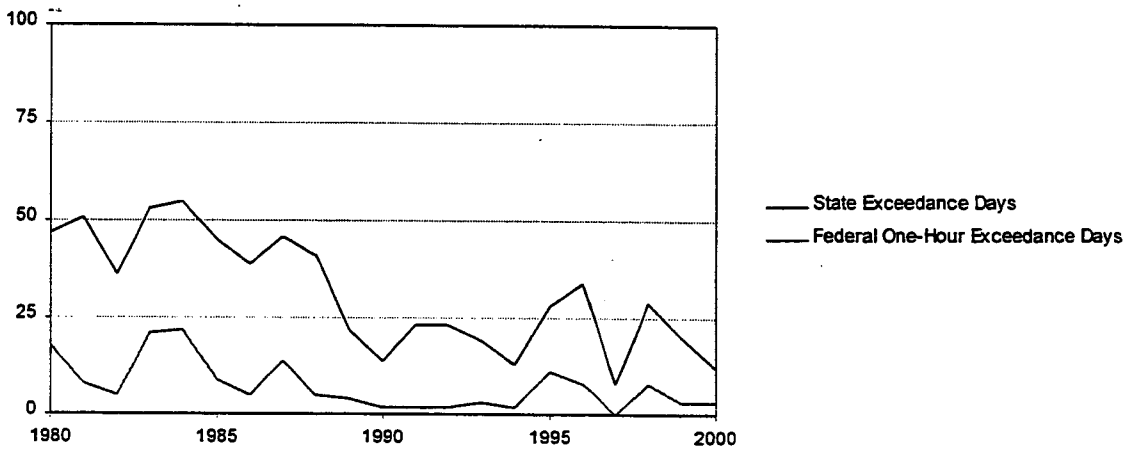
The San Francisco Bay Area Air Basin's impact on other areas

Area	*Day Specific Findings*
Broader Sacramento Area	Overwhelming Significant Inconsequential
Mountain Counties	Significant
North Central Coast	Overwhelming Significant
North Coast	Overwhelming
San Joaquin Valley	Overwhelming Significant Inconsequential
South Central Coast	Significant

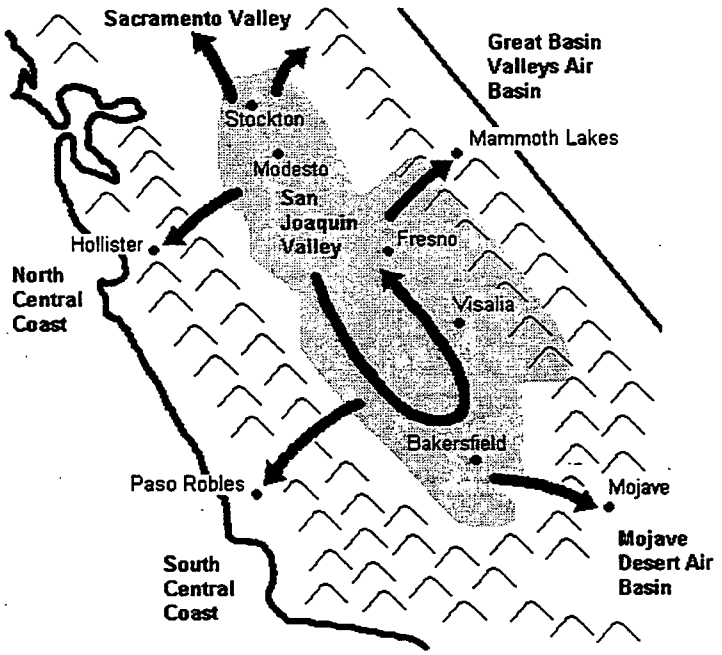
Other areas' impact on the San Francisco Bay Area Air Basin

Area	*Day Specific Findings*
Broader Sacramento Area	Significant Inconsequential

San Francisco Bay Area Air Basin
Ozone Exceedance Trends



San Joaquin Valley Air Basin



The San Joaquin Valley Air Basin continues to violate the State and Federal ozone standards. Because the area failed to meet the Clean Air Act 1999 attainment deadline for the Federal standard, the Valley was reclassified as severe nonattainment. Although the Valley is impacted by pollutants transported from other air basins, the impact declines from north to south. The Valley's worst air quality is primarily a result of local emissions. In addition, the Valley transports pollutants to most of the surrounding air basins. To meet the Federal ozone standard by the 2005 deadline, the Valley will need to substantially reduce emissions, an effort that will also aid progress towards attaining the State standard.

Area Description

The San Joaquin Valley, with a population of 3.3 million, is one of the fastest growing regions of California. The Valley stretches 300 miles, about one-third the length of the State. Its major population clusters, Stockton-Modesto, Fresno-Visalia and Bakersfield, are widely separated, linked together by State Route 99. While they share similar topographical settings and climate, each has its own distinct impact on surrounding areas.

Most of the Valley's industry is related to agriculture. Nevertheless, forest products and oil production and refining form a significant portion of the industrial base and emission inventory. Emissions from agricultural operations are generated throughout the Valley. Motor vehicle emissions are concentrated along the Highway 99 and Interstate 5 corridors, while larger industrial sources and their impact are clustered mainly in the southern region.

The San Joaquin Valley is bounded on the west by the Coast Ranges, on the east by the Sierra Nevada, and on the south by the Tehachapi Mountains. While these mountain ranges are substantial barriers to airflow, river canyons and passes provide channels through which pollutants can flow into other areas of the State. Since the valley is broad and flat with no significant hills or geographical features, air flows unobstructed throughout the Valley. The Valley's sunny climate and growing population lead to high ozone concentrations.

Transport Characterization

Peak summer ozone concentrations throughout the Valley have remained fairly constant for the last decade. Although the number of days violating the State ozone standard has decreased slightly, northern, central and southern regions all continue to violate the State ozone standard during much of the summer. While the northern part of the Valley is impacted by transport from neighboring air basins to some degree, the further south one goes the smaller the impact of transport. Throughout the basin local emissions have a dominant influence on ozone concentrations.

Transport of pollutants within the San Joaquin Valley plays a significant role in ozone violations there. Prevailing winds blow from the northern part of the Valley to the south, and can carry pollutants from San Joaquin and Stanislaus Counties to the Fresno area. Pollutants transported from the San Francisco Bay Area south to Fresno must pass through the northern Valley, so transport from the San Francisco Bay Area to Fresno is combined with a northern Valley contribution. Further south, eddy currents can carry pollutants along the east side of the Valley from Tulare County and northern Kern County to the Fresno Area.

The northern part of the Valley, comprising the urban areas of Stockton, Modesto and Turlock, is due east of San Francisco Bay Area. It has a combined population of roughly 1.2 million. On summer days, the so-called delta breeze blows through the Carquinez Strait, eastward into the Central Valley. As it blows east, the delta breeze fans out to the north and south. In the vicinity of Stockton, the prevailing wind direction on most summer mornings is toward the south.

On some days, pollutants transported from the Bay Area impact the northern San Joaquin Valley, mixing with local emissions to contribute to State and Federal violations at Stockton and Modesto. On other days, violations of the State standard are due entirely to local emissions. The impact of Bay Area transport diminishes with distance, so metropolitan areas such as Fresno and Bakersfield to the south are less affected.

Under certain conditions, winds blowing from the south and southwest can carry pollutants from the northern Valley towards Sacramento. Although there is a potential for transport impacts, transport from the northern Valley to the southern part of Sacramento occurs infrequently.

The delta breeze typically carries polluted air from the Valley into the Sierra Nevada foothills to the southeast, causing ozone violations in the foothill areas such as Sonora, in Tuolumne County, and in Yosemite National Park. In the foothills further to the north, pollutants from the Valley combine with pollutants transported from the San Francisco Bay Area and Broader Sacramento Area to cause ozone violations in Amador and Calaveras Counties. Since the foothill communities are small and do not generate significant local emissions, these violations are considered to be entirely the result of transport.

Occasionally, winds aloft carry pollutants from the northern Valley westward to the Hollister area, in the North Central Coast Air Basin. There, they mix down to the ground and combine with local emissions and pollutants transported from the San Francisco Bay Area to cause ozone violations. The San Francisco Bay Area is believed to contribute the largest share of pollutants.

The central portion of the Valley includes the cities of Fresno and Visalia. With a rapidly growing population currently estimated at roughly 1.4 million, the central Valley has a broad impact on air quality in surrounding areas. For the last several years the Fresno area has experienced the highest ozone concentrations in the Valley, consistently violating the State ozone standard. These violations are predominantly caused by local emissions.

Transport from the central portion of the Valley is responsible for ozone violations in Mammoth Lakes, on the eastern slope of the Sierra Nevada. From the Valley, winds carry pollution eastward up the canyons of the western Sierra Nevada during the day, as far as the crest of the Sierra. From there, pollutants flow east to the Mammoth Lakes area via gaps in the crest. Typically, the violations in Mammoth Lakes occur late at night or in the early morning; a pattern always associated with transported emissions.

Winds also carry pollutants from the Valley to the west. Under rare weather conditions, these pollutants can combine with local emissions and ozone transported south from the San Francisco Bay Area to cause ozone violations in northern San Luis Obispo County. The communities of Paso Robles and Atascadero are separated from the San Joaquin Valley by the Cholame Hills and the Temblor Range, which run northwest-southeast almost in a straight line.

Infrequently, as ozone from the Valley rises, it is carried west over the intervening mountains by the wind, and arrives at Paso Robles by midday. There, it mixes down to the ground and combines with ozone flowing southward from the San Francisco Bay Area to cause violations at ground level. This polluted air mass can then gather local emissions and flow south to Atascadero. Thus, violations at Paso Robles can be caused by transported pollutants, while violations on the same day at Atascadero are caused by a mixture of local emissions and transport.

The southern part of the Valley consists of Kings County and the western half of Kern County. It includes Bakersfield and surrounding communities. The population of the southern Valley is roughly 700,000. In addition to motor vehicle emissions, oil production and refining contribute to ozone precursor emissions from this area. Violations in Kern County are almost entirely due to local emissions.

In the summer, persistent winds blow from the San Joaquin Valley southeastward through the Tehachapi Pass into the Mojave Desert. Ozone violations in eastern Kern County, immediately downwind of the pass, have been shown to be caused by this transport. The emissions from eastern Kern County are too small to constitute a significant source of local emissions. Further downwind at Lancaster, in the Mojave Desert portion of Los Angeles County, violations have been caused by transport from the southern Valley. However, air quality in the Lancaster area is dominated by transport from the South Coast, and local emissions also make a substantial contribution.

San Joaquin Valley Air Basin Facts

		Percent of State total
Estimated 2000 Population	3.3 million	10%
Vehicle Miles Traveled	94.2 million miles/day	12%
Est. 2000 NOx Emissions	596 tons/day	17%
Est. 2000 ROG Emissions	513 tons/day	15%

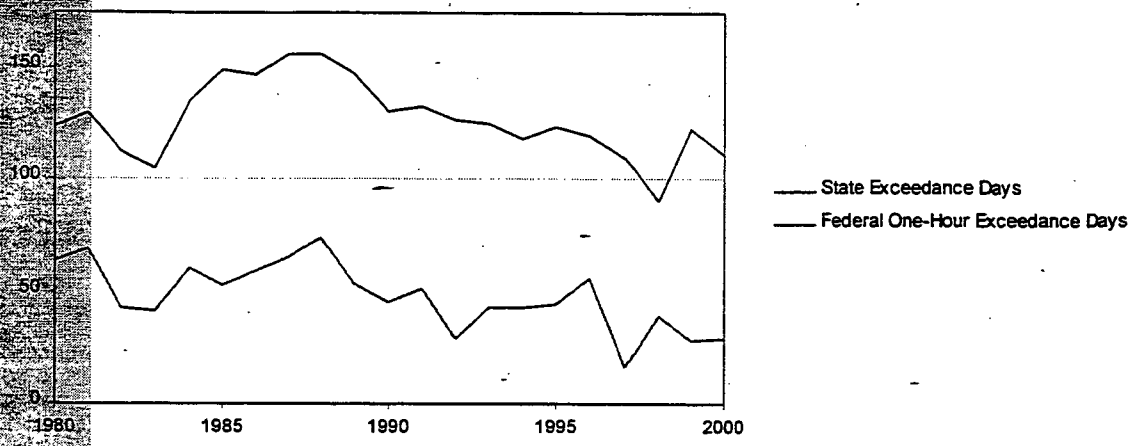
The San Joaquin Valley Air Basin's impact on other areas

Area	*Day Specific Findings*
Broader Sacramento Area	Significant Inconsequential
Great Basin Valleys	Overwhelming
Mountain Counties	Overwhelming
Mojave Desert	Overwhelming
North Central Coast	Significant
South Central Coast	Significant Inconsequential

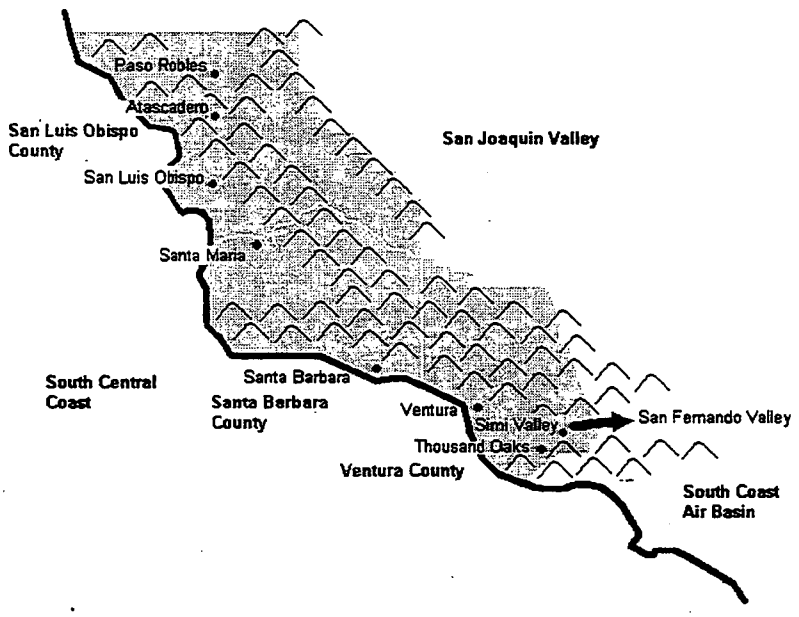
Other areas' impact on the San Joaquin Valley Air Basin

Area	*Day Specific Findings*
Broader Sacramento Area	Significant Inconsequential
San Francisco Bay Area	Overwhelming Significant Inconsequential

San Joaquin Valley Air Basin
Ozone Exceedance Trends



South Central Coast Air Basin



All three counties in the South Central Coast Air Basin continue to violate the State ozone standard. The number of violations decreases as one moves north from the Ventura – Los Angeles county border. Although air quality in Ventura County is considered severe with respect to the Federal one-hour ozone standard, Santa Barbara County is close to attaining and San Luis Obispo County attains the Federal standard. Although the air basin is impacted by transport from three air basins and oil operations in the coastal waters offshore, local emission controls are needed throughout the South Central Coast to attain all ozone standards.

Area Description

The South Central Coast includes San Luis Obispo, Santa Barbara and Ventura Counties. Topography and wind patterns link Santa Barbara and Ventura Counties with the South Coast Air Basin. San Luis Obispo County is separated from the other two counties by mountains, and its air quality is more closely linked with that of the San Francisco Bay Area and San Joaquin Valley. Because of the differences in topography and air quality, the three counties are treated as separate planning areas.

Santa Barbara and Ventura Counties lie immediately to the northwest of the South Coast, and are both sources and recipients of transported pollutants. While the population and total emissions of pollutants in Santa Barbara and Ventura Counties are dwarfed by those of the South Coast, the two counties constitute a significant source of pollutants. The two counties have a combined population of roughly 1.2 million. Power plants, oil extraction and oil refining emit substantial amounts of ozone precursors. Transportation and agricultural activities also contribute emissions.

San Luis Obispo County supports a population of roughly 255,000 people. Much of the population lives in the city of San Luis Obispo and nearby coastal communities. To the north,

separated from the coast by mountains, lie the towns of Paso Robles and Atascadero, each numbering roughly 25,000 inhabitants.

Transport Characterization

Ozone violations in Santa Barbara and Ventura Counties are sometimes caused by local emissions, and sometimes caused by a mixture of transported and local emissions. Pollutants from the South Coast Air basin can be blown offshore and carried to the coastal cities of both counties. Pollutants can also impact Ventura County by way of an inland route from the San Fernando Valley in Los Angeles County.

The San Fernando Valley extends almost up to the western boundary of Ventura County, separated only by moderately high hills. Modeling studies have shown that when winds blow from the coast, eastward through the Simi Valley, pollutants from Santa Barbara and Ventura County can be carried into the San Fernando Valley and contribute to violations there.

Ozone violations in San Luis Obispo County occur in the northern portion of the county, measured at monitors in the cities of Paso Robles and Atascadero. Air quality in Paso Robles is impacted by pollutants transported aloft from the San Francisco Bay Area, and infrequently from the San Joaquin Valley. Transported pollutants can then mix with local emissions from Paso Robles and be blown south to cause violations at Atascadero.

While Santa Barbara and Ventura Counties are impacted by transport from the South Coast, local emissions have a significant impact on local air quality. San Luis Obispo County receives transported pollutants from the San Francisco Bay Area and San Joaquin Valley, but local emissions also contribute to ozone violations in Atascadero. Under some conditions Santa Barbara and Ventura Counties can contribute to ozone violations in the South Coast.

South Central Coast Air Basin Facts

		Percent of State total
Estimated 2000 Population	1.4 million	4%
Vehicle Miles Traveled	34.9 million miles/day	4%
Est. 2000 NOx Emissions	136 tons/day	4%
Est. 2000 ROG Emissions	141 tons/day	4%

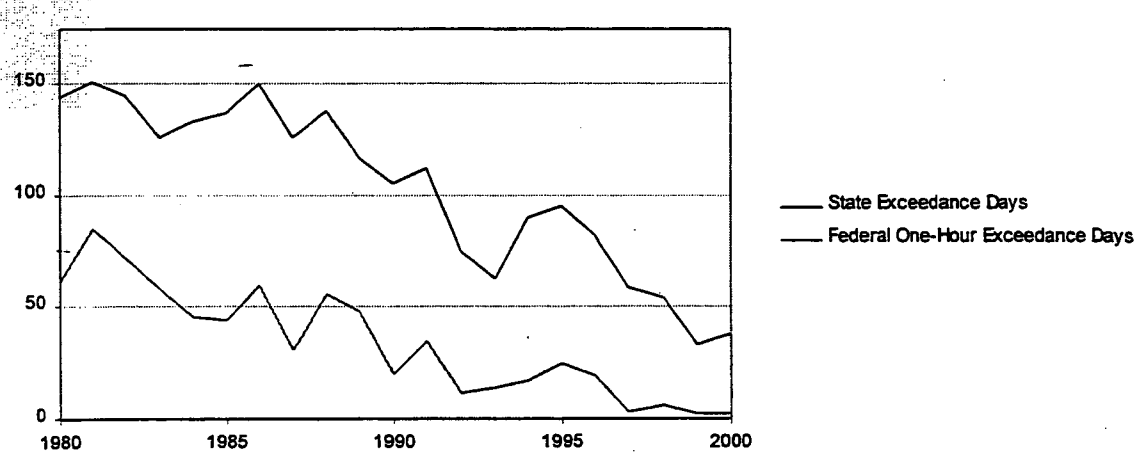
The South Central Coast Air Basin's impact on other areas

Area	*Day Specific Findings*
South Coast	Significant Inconsequential

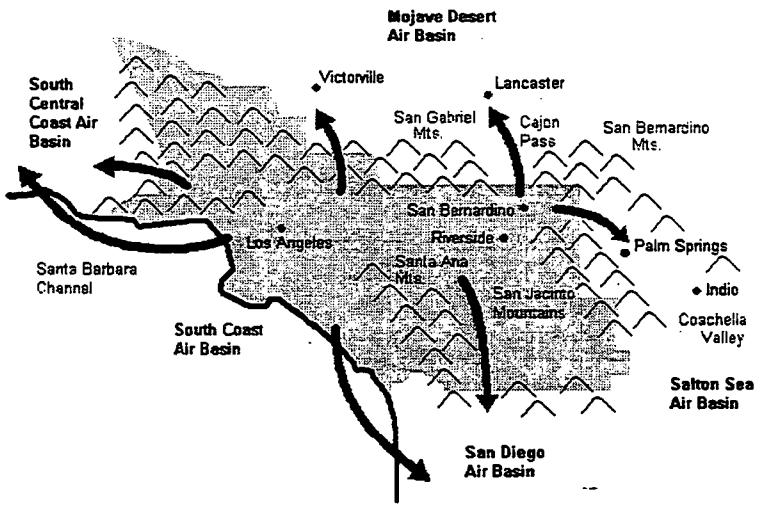
Other areas' impact on the South Central Coast Air Basin

Area	*Day Specific Findings*
San Francisco Bay Area	Significant
San Joaquin Valley	Significant
South Coast	Significant Inconsequential

South Central Coast Air Basin
Ozone Exceedance Trends



South Coast Air Basin



With roughly 40 percent of the State's population, emissions from the South Coast Air Basin cause or contribute to violations of the State ozone standard in almost all adjacent air basins. While air quality in the South Coast has improved markedly over the last decade, significant additional reductions will be needed beyond 2010 to achieve the State ozone standard in the South Coast and neighboring areas.

Area Description

The South Coast, with an estimated 2000 population of nearly 15 million, is the largest urban area in the western United States. Virtually all of the coastal portion of the South Coast, an area of over 1,000 square miles, is urbanized. The area is served by an enormous transportation network of freeways, surface streets, airports, seaports, and railroads, all of which contribute ozone precursor emissions. The area's large and diverse industrial and commercial sectors, as well as construction activities, fuel refining and distribution, and consumer product usage also contribute to the region's emissions.

The South Coast is bounded on the west by the Pacific Ocean, and surrounded on the other sides by mountains which tend to channel and confine airflow. To the north lie the San Gabriel Mountains, to the north and east the San Bernardino Mountains, to the southeast the San Jacinto Mountains, and to the south the Santa Ana Mountains. Winds aloft can carry pollutants over the surrounding mountains and play an important role.

Transport Characterization

While the South Coast has historically suffered the highest ozone concentrations in the United States, the region has seen dramatic improvements in air quality in the last two decades. Since the South Coast dwarfs its neighboring areas, air quality throughout most of the basin is dominated by emissions from within the South Coast.

The urbanized area of the South Coast extends within 20 miles of the boundary of San Diego County, its neighbor to the south. Transport from the South Coast can cause violations at

coastal sites in San Diego County such as Oceanside and Del Mar. This typically occurs when offshore winds sweep polluted air from the South Coast over the ocean. Coastal winds carry the polluted air south, and the usual onshore breeze then carries the polluted air over coastal areas of San Diego County.

Transport may also take place via one or more inland routes. The South Coast can be the source of high ozone levels in Escondido, and a contributor to violations in the foothills east of San Diego. However, the South Coast's contribution to ozone violations in San Diego County varies from one day to another. The San Diego urban area is a significant source of ozone precursor emissions and can be the sole cause of violations in the eastern part of the county on some days.

The Salton Sea Air Basin comprises the desert area to the southeast of the South Coast. It includes the Coachella Valley, with its communities of Indio and Palm Springs, and the Imperial Valley to the south. In the summer, prevailing winds push polluted air eastward from the South Coast, through the San Gorgonio Pass, then southeast through the Coachella Valley. Air quality at Palm Springs and Indio is dominated by pollutants transported from the South Coast.

From the Coachella Valley, winds can carry these pollutants further southeastward into the Imperial Valley. However, ozone from the South Coast must travel over 100 miles to reach the Imperial Valley. By the time it arrives, the ozone is diluted. Ozone violations in the Imperial Valley are considered to be caused by a mixture of South Coast transport, local emissions, and transport from Mexicali, across the border in Mexico.

Ozone transported from the South Coast is primarily responsible for violations in the populated areas of the Mojave Desert Air Basin immediately to its north. The Mojave Desert Air Basin is separated from the South Coast by the San Gabriel and San Bernardino Mountains. When the inversion layer is sufficiently high, winds carry ozone through passes and over the mountains into the Mojave Desert where pollutants mix down to the ground and impact air quality.

Transport can also take place along the surface through Cajon Pass and Soledad Pass. The roughly 400,000 people living in the strip of the Mojave Desert immediately adjacent to the South Coast are the most affected. Violations at Lancaster, Hesperia, Victorville and Phelan are usually dominated by transport from the South Coast. However, meteorological analyses have demonstrated that ozone violations in this area can be caused by a mixture of local emissions as well as transport from the South Coast. As far east as Barstow, pollutants transported from the South Coast can cause or contribute to ozone violations.

The coastal counties of Ventura and Santa Barbara County lie immediately to the northwest of the South Coast, and their air quality is heavily influenced by transport from the South Coast. In 1996, transport from the South Coast was shown to have contributed to all violations of the Federal ozone standard in Santa Barbara County.

Transport from the South Coast to the South Central Coast can take place at the surface or aloft. At the surface, winds blowing northwestward from the South Coast carry ozone over the ocean to Ventura and Santa Barbara Counties. Ozone trapped aloft above the South Coast can accumulate in high concentrations, be blown northwest, mix down to the surface and combine with local emissions to cause violations.

Air quality in the South Coast Air Basin is driven almost entirely by emissions generated within the basin. The exception is the San Fernando Valley in west-central Los Angeles County, which is occasionally impacted by emissions from Ventura and Santa Barbara Counties.

South Coast Air Basin Facts

		Percent of State total
Estimated 2000 Population	14.9 million	43%
Vehicle Miles Traveled	320 million miles/day	40%
Est. 2000 NOx Emissions	1,207 tons/day	34%
Est. 2000 ROG Emissions	1,092 tons/day	33%

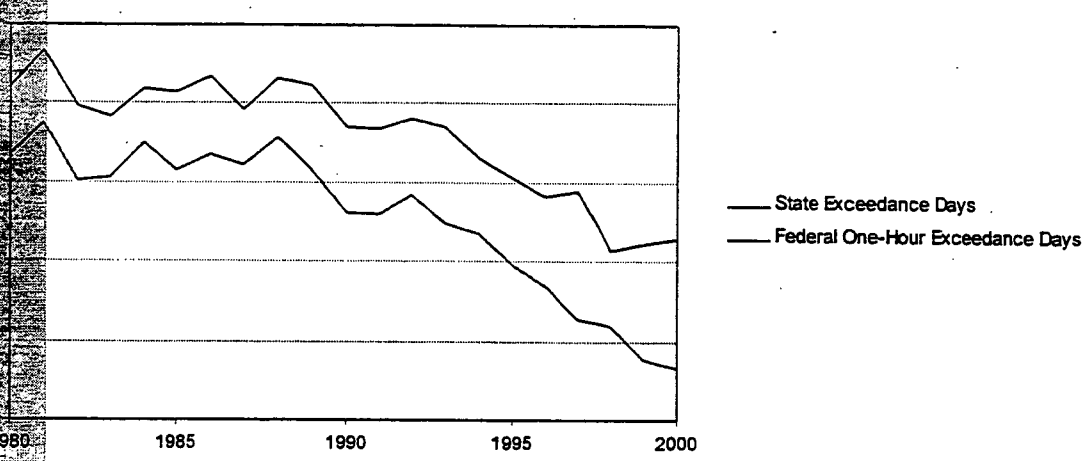
The South Coast Air Basin's impact on other areas

Area	*Day Specific Findings*
Mojave Desert	Overwhelming Significant
Salton Sea	Overwhelming Significant
San Diego	Overwhelming Significant Inconsequential
South Central Coast	Significant Inconsequential

Other areas' impact on the South Coast Air Basin

Area	*Day Specific Findings*
South Central Coast	Significant Inconsequential

South Coast Air Basin
Ozone Exceedance Trends



References

(1) The 2001 California Almanac of Emissions and Air Quality. California Air Resources Board, Technical Support Division.

(2) Assessment of the Impacts of Transported Pollutants on Ozone Concentrations in California, 1990. California Air Resources Board, Technical Support Division.

(3) Biennial review of the Assessment of the Impacts of Transported Pollutants on Ozone Concentrations in California, 1993. California Air Resources Board, Technical Support Division.

(4) Second Triennial review of the Assessment of the Impacts of Transported Pollutants on Ozone Concentrations in California, 1996. California Air Resources Board, Technical Support Division.

(5) Assessment of the Impacts of Transported Pollutants on Ozone Concentrations in California, 2001. California Air Resources Board, Planning and Technical Support Division.

All of the publications listed above are available from the California Air Resources Board by calling the Public Information Office at (916) 322-2990. The 2001 California Almanac of Emissions and Air Quality can also be downloaded from the ARB web site at

http://www.arb.ca.gov/aqd/almanac2001/almanac01.htm

Additionally, air quality data from 1980 forward are available on a CD-ROM which can be obtained from the Public Information office or by ordering from the ARB web site.

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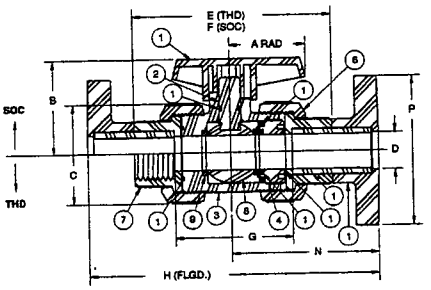

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General Comments and Hints
Do's and Don'ts

DO:
- Clean and prepare pipe and fitting (see Preparation for Joining, page 16).
- Use the proper applicators (see Selection of Applicators for..., page 17).
- Scrub primer into joint surfaces until a lemon peel may be curled with an edge.
- Apply Cement while the primer is still moistened.
- Maintain two wet beads at the pipe and fitting chamfers throughout joint insertion.
- Follow the instructions completely.

DON'T:
- Attempt to solvent weld in wet and/or wind without shielding.
- Solvent weld below 35° or above 90° F under direct sun exposure without precautions (see Hot and Cold Weather Cementing below).
- Discard leftover cans of solvent in trench with piping. Concentrated fumes can cause piping failure.
- Skip any priming or cementing steps.
- Skimp with cement on pipe or overdo cement in sockets, but apply enough for wet bead formation during joint insertion.

Hot Weather Cementing
Hot weather can be the nemesis of solvent cementing. As the temperature and/or wind increase, the rate of solvent evaporation quickens. Hence, it becomes more difficult to keep primed surfaces moistened. Even the cement itself can begin to "film over" prior to joining. Rather than using hot weather as an excuse to compromise the functional elements required for reliable joining, the problem must be overcome by adjusting the approach to priming, cement application and pipe insertion techniques in order to appropriately reduce the lapsed joining time. As corrective measures to combat wind and/or temperature in excess of 90° F, the following may be done:

1. Increase the crew size and organize the team to achieve speed while making no compromise to functional performance.

2. Construct a windscreen from polyethylene film or tenting around the joint and crew.

3. Shade the pipe, fittings, valves and solvent materials from the sun prior to joining in order to eliminate heat absorption by the dark color. Fittings, valves and solvent supplies may be kept in a box. Shading the pipe to be joined may be more difficult, but not impossible. Under adequate lighting, the joining may be done at night or early morning.

Cold Weather Cementing
Solvent in the primer and cement will not evaporate as readily when the temperature is below 35°/40° F. Severe scouring with a stiff bristle brush is required to work the primer solvents into the surfaces. Secondly, it takes appreciably more time for the solvents to evaporate once the joint is made. Therefore, joints must be held together longer to prevent the pipe backing out of the socket. Joints must be left undisturbed longer to prevent breaking the bond by movement. And joints must be given longer drying times before pressurization. We offer the following common sense recommendations if solvent cementing must be done when the temperature approaches freezing: Store the pipe, fitting, valves and cementing supplies in a heated area until you are ready to use them. Also, water or moisture is an enemy and frost is commonplace at near freezing temperature. So, the pipe and fittings must be kept dry prior to joining and the joints should be kept dry until the cement has had sufficient time to set – not dry, just set so they can be moved without fear of breaking the initial bond.

1. Pre-fab as much of the system as possible in a heated work area. By using flange or union connections for system erection, the number of in-place cemented joints can be minimized.

2. Field joints that must be made outside should be protected with a portable shelter, preferably black to absorb heat from the sun, and otherwise heated indirectly to produce a 40° F surface temperature on the pipe, fittings, valves and cementing supplies. The shelter should remain in place until the joint is set. And you can figure the set time to be roughly twice what it would be for a 70° joint. Good ventilation of the shelter is an absolute safety necessity for worker health and fire prevention reasons.

CAUTION: DO NOT ATTEMPT TO SPEED THE DRYING OF THE CEMENT BY APPLYING DIRECT HEAT TO THE SOLVENT WELDED JOINT. Forced rapid drying by heating with an electric blow drier, for example, will cause the cement solvents to boil off, forming porosity, bubbles and blisters in the cement film.

Joint Integrity
In hot, mild or colder weather, if the basic joining steps are followed with discipline, the chemical fusion joining method for thermoplastic piping is extremely reliable and cost efficient. Because of significant contributions to commercial and industrial construction, both thermoplastic piping and solvent welding are here to stay. By virtue of their permanent resistance to chemical attack and undeniable economic impact, value engineering has reached the stage where even mundane processes, such as water disinfection, or exotic processes, such as bulk and dilute acid feed, are absolutely dependant upon PVC or CPVC piping with solvent cemented joints. In spite of the higher standards of skill required for industrial chemical installations, relative to the marginal standards required for domestic small diameter utility applications, we are beyond the time when joint failure can be excused because of inexperience or poor workmanship. Since the difference between cementing a joint and gluing it is common knowledge today, the 40 plus year-old technology for solvent cementing justifiably demands professional discipline in its execution. As a result, the low bidder for any PVC or CPVC piping installation can reasonably be expected to exercise control over joining performance.

Solvent Cement Usage Estimates
The PVC and CPVC solvent cement usage estimates given in the table below should only be considered as a guideline. Actual usage could vary according to a wide variety of installation conditions. Further, these estimates should in no way be used to restrict the liberal instructions in the Six Step Application Techniques starting on page 18.

Number of Joints per Container Size

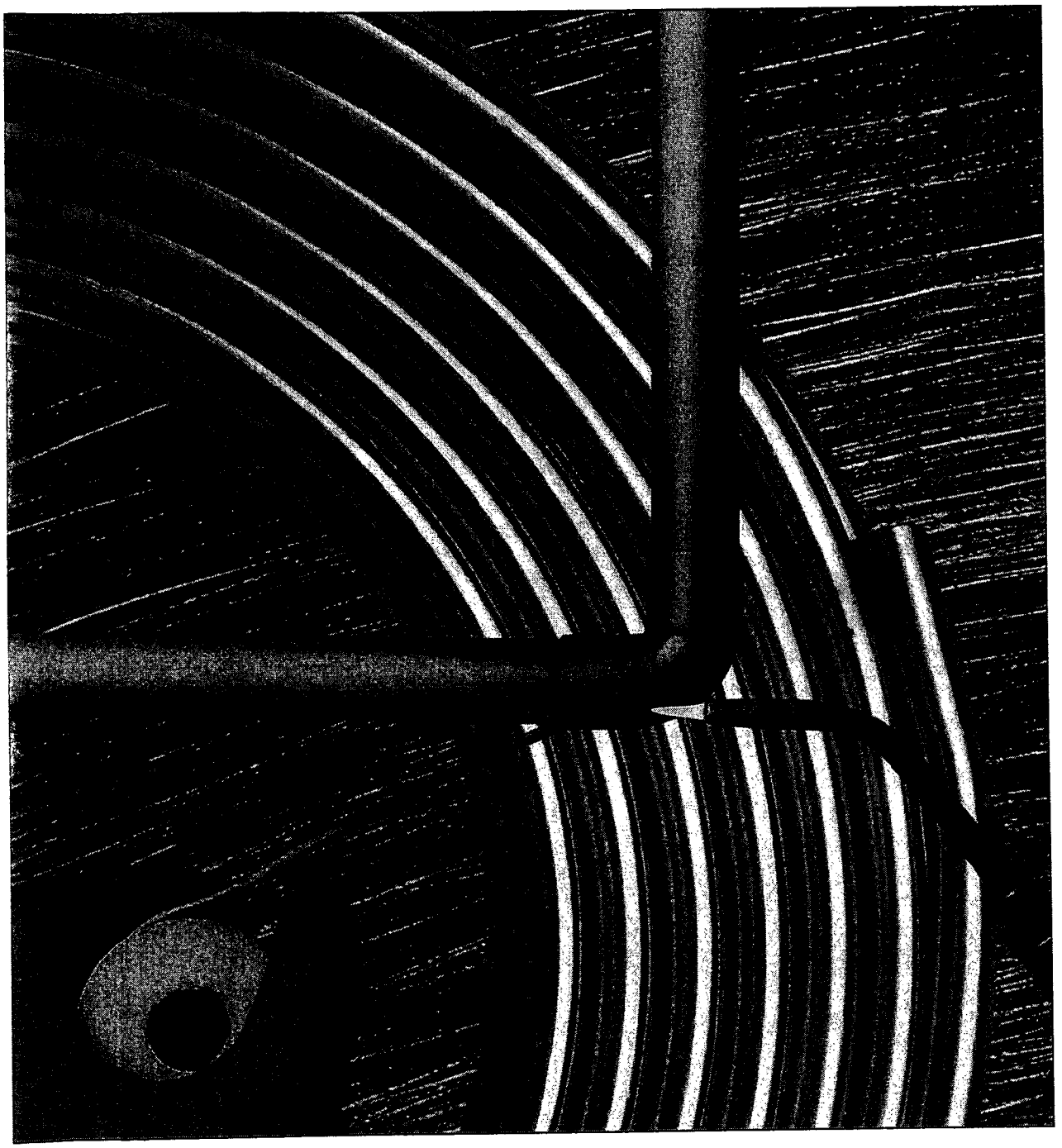
Pipe Size	Pint	Quart	Gallon
½"	130	260	1040
¾"	80	160	640
1"	70	140	560
1¼"	50	100	400
1½"	35	70	280
2"	20	40	160
2½"	17	34	136
3"	15	30	120
4"	10	20	80
6"	N/R	8	32
8"	N/R	3	12
10"	N/R	N/R	10
12"	N/R	N/R	6

Thermo-Seal (Socket Fusion) Joining for Polypropylene and PVDF (KYNAR®) Pressure Piping Systems

Materials and Tools
Preparation of Components
A socket heat fusion joint requires pipe with a square cutoff and chamfered outside edge. Both pipe and fitting socket must be cleansed of clinging debris. For further insight see the Thermo-Fusion paragraph in the Joining Methods for Pressure Piping section on page 15. The theory of joining is extended in the Six-Steps of Joining Mechanics, which follows on page 24. The specific instructions for component preparation are provided in the Preparation of Pipe and Fittings for All Joining Methods section on page 16.

Do not use or test the products in this catalog with compressed air or other gases. See Chemtrol Chem-Aire® literature for information about shatter-resistant thermoplastic piping systems specifically designed for compressed air and other gases.

THE COPPER TUBE HANDBOOK



CDA

Copper Development Association

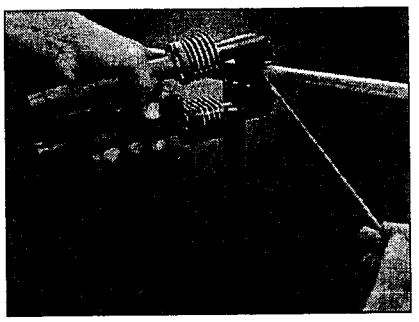


FIGURE 24: Electric Resistance Hand Tool

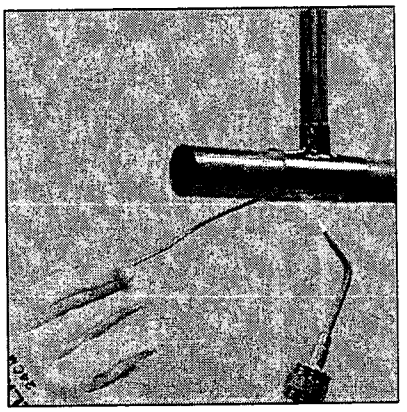


FIGURE 25: Soldering

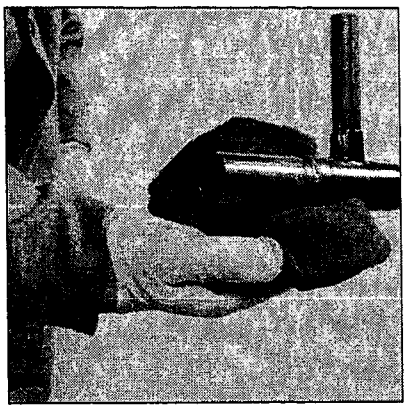


FIGURE 26: Cleaning

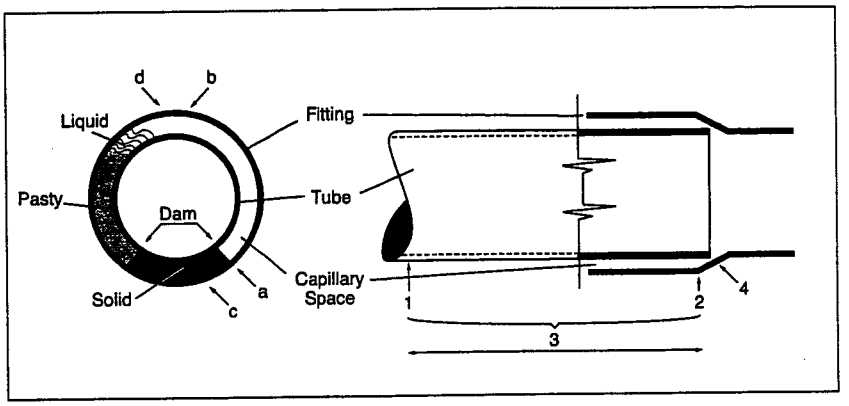


FIGURE 27: Schematic of Solder Joint

the base of the fitting and slightly ahead of the point of application of the solder. Continue this technique across the bottom of the fitting and up one side to the top of the fitting (**Figure 27,** postion b).

The now-solidified solder at the bottom of the joint has created an effective dam that will prevent the solder from running out of the joint as the side and top of the joint are being filled.

Return to the point of beginning, overlapping slightly (**Figure 27,** position c), and proceed up the uncompleted side to the top, again, overlapping slightly (**Figure 27,** position d). While soldering, small drops may appear behind the point of solder application, indicating the joint is full to that point and will take no more solder. Throughout this process you are using all three physical states of the solder: solid, pasty and liquid.

For joints in the vertical postion, make a similar sequence of overlapping passes starting wherever is convenient.

Solder joints depend on capillary action drawing free-flowing molten solder into the narrow clearance between the fitting and the tube. Molten solder metal is drawn into the joint by capillary action regardless of whether the solder flow is upward, downward or horizontal.

Capillary action is most effective when the space between surfaces to be joined is between 0.002 inch and 0.005 inch. A certain amount of looseness of fit can be tolerated, but too loose a fit can cause difficulties with larger size fittings.

For joining copper tube to solder-cup valves, follow the manufacturer's instructions. The valve should be in a partially open position before applying heat, and the heat should be applied primarily to the tube. Commercially available heat-sink materials can also be used for protection of temperature-sensitive components during the joining operation.

The amount of solder consumed when adequately filling the capillary space between the tube and either wrought or cast fittings may be estimated from **Table 10,** page 39. The flux requirement is usually 2 ounces per pound of solder.

Cooling and Cleaning

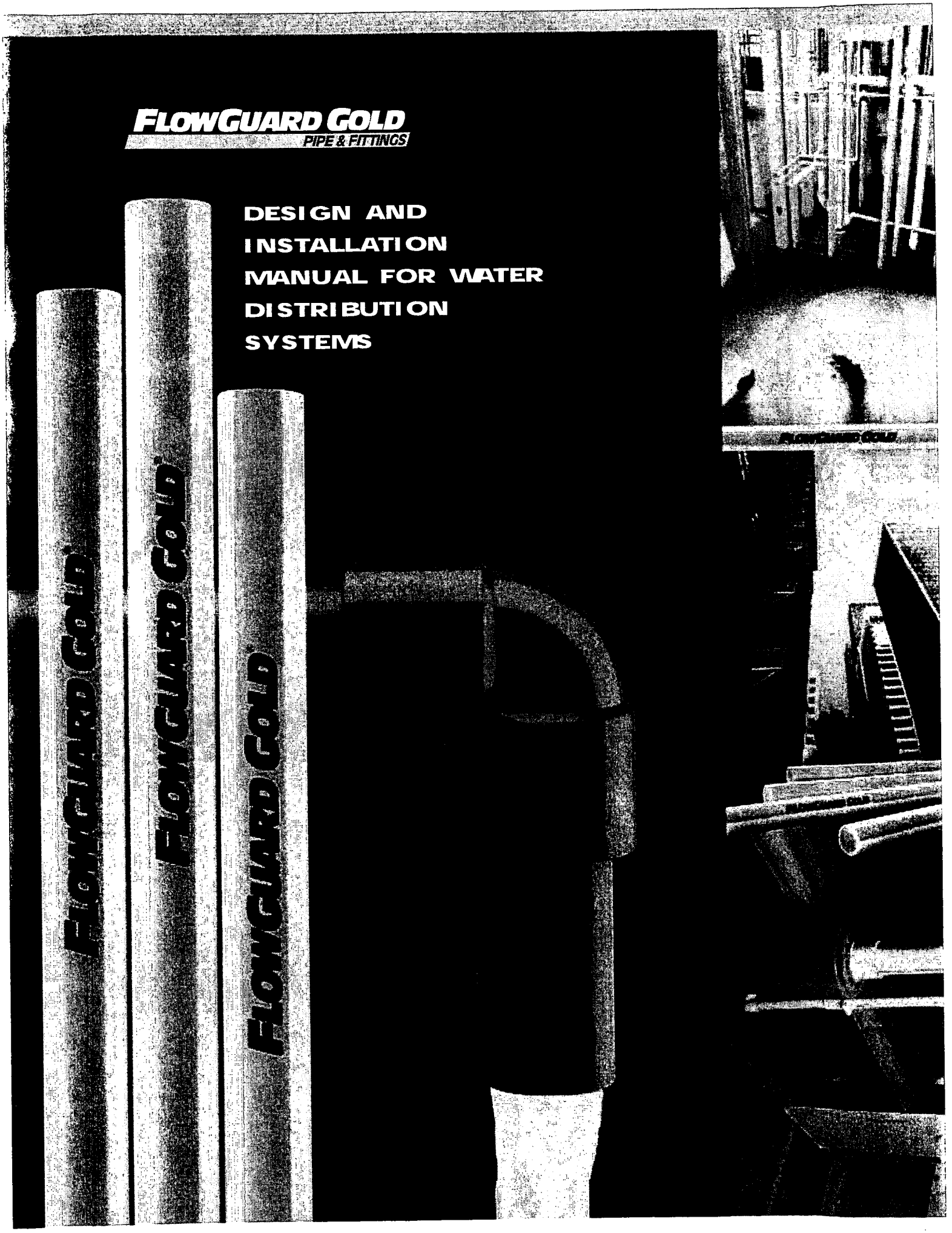
Allow the completed joint to cool naturally. Shock cooling with water may stress the joint. When cool, clean off any remaining flux residue with a wet rag (**Figure 26**). Whenever possible, based on end use, completed systems should be flushed to remove excess flux and debris.

Testing

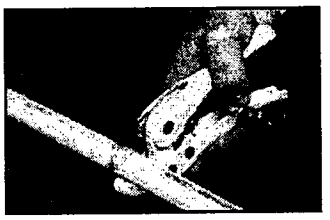
Test all completed assemblies for joint integrity. Follow the testing procedure prescribed by applicable codes governing the intended service.

FLOWGUARD GOLD
PIPE & FITTINGS

DESIGN AND INSTALLATION MANUAL FOR WATER DISTRIBUTION SYSTEMS

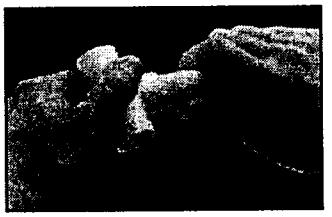


Joining FlowGuard Gold® Pipe & Fittings

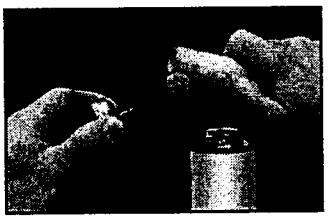


1. Cutting. FlowGuard Gold® pipe can be easily cut with a wheel type plastic tubing cutter, ratchet cutter or fine tooth saw. Ratchet cutters should be sharpened regularly. When saw cutting, a miter box should be used to insure a square cut. Cutting tubing as squarely as possible provides optimal bonding area within a joint. If any indication of damage or cracking is evident at the tubing end, cut off at least 2 inches beyond any visible crack.

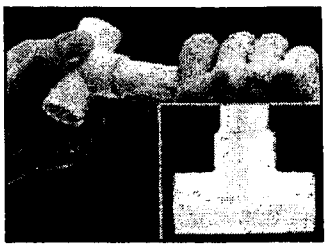
2. Deburring/Beveling. Burrs and filings can prevent proper contact between tube and fitting during assembly, and should be removed from the outside and inside of the tubing. A chamfering tool is preferred but a pocketknife or file are suitable for this purpose. A slight bevel on the end of the tubing will ease entry of the tubing into the fitting socket and minimize the chances of pushing solvent cement to the bottom of the joint.



3. Fitting Preparation. Using a clean and dry rag, wipe dirt and moisture from the fitting sockets and tubing end. Check the dry fit of the tubing and fitting. The tubing should make contact with the socket wall 1/3 to 2/3 of the way into the fitting socket. At this stage there should be an interference fit, tubing should not bottom out in the socket.



4. Solvent Cement Application. USE ONLY CPVC CEMENT OR AN ALL-PURPOSE CEMENT CONFORMING TO ASTM F-493 OR JOINT FAILURE MAY RESULT. As a result of extensive testing, Noveon recommends the application of FlowGuard Gold® One Step Cement on 1/2"-2" CTS tubing as the technically preferred method (a primer should be used when joining Corzan® IPS pipe and fittings 2½" and larger). However, if required by local code, primer, when properly applied, will have no negative effect on FlowGuard Gold® CPVC joint integrity. When making a joint, apply a heavy, even coat of cement to the pipe end. Use the same applicator without additional cement to apply a thin coat inside the fitting socket. Too much cement can cause clogged waterways. DO NOT ALLOW EXCESS CEMENT TO PUDDLE IN THE FITTING AND PIPE ASSEMBLY AS THIS MAY LEAD TO PREMATURE FAILURE.



5. Assembly. Immediately insert the tubing into the fitting socket, rotating the tube 1/4 to 1/2 turn while inserting. This motion ensures an even distribution of cement within the joint. Properly align the fitting. Hold the assembly for approximately 10 seconds, allowing the joint to set-up. An even bead of cement should be visible around the joint. If this bead is not continuous around the socket edge, it may indicate that insufficient cement was applied. In this case, remake the joint to avoid potential leaks.

Wipe excess cement from the tubing and fittings surfaces for an attractive, professional appearance.

Cure Times. A joint which has cured sufficient to pressure test may not exhibit its full joint strength. Solvent cement set and cure times are a function of pipe size, temperature, and relative humidity. Curing time is shorter for drier environments, smaller sizes, and higher temperatures. Refer to the following table for minimum cure times after the last joint has been made before pressure testing can begin. Use of primer and/or the presence of hot water extends cure time required for pressure testing. Refer to the manufacturer's recommendations for sizes larger than 2".

(Table 22)

Minimum Cure Prior to Pressure Testing at 100 psi for One Step Solvent Cement

	Ambient Temperature During Cure Period			
Tube (in.)	60°F	40°F	32°F	0°F
1/2	10 min.	10 min.	15 min.	30 min.
3/4	10	15	15	30
1	10	15	20	30
1 1/4	10	15	20	30
1 1/2	15	15	30	45
2	15	15	30	60

Special care should be exercised when assembling FlowGuard Gold® systems in extremely low temperatures (below 40°F) or extremely high temperatures (above 100°F). In extremely hot temperatures, make sure both surfaces to be joined are still wet with cement when putting them together.

IPS

WELD·ON

Guide to Solvent Cementing PVC and CPVC Plastic Pipe and Fittings

This guide describes the basic principles for solvent cementing plastic pipe and fittings and gives recommended techniques for making high strength joints in a wide variety of conditions.

Average Initial Set Schedule
For WELD-ON PVC / CPVC Solvent Cements**

Temperature Range	Pipe Sizes ½" to 1¼"	Pipe Sizes 1½" to 2"	Pipe Sizes 2½" to 8"	Pipe Sizes 10" to 15"	Pipe Sizes 15"+
60°-100°F	2 minutes	5 minutes	30 minutes	2 hours	4 hours
40°-60°F	5 minutes	10 minutes	2 hours	8 hours	16 hours
0°-40°F	10 minutes	15 minutes	12 hours	24 hours	48 hours

Note - Initial set schedule is the necessary time to allow before the joint can be carefully handled. In damp or humid weather allow 50% more set time.

Average Joint Cure Schedule
For WELD-ON PVC / CPVC Solvent Cements**

Relative Humidity 60% or Less	Cure Time Pipe Sizes ½" to 1¼"		Cure Time Pipe Sizes 1½" to 2"		Cure Time Pipe Sizes 2½" to 8"		Cure Time Pipe Sizes 10" to 15"	Cure Time Pipe Sizes 15"+
Temperature range during assembly and cure periods	up to 160 psi	above 160 to 370 psi	up to 160 psi	above 160 to 315 psi	up to 160 psi	above 160 to 315 psi	up to 100 psi	up to 100 psi
60°-100°F	15 min	6 hrs	30 min	12 hrs	1½hrs	24 hrs	48 hrs	72 hrs
40°-60°F	20 min	12 hrs	45 min	24 hrs	4 hrs	48 hrs	96 hrs	6 days
0°-40°F	30 min	48 hrs	1 hour	96 hrs	72 hrs	8 days	8 days	14 days

Note-Joint cure schedule is the necessary time to allow before pressurizing system. In damp or humid weather allow 50% more cure time.

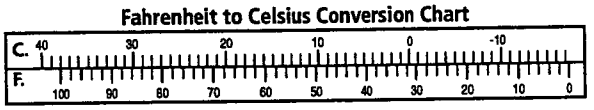
**These figures are estimates based on our laboratory tests; extended set and cure times are required for chemical applications. Due to the many variables in the field, these figures should be used as a general guide only.

Average Number of Joints/Qt. of WELD-ON Cement*

Pipe Diameter	½"	¾"	1"	1½"	2"	3"	4"	6"	8"	10"	12"	15"	18"
Number of Joints	300	200	125	90	60	40	30	10	5	2-3	1-2	¾	½

***For Primer: Double the number of joints shown for cement.**
These figures are estimates based on our laboratory tests. Due to the many variables in the field, these figures should be used as a general guide only.

Fahrenheit to Celsius Conversion Chart



WARNING - IPS Weld-On products must never be used in a PVC or CPVC system using or being tested by compressed air or gases.

web site: www.ipscorp.com

IPS WELD-ON

PPFA

INTRODUCTION

This installation *Handbook* is prepared through the voluntary efforts of the members of the Plastic Pipe and Fittings Association. The Plastic Pipe and Fittings Association (PPFA) is the trade association of manufacturers of plastic pipe and fittings, producers of raw materials used in them, and suppliers of related products and services to the plastic pipe and fittings industry. PPFA provides a full range of association services for its members and the industry.

The *Handbook* is organized in sections based on the application or end use for each type of plastic piping, namely, Drain, Waste and Vent (DWV); Water Service Piping; Hot and Cold Water Distribution; and Sewer and Drains.

PURPOSE and SCOPE

The purpose of the *Handbook* is to provide plumbers and other interested persons with a single publication that describes plastic pipe products and many of the generally accepted installation practices for plastic pipe and fittings currently being utilized in the United States. It does not contain all of the information needed for comprehensive plumbing design and practices using plastic piping. While PPFA has attempted to collect and describe the most widely used, generally accepted installation techniques, there are undoubtedly some that were not included in this *Handbook*. Subsequent editions may add, drop, amend, or revise practices contained herein.

It should be clearly understood that neither PPFA nor its members recommend any single (or even all) installation practice described in this *Handbook* for any specific application or system. Both practical considerations and logic preclude such recommendations because of the wide variety of products and the considerable variation in circumstances surrounding the installation of these products. Accordingly, any plumber or other installer must refer first to the manufacturer's installation instructions and recommendations for the product or products being used. Any inconsistency or discrepancy between those recommendations and instructions and the material in this *Handbook* must be resolved in favor of the manufacturer's installation recommendations or instructions.

We urge you to read and study all information available to you on plastic piping.

Plastic piping is used extensively in the plumbing field for DWV, water service, hot and cold-water distribution systems, sewers, and drains. Learn to recognize and compare the various types of plastic pipe and tubing. The general term "plastic pipe" is no more definitive than saying "metal pipe." Just as you recognize cast iron, galvanized steel, copper, stainless steel, and brass, you will want to become familiar with the different kinds of plastic pipe and the advantages each offers.

Tools designed exclusively for use with plastic piping are available. We suggest that you secure brochures from your suppliers covering these tools. They contribute greatly to the ease and precision of the installation.

Neither PPFA nor its members make any warranties or representations whatsoever, either stated or implied, relative to the fitness of any product, materials, or procedures referred to in this *Handbook* for any particular purpose or use. Many of the products in this *Handbook* are interrelated, and we strongly suggest you read it in its entirety before you begin working with plastic pipe and fittings.

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Select the proper cement for whichever material you are installing and the use conditions (e.g., pipe size and temperature). Check for the material designation (e.g., ABS or PVC), the ASTM number, and for a certifying laboratory seal or mark on the can.

Water testing of DWV systems usually can take place within one hour after the last joint is made. These piping systems shall not be tested with compressed air or other gases unless the procedure being used has been clearly and specifically approved by the manufacturer(s) of the plastic product or system to be tested.

Note: By virtue of their compressibility, compressed air and gases contain large amounts of stored energy which present serious safety hazards should a piping system fail for any reason.

SAFE HANDLING OF SOLVENT CEMENTS, PRIMERS, AND CLEANERS

NOTE: Solvent cements, primers, and cleaners MUST be handled properly.

ASTM Standard F 402, *Standard Practice for Safe Handling of Solvent Cements, Primers, and Cleaners* contains the following directions:

"Avoid prolonged breathing of solvent vapors. When pipe and fittings are being joined in partially enclosed areas, use a ventilating device as to maintain a safe level of vapor concentration with respect to toxicity and flammability in the work area. Select ventilating devices and locate them so as not to provide a source of ignition to flammable vapor mixtures."

KEEP CEMENTS, PRIMERS, AND CLEANERS AWAY FROM ALL SOURCES OF IGNITION, HEAT, SPARKS, AND OPEN FLAME.

Keep containers of cements, primers, and cleaners tightly closed except when the product is being used.

"Most of the solvents used in pipe cements, primers, and cleaners can be considered eye irritants and contact with the eye should be avoided as it may cause eye injury. Proper eye protection and the use of chemical goggles or face shields are advisable where the possibility of splashing exists in handling these products. In case of eye contact, flush with plenty of water for 15 min. and call a physician immediately."

"Avoid contact with the skin. Wear proper gloves impervious to and unaffected by the solvents when contact with the skin is likely. Application of the primers, cleaners, or solvent cements with rags and bare hands is not recommended. Brushes, daubers, and other suitable applicators can be used effectively for applying these products, thus avoiding skin contact. Dispose of used applicators in the same manner as the rags. In the event of contact, remove contaminated clothing immediately and wash skin with soap and water. Wash contaminated clothing before wearing them again."

Additional health and safety information is available on the manufacturer's Material Safety Data Sheet (MSDS).

Dispose of all rags and other materials used for mopping up spills in accordance with regulatory requirements. For additional information, review the MSDS for the product.

PVC-DWV - solvent cement joining

In addition to the above general solvent cement joining section, the following applies specifically to solvent cement joining of PVC pipes.

In the case of PVC-DWV, some codes require that a colored primer conforming to ASTM Standard F 656 be used prior to the application of PVC cement. CAUTION: DO NOT mix primer with cement in one container. Do not use cements that have gelled. Do not use so much cement or primer inside the joint that it leaves a puddle after assembly. The joining surfaces of both the pipe and the fitting should be wiped with a clean cloth to remove dirt and moisture. Apply the primer to the pipe and the fitting socket. Apply a heavy coat to the pipe and a thinner coat to the fitting socket. Immediately insert the pipe into the fitting socket turning the pipe 1/8 to 1/4 turn in the socket until it bottoms. This will help to obtain an even spread of cement. Be sure to align scribed marks on pipe and fittings at this point. Hold firmly for at least 15 seconds to prevent the pipe from "backing out" of the fitting. Wipe excess cement from the outside of the joint. Allow the joint to set properly vented to the atmosphere. Plastic pipe cements set up very rapidly; consult the cement manufacturer's instructions for curing times and other details. Some local codes may not require the use of primer. Be sure to check the requirements of the local codes and follow the instructions on the can of solvent cement for making the joint.

ABS-DWV - solvent cement joining

In addition to the above general solvent cement joining section, the following applies specifically to solvent cement joining of ABS pipes.

ABS-DWV joints are made in the same manner as PVC-DWV joints except that a primer is not used. The pipe and fitting surfaces must be clean and dry.

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Journal of Chromatography A, 775 (1997) 295–306

JOURNAL OF CHROMATOGRAPHY A

Speciation of organotin compounds released from poly(vinyl chloride) at increased temperature by gas chromatography with atomic emission detection

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Abstract

A method for sampling and analysis of airborne organotin compounds emitted from poly(vinyl chloride) (PVC) was developed and tested. The organotins originating from dibutyltin maleate, mono- and dioctyltin mercaptoacetate stabilizers were released from PVC under controlled conditions and recovered from the sorption part of a sampling tube. The composition of the sampling material in the tube was optimized to get a reproducible release and complete sorption of the target compounds and to simplify the extraction procedure. An optimized extraction procedure together with aqueous phase derivatization and determination by gas chromatography–atomic emission detection resulted in a selective and reproducible determination of the organotin compounds. Influences of different thermoplast temperatures, heating times, purge flow gases and purge flow rates on the release of organotins from PVC have been evaluated. Significant amounts of dibutyltin were found to be released from a PVC sample stabilized with dibutyltin maleate at temperatures of 108°C to 200°C. © 1997 Elsevier Science B.V.

Keywords: Sample handling; Derivatization, GC; Organotin compounds; Poly(vinyl chloride)

1. Introduction

Organotin compounds used as stabilizers for poly(vinyl chloride) (PVC) are applied in a large industrial scale. World consumption of organotins can be estimated to be about 25 000 tons per year [1,7]. These compounds are applied as additives to prevent dehydrochlorination of the polymer during processing and to strengthen the finished product against long-term degradation. Dialkyltin compounds are of the general structure R_2SnX_2 in which R usually corresponds to a methyl, *n*-butyl or *n*-octyl group; X may be a mercaptide or mercapto acid ester group or a carboxylate group such as maleate or laurate. Dialkyltins are esteemed because of their excellent thermostabilizing properties. In the case of elevated thermoplast temperatures which occur during the processing of the plastics like extrusion, milling, hot-wire cutting or bandsawing or in case of fire the stabilizers react with hydrochloric acid formed in the thermoplast to their corresponding dialkyltin dichlorides. These chemicals can therefore be expected to be present in environments where PVC is processed.

Organotin compounds have widely been applied in

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antifouling paints and as agrochemicals which has resulted in a substantial release of these substances into the aquatic environment. Due to the quantities involved and due to their toxicity to aquatic organisms, alkyltins are considered to be environmental pollutants [2–4]. Among them, tributyltin (TBT) and dibutyltin (DBT) have been included in the priority pollutant list of contaminants issued by the European Union [5]. Release of alkyltin compounds from other organotin-containing materials like PVC pipes has been suggested as a source of DBT and monobutyltin (MBT) in river water and effluents from sewage treatment plants [6–9]. Investigations on the occurrence of organotins in air have been made to a small extent [10,11]. Besides the simulation of the process of PVC combustion in an incineration plant [13], one work shows degradation products of dibutyltin mercaptide and dioctyltin mercaptide stabilizers detected in fumes released from PVC at 225°C [12]. References which specifically investigate organotin emissions from PVC into ambient air under various conditions and temperatures of plastics processing have not yet been published. Thus, the purpose of this study was to develop a method for quantitative determination of organotins released from PVC under controlled temperature and flow conditions.

In general, organotin compounds used as PVC stabilizers have not been found to be highly acutely toxic in toxicological investigations. On the other hand evidence was found for immunotoxic, genotoxic and teratogenic effects to rodents for dibutyltin dichloride and partly for dioctyltin dichloride [14,15]. Experiments which compared toxic effects of di- and tributylated tins on rodents state that an estimation of organotin toxicity should consider the toxicity of dibutyltin compounds beside the tributylated species [3]. For the present sufficient toxicological data are not available to evaluate their toxicity to mammalians.

Experimental parameters of this study have been chosen with consideration given to earlier results. Filters and adsorbents like Chromosorb 102, a set of two quartz fibre filters and charcoal filter as well as glass fibre filters were tested for sorption of alkyltins from ambient air or cooled PVC fumes [10–12]. However, the sorption efficiency of the materials was tested as retention efficiency of the materials spiked with pure organotins. In stability tests, the target compounds were shown to be stable for several weeks if stored on an adsorbent or a filter and kept at −20°C [3,11,16].

For the extraction of organotins from adsorbents and filters, from sediments or from polymers basically three procedures are used; extraction with solvents with or without a complexing agent, acid digestion followed by a solvent extraction or extraction by supercritical fluids. Dialkyltins can be quantitatively extracted from glass fibre filter (GFF) by hexane [12], whereas extraction of di- and trialkyltins from activated carbon fibre collection filter is difficult [11]. Acid digestion was found to be necessary for efficient extraction from particulate matter [2]. Diluted HCl (0.1 *M*) was found to be too weak, but on the other hand 2–8 *M* HCl caused degradation of the analytes [17]. One of the most often used extractants was methanolic HCl itself [3,4,11,18] or in combination with tropolone [6,19,20] or some other complexing agent [21]. While pure acetic acid was shown to be an inefficient extraction medium [22], methanolic acetic acid (0.5 *M*) used for the microwave assisted extraction of di- and tributyltins from sediments was proven to be successful [23]. Sonication was also found to be effective for extraction of organotins from sediment with 0.5 *M* HCl in MeOH [24]. On the other hand Soxhlet extraction using hexane–acetone was found to be an inappropriate method for DBT and MBT extraction from sediments [25]. Application of formic acid modified carbon dioxide for supercritical fluid extraction and chromatography of dimethyltin from PVC yielded complete extraction recoveries [26].

For GC analyses it is necessary to convert the dialkyltin dichloride species into fully alkylated derivatives. Among the available methods such as hydride generation [3,12], alkylation by Grignard reagents and direct aqueous phase ethylation using sodium tetraethylborate, the last method offers several advantages. Compared to hydride generation, alkyl derivatives obtained by direct aqueous phase ethylation or Grignard alkylation are more stable and can be stored for a limited time [7]. Direct aqueous phase ethylation [4] can be performed in a simple, fast way; solutions obtained by extraction of the derivatives into isooctane [23], pentane, or hexane [27] are directly applicable to GC. Ethylation of organotins in complex matrices is said not to suffer from interfer-

ences [24,28]. On the other hand, the yield of the ethylation reaction is influenced by the degree of alkylation and/or by the nature of the alkyl groups [28] of an organotin compound. The derivatization is also affected by pH, temperature of the solution, reaction time and concentration of the reagent [23,28].

An appropriate method for the determination of organotins consists in capillary GC with a selective detector. Several detectors used for the identification and the determination of organotins were compared in literature [21,25,29]. Most promising seems to be atomic emission detection (AED) with a microwave induced plasma. The advantages consist in multi-element and multi-channel detection, good linearity, selectivity and high sensitivity [17,21,30,31].

This work presents a sampling method for organotins released under controlled conditions from PVC at thermoplast temperatures between 108°C and 200°C and a method for their extraction from adsorbents, derivatisation by aqueous phase ethylation and determination by GC–AED.

2. Experimental

2.1. Apparatus

An adapted gas chromatograph Chrom 6 (Laboratory Works, Prague, Czech Republic) was used for sampling of organotins from heated PVC onto adsorbents. The instrument was provided with a high pressure (1.5 MPa) GC gas supply and a flow control. Using copper tubing the carrier gas output was connected to the sampling tube input near the bottom of the oven space. The sampling tube was fixed in a vertical position having the desorption part in the oven and protruding the injector chamber above the instrument box (Fig. 1). The adsorption part of the sampling tube was situated on top of the instrument. The sampling tube was isolated from the hot oven wall by a PTFE ring above which a round plastic bottle sealed in a fitting by silicone ring was placed round the sorption part of the sampling tube. The plastic bottle contained a water bath at 0°C.

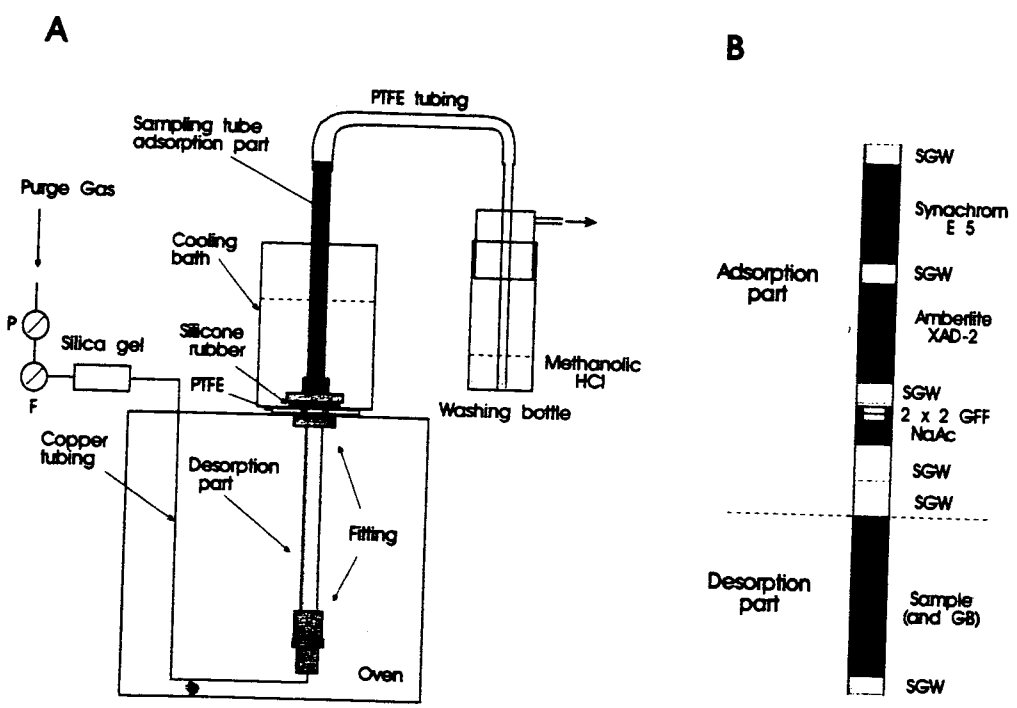

Fig. 1. Schematic diagram of the apparatus for sampling of organotin compounds (A) overwiew (B) composition of the sampling tube

Using a PTFE tubing the output of the sorption tube was connected to a washing bottle.

A Bransonic B 220 ultrasonic bath with an output power of 50 W was used to increase the mass transfer during the extraction and the derivatization of the organotins.

Separation of ethylated organotin species was performed using an HP Model 5890 Series II gas chromatograph (Hewlett–Packard, Avondale, PA, USA) coupled to an HP 5921A atomic emission detector. The GC system was equipped with an HP 7673 A automatic sample injector and an HP on-column injection inlet. This was fitted with a deactivated retention gap (HP, 0.3 m×0.53 mm I.D.) connected in series to a DB-1 fused-silica column (20 m×0.25 mm I.D., 0.1-μm film, J&W Scientific, Folsom, CA, USA). The GC column was connected directly to the AED cavity. Helium of 99.9999% purity was used as a carrier gas at a linear velocity 0.30 m s^{-1}. The GC–AED system was controlled by an HP 9000 CHEMSTATION. The AED response of the atomic emission detector was optimized to get the best selectivity and linearity. Optimal conditions were similar to those described in the literature [17,21,31]. The carbon channel at 248 nm was monitored together with the tin selective line at 271 nm. No interferences were noticed on the tin selective channel.

An Incos 50 quadrupole mass spectrometer (Finnigan MAT, San Jose, CA, USA) connected to a Varian 3400 gas chromatograph (Varian, Palo Alto, CA, USA) equipped with a DB-5-MS column (30 m×0.25 mm I.D., 0.25-μm film, J&W Scientific) was used for complementary solute identification.

2.2. Reagents

Dibutyltin dichloride was obtained from Fluka (Buchs, Switzerland), dioctyltin dichloride from Riedel-de Haën (Hannover, Germany), dimethyltin dichloride from Merck–Schuchardt (Hohenbrunn, Germany), dicyclohexyltin dibromide from Alfa (Karlsruhe, Germany), monobutyltin trichloride and tetrabutyltin from Aldrich (Milwaukee, WI, USA). They were all used as standards. Sodium tetraethylborate was obtained from Strem Chemicals (Bischheim, France). The chemicals were used without further purification. Isooctane and methanol as well as acetic acid and sodium acetate (all from Merck) were of analytical grade. Hydrochloric acid (Merck) was of suprapure quality. Silane treated glass wool and Amberlite XAD-2 were obtained from Supelco (Bellefonte, PA, USA). Whatman glass fibre filters type GF/B were used (Whatman, Maidstone, UK) and regular glass beads, 80–120 mesh, were from Applied Science Labs. (State College, PA, USA). All other chemicals were of suprapure quality and were obtained from Lachema (Brno, Czech Republic).

2.3. PVC samples

Two different PVC samples were applied. Sample 1 consisted of pellets containing a mixture of di-*n*-octyltin di(2-ethylhexyl-mercaptoacetate) and mono-*n*-octyltin tris(2-ethylhexyl-mercaptoacetate) at a content of 0.21% Sn. Sample 2 was a powder containing dibutyltin di(methylmaleate) at a content of 0.62% Sn. Both samples were obtained from Hydroplast (Helsingborg, Sweden).

2.4. Procedure

2.4.1. Sampling

Sampling of the organotins released at elevated temperatures from the PVC samples was achieved by using a glass tube (0.30 m×7 mm I.D.), consisting of a desorption part filled with a PVC sample and immersed in the GC oven, as shown in Fig. 1, and a cooled sorption part packed with filters and adsorbents. Regular glass beads were in some cases mixed with the PVC sample 1 in order to prevent clogging of the tube. The optimal set-up of the sorption part corresponding to 1.5 g of PVC in the desorption part consisted of 0.2 g of sodium acetate, two couples of Whatman GF/B glass fibre filters, 0.8 g of Amberlite XAD-2 and 0.6 g of Synachrom E5. Each layer was separated from the upper and the lower layer with a small plug of silylated glass wool. Twice the amount of the silylated glass wool was placed in between the desorption and adsorption part of the glass tube. The glass fibre filters were fixed in the glass tube by PTFE-coated rings cut out from a GC inlet septa. The washing flask connected with the outlet of the sorption part of the glass tube was filled with 25 ml of 1 *M* HCl in methanol. A flow of

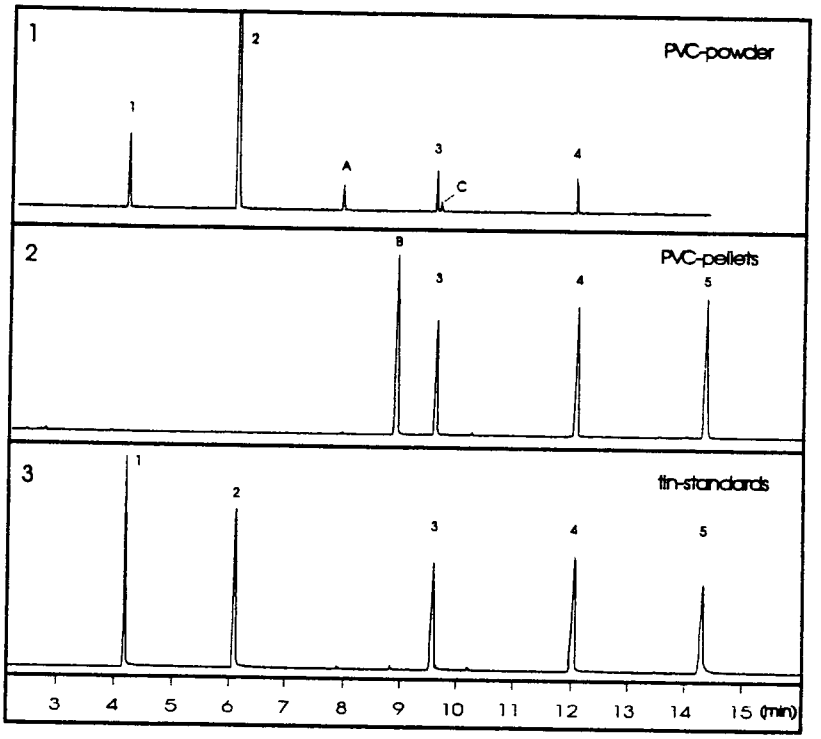

Fig. 2. Gas chromatographic separation of organotin compounds using the tin-selective channel at 271 nm emission wavelength for detection. Chromatograms 1 and 2: organotin compounds released from PVC (conditions: temperature 200°C, purge gas air, 2 h sampling) compound A=tributyltin chloride, B=monooctyltin trichloride, C=octylbutyltin dichloride, other peaks correspond to chromatogram 3. Chromatogram 3: standard compounds: 1=monobutyltin trichloride, 2=di-butyltin dichloride, 3=tetrabutyltin (I.S.), 4=dicyclohexyltin dibromide (spiked), 5=dioctyltin dichloride.

nitrogen or air was precleaned by passing through a tube with a dry silica gel prior to entering the glass sampling tube and the GC oven was heated up to the desired temperature for a particular time. Each experiment was done twice. The sampling tubes were stored at −20°C for about 6 weeks before the analyses.

2.4.2. Leaching and derivatization

The adsorption part of the sampling tube including the glass wool between the desorption and adsorption part was cut into pieces and transferred into a screw-capped extraction tube. Each sample was spiked with dicyclohexyltin dibromide as internal standard and extracted with 6 ml of 0.01 *M* HCl or 1 *M* acetic acid in methanol under sonication for 90 min. After each 30 min, 4 ml of the extraction solution was exchanged for new solvent. The direct aqueous phase derivatization was performed similarly to a procedure described in the literature [23,28]. The pH of the collected extraction solution was adjusted to between 4.5 and 5.0 by an acetic acid–acetate buffer. A 1-ml volume of a freshly prepared solution of sodium tetraethylborate ($NaBEt_4$) in Milli-Q water (25 mg ml^{-1}) giving about a 20-fold molar excess to an assumed maximum quantity of 2 mg dialkylated tin compound was given to each extract at room temperature. After standing for 2–3 min the second internal standard, tetrabutyltin (TeBT) was added in 2 ml of isooctane. After being vigorously shaken for 5 min the mixture was left to separate and the organic phase containing the ethylated derivatives was exchanged with pure isooctane. This was repeated twice. The collected isooctane phase was directly analyzed by GC–AED.

GC–AED analysis: A 1-μl volume of sample was injected on-column at an initial oven temperature of 80°C. The temperature was held for 1 min, then

raised at a rate of 10°C min^{-1} to 220°C and further at a rate of 40°C min^{-1} to 300°C and kept there for 2 min.

3. Results and discussion

3.1. Optimization of the determination of organotins

3.1.1. Extraction efficiency

The effect of the extraction time and type of extractant on the extraction yield of the expected main decomposition products (dibutyltin dichloride, dioctyltin dichloride) from organotin stabilizers used in the PVC samples was estimated for the sorption materials applied in the sampling tube. For this, sodium acetate, glass fibre filter and Amberlite XAD-2 at an amount of 0.5 g as well as blanks were spiked with equal amounts of dibutyltin and dioctyltin dichlorides, each at a level of 0.33 mg total tin per gram adsorbent. Following extraction, derivatization and quantitation with internal standard were carried out in the same way for both the adsorbents and blanks. Recoveries from the adsorbents were related to blank recoveries. Two different extractants, 0.01 *M* HCl in methanol and 1 *M* acetic acid in methanol were applied at 3 different extraction times (15, 30 and 90 min). More concentrated methanolic HCl was avoided with respect to possible salt precipitations during the buffering process before the aqueous phase ethylation. While dibutyltin dichloride was quantitatively recovered from all adsorbents after 15 min of extraction with any of the extractants applied, 90 min extraction time was necessary for good recovery of dioctyltin dichloride from glass fibre filters and from XAD-2 adsorbent. The results for 90 min extraction time are summarized in Table 1. Both applied extractants showed almost equal abilities to extract the dialkytins. Methanolic HCl was selected for further experiments due to slightly better recoveries of dioctyltin (DOT) from Amberlite XAD-2. To enhance the extraction, the solution was exchanged with fresh extractant every 30 min. A lowered recovery for DOT from Amberlite XAD-2 indicates the need for a bit less polar extraction reagent to achieve an efficient extraction. Preliminary experiments showed that the more polar species monobutyltin could be fully sorbed and extracted from the sodium acetate layer applied in this study. In this way incomplete extraction of this compound reported can be overcome [3,4].

3.2. Derivatization

The choice of parameters for the ethylation procedure was adopted from experimental results described in [23,28]. The somewhat lower recoveries of DOT were shown to originate from the extraction step by blank experiments in which both dicyclohexyltin (DCyHT) and DOT showed the same complete derivatisation as DBT. The aqueous phase ethylation of the extracted ionic organotin species was compared to a direct in situ ethylation. In the later case the solution of sodium tetraethylborate was added directly onto the Amberlite XAD-2 adsorbent spiked with the organotin mixture and suspended in buffered methanolic HAc (pH 5.0). The extraction/derivatization was performed for 15 min and then the ethylated species reextracted into isooctane containing TeBT as the internal standard, similarly as with the direct aqueous phase ethylation. The results summarized in Table 2 show much lower recoveries for in situ derivatization. Therefore, the two-step procedure was used in this work. It must be noted that the in situ derivatization has been successfully

Table 1
Extraction recoveries (%) of organotin species from sorption materials used in the sampling tube

	Sorbent/Extractant				
	NaAc/HAc	GFF/HCl	GFF/HAc	XAD-2/HCl	XAD-2/HAc
DBT	109	108	94	94	93
DOT	110	99	99	80	68

NaAc, sodium acetate; GFF, glass fibre filter; XAD-2, Amberlite; HAc, acetic acid.
Extraction time 90 min.

Table 2
Organotin recoveries (%) from Amberlite XAD-2 by a two-step procedure of extraction and derivatization compared to one-step in situ derivatization

	Procedure	
	Two-step	One-step in situ
DBT	104	72
DOT	72	<10

Extraction time 15 min.

used for the determination of organotin compounds in tissues, however, at a cost of a strong increase in the consumption of the reagent [17].

3.3. GC determination and evaluation

Fig. 2 shows tin-specific chromatograms from the GC–AED analysis of the alkyltin compounds released from PVC samples using air as purge gas. The peaks were identified with the help of standards using GC–AED and from GC–MS analyses. The main tin containing decomposition products released from PVC were considered to be the chloride derivatives of the original monooctyltin, dioctyltin and dibutyltin stabilizers. While DOT was not proven to dealkylate to MOT dealkylation of DBT to MBT was found when using air as purge gas. Other minor tin components tentatively identified (tributyltin and butyloctyltin species) were considered to be a biostabilizer of the plast and a contaminant respectively.

Only a few tin-free compounds were found among the decomposition products in the extract of the adsorbents from the sampling tube as shown for sample 2 in Fig. 3. This documents a selective sorption and a selective extraction of the organotin species from the adsorbents.

The minimum detectable amount of tin released from PVC by the procedure was estimated from a spiking experiment. The glass wool placed between the desorption part, packed with a raw, tin-free PVC sample, and the trapping part of the sampling tube was spiked with 6.2 mg tin as DBT. The sampling tube was heated to 200°C for 4 h which was found sufficient to release all DBT from the glass wool. The minimum detectable level based on a ratio of DBT response to noise level equal three (peak

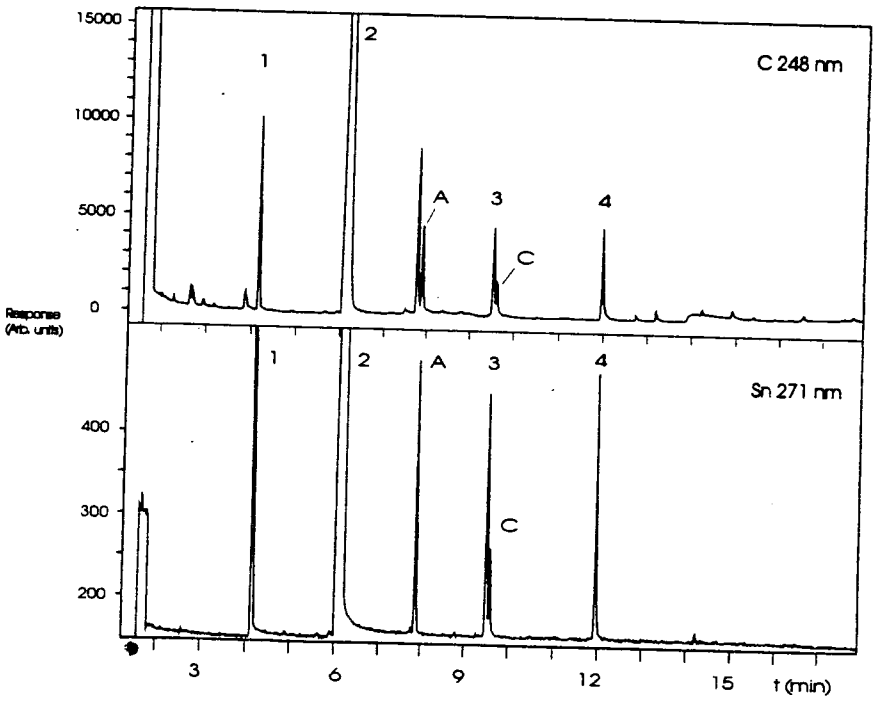

Fig. 3. Carbon and tin specific chromatograms of the derivatised extract from sample 2; conditions and solute identification as in Fig. 2

heights measured) was estimated to 20 ng tin per gram PVC.

Two internal standards were used for the evaluation. Quantification of DBT was done by help of TeBT added after the derivatization. DCyHT was shown to exhibit complete recovery and was used for quantification of DOT.

The linearity of GC–AED was about 3 orders of magnitude from the minimum detectable level using peak heights and even better when peak areas were used. However, this was not enough for estimation of low concentrations of some decomposition products at the same time as high concentrations of the main released organotins, especially of DBT. In this case one level of I.S. concentration was not applicable. Therefore, the amount of I.S. added before GC–AED analysis was selected to fit to minor components and the major components were determined from a diluted sample by the method of standard addition of the I.S. In this way, the absolute AED response overcame the lack of linearity for the major components. Peak heights were used for the peak evaluation, as they were shown to give slightly more precise results for small peaks when using GC–AED [32]. The relative standard deviation of the solute amount estimated by the above described procedure using different dilution was mostly below 10%.

3.4. Sampling of organotins released from the PVC samples

A set-up for controlled heating and release of organotin compounds from a PVC sample has been designed and tested at different temperatures and purge gas flows for different geometrical shapes of the sample. At the temperature interval applied, it was possible to maintain a constant purge gas flow through sample 2 (PVC powder containing dibutyltin methylmaleate). The pellets of the sample 1 were much more prone to stick together and therefore their mixing with an inert material was necessary together with an increased pressure of the purge gas at the sampling tube inlet to maintain a constant flow. Glass beads, 80–120 mesh, proved to serve well for this purpose at 65% of the PVC mass. An increased amount of glass beads had no effect on the release of the organotin compounds from the PVC sample.

Preliminary experiments using an atomic absorption spectrometer were aimed at determining a possible breakthrough of organotins into methanolic HCl, placed after the sorption system, as shown in Fig. 1. The collection efficiency of the set-up of filters and adsorbents was over 99.5% for gas volumes up to 200 l (3 experiments). Higher gas volumes were not investigated. A washing bottle with the methanolic HCl was placed behind the sorption part of the sampling tube in all experiments. In selected cases the content of the washing bottle was analyzed for tin species. In these cases tin compounds were proved to be absent. All the materials used for the sorption part of the sampling tube as well as the glass tube, glass wool and the glass beads were proved to be tin-free.

The sorption part of the sampling tube (Fig. 1) was designed to retain quantitatively organotins from both the vapor and particulate phase and to provide a sufficient retention capacity. The sorption ability of the different adsorbent layers and of the glass fiber filters was tested with a basic set of conditions (temperature at 200°C, gas purge flow at 100±20 ml min^{-1} and 4 h of heating).

Additionally, the organotins should be protected from decomposition when being stored for several weeks. Heated PVC releases hydrochloric acid, which possibly could increase the elution power of the purge gas and thus spread the organotins over the entire sorbing system or even decrease the recovery. Furthermore, the stability of organotin compounds under strongly acidic conditions has been questioned [18]. For this reason the first layer in the sorption part consisted of sodium acetate. As shown in Table 3 omitting this layer resulted in incomplete recovery.

Table 3
Dibutyltin amounts in different sorption layers of the sampling tube

Sample	1 (mg g^{-1})	2 (mg g^{-1})	3 (mg g^{-1})	4 (mg g^{-1})
NaAc	2.18	Na	Na	[a]
GFF	1.54	0.46	Na	[a]
XAD	0.43	2.36	2.41	[a]
Total	4.15	2.82	2.41	4.36

[a] The layer was applied in the sorption part, the amount of DBT was estimated from all sorption layers together.
Na=not applied.
Purge flow gas nitrogen.

On the other hand, when included, the main part of the released organotins was found in the sodium acetate layer. Almost equal total amounts of collected dibutyltin species were obtained from two comparable sampling tubes, of which the first one was analyzed partially layer by layer, the other in one analysis of all adsorbents together. Though the particulate phase which may contain the polar organotin compounds might be sorbed as well on the applied adsorbent (XAD-2), the best way to collect it consists in sorption on a GFF. Therefore, two sets of GFF were included after the sodium acetate layer. When using the standard set-up (see Fig. 1), including sodium acetate, glass fibre filters, XAD-2 and Synachrom E5 in series, the last layer of Synachrom E5 did not contain any organotin compounds sorbed. It was therefore excluded. The distribution of all alkyltins in the applied sorption system when using air as purge gas is shown in Table 4. The sampling tubes containing sodium acetate were found applicable for storage up to two months at −20°C. This was proved by spiking experiments which showed complete recovery of the spiked amounts.

Both nitrogen and air were used as purging gases to consider inert processing atmosphere as well as thermal stressing by air. While the released organotin species and their composition did not differ for different purge gases for the octyltin mixture, a slightly increased release of dibutyltin and decomposition to its monoalkylated form was found for the dibutyltin stabilizer (Table 5) when using air as purge gas. Taking literature data [1] into account, an almost equal release of DBT for different purge gases indicates the possibility for a release of the stabilizer itself beside the derivative from the decomposition process. A release of MBT indicates a dealkylation of the stabilizer in the presence of oxygen. DBT accounted for up to 98% of all released organotins from sample 2, while MBT contributed about 0.8%. The amounts of other minor components present in the sample 2 as TBT and BOT were similar irrespective of the purge gas applied.

Table 5
Comparison of the release of organotin compounds from PVC samples using nitrogen and air as a purge gas

Purge gas	MBT (mg g^{-1})	DBT (mg g^{-1})	MOT (mg g^{-1})	DOT (mg g^{-1})
N_2	0.06	4.15	0.29	0.60
Air	0.27	4.35	0.25	0.60

3.5. Effect of temperature, heating time and purge gas flow on the release of organotin compounds

3.5.1. Temperature

The amounts of released dibutyl- and octyltin compounds from commercially available PVC at temperatures of 110°C, 150°C and 200°C at different heating times are shown in Fig. 4 and Table 6. For thermoplast temperatures of 200°C high quantities of both target compounds could be determined. At 150°C the release of the less volatile octyltins is significantly decreased and occurs only for heating times above 8 h. At this temperature dibutyltin is still emitted with quantities of milligram per gram PVC. When the temperature is reduced to 108°C only DBT is detectable. At a sampling time of 32 h an increased DBT-release could be observed in the range of microgram DBT per gram PVC. A decrease

Table 4
Alkyltin distribution in the applied sorption system

Sorbent	MOT (mg g^{-1})	DOT (mg g^{-1})	MBT (mg g^{-1})	DBT (mg g^{-1})	TBT (mg g^{-1})	BOT (mg g^{-1})
NaAc	0.12	0.27	0.25	0.95	0.00	0.08
GFF	0.01	0.44	0.00	3.08	0.09	0.00
XAD	0.12	0.00	0.00	0.32	0.04	0.00
Total	0.25	0.71	0.25	4.35	0.13	0.08
AAT	0.32	0.62	0.25	4.43	0.10	0.05

Conditions: temperature 200°C, purge gas flow 100 ml min^{-1} air, sampling time 4 h.
AAT: all sorption layers analyzed together.

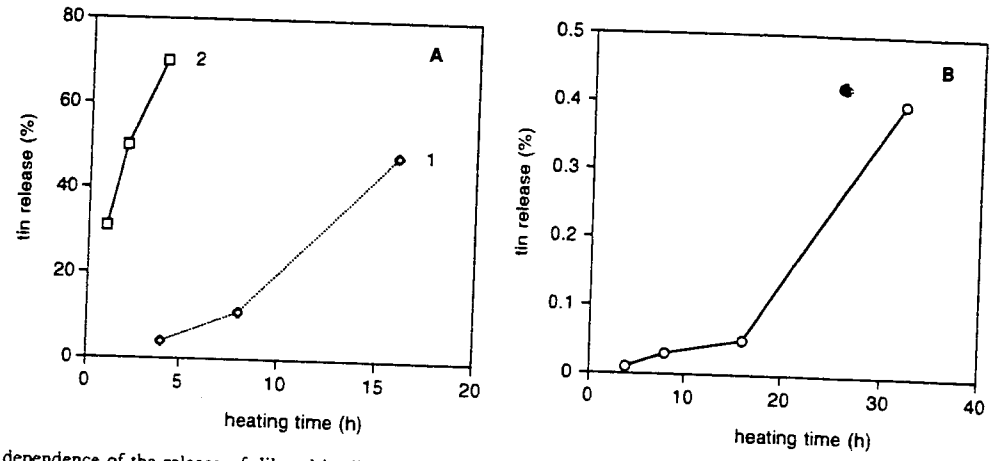

Fig. 4. Time dependence of the release of dibutyltin dichloride from PVC. (A) At a temperature of (1) 150°C and (2) 200°C: (B) at 110°C (unit: percent of total tin-content in the thermoplast)

of the release of MBT with decreasing temperature was found to be much more profound than for DBT, which indicates that MBT is formed to a lower extent at lower temperatures. This effect could not be seen for MOT and DOT.

3.5.2. Heating time

The dependence of the release of all detected organotins on heating times between 1 and 4 h was determined. The results are summarized in Fig. 5 and Table 7. A comparable speed of tin release was found for both PVC samples, the amounts of release were quite different. The differences consisted of increased volatility of DBT and highly differing surface areas of both materials. The number of measurements is too limited to be able to suggest kinetic data of the release.

Table 6
Alkyltin emission quantities (mg g^{-1} PVC) depending on PVC-temperature and heating time

Temperature (°C)	Heating time (h)	MBT	DBT	TBT	MOT	DOT
200	4	0.270	4.350	0.14	0.250	0.710
150	4	Nd	0.223	0.10	0.003	Nd
150	8	Da	0.680	0.16	0.003	Da
150	16	0.002	3.000	0.19	0.004	0.007
110	16	Nd	0.003	0.06	Nd	Nd
110	32	Nd	0.024	0.06	Nd	Nd

Nd=not detected.
Da=detectable amount.

3.5.3. Purge gas flow

The release of organotins consists of the transport inside the PVC bulk material, transfer into the gas phase, and transport in the gas phase. A purge gas velocity of about 60 mm s^{-1} was used in this study. This was supposed to be sufficient to sweep out the released organotins. Small fluctuations of the purge gas flow should not influence the results because diffusion inside the bulk material limits the release process. The effect of the purge gas flow on the amount of the organotins released from PVC sample 2 is shown in Table 8. It is possible to conclude that the differences in the estimated amount of released DBT at different purge gas flows are insignificant.

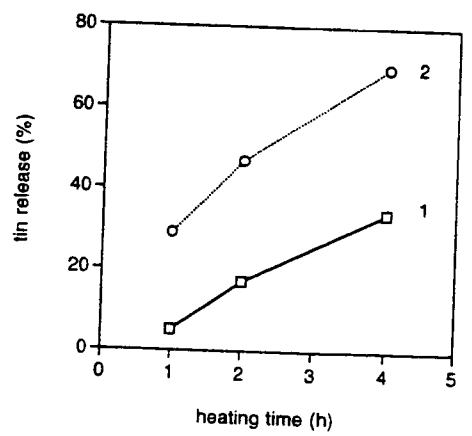

Fig. 5. Time dependence of the release of the main organotin compounds from PVC samples at a temperature of 200°C. (1) DOT, (2) DBT.

Table 7
Dependence of the release of alkyltin chlorides on the heating time

Time	MOT		DOT		MBT		DBT		TBT		BOT	
	mg g^{-1}	% Sn	mg g^{-1}	% Sn	mg g^{-1}	% Sn	mg g^{-1}	% Sn	mg g^{-1}	% Sn	mg g^{-1}	% Sn
1 h	0.18	9	0.10	5	0.08	1	1.94	31	0.07	1	0.00	
2 h	0.40	19	0.34	16	0.18	3	3.11	50	0.11	1	0.03	
4 h	0.25	12	0.60	30	0.25	4	4.35	70	0.13	1	0.08	1

Conditions: temperature 200°C, purge gas flow 100 ml min^{-1} air.

However, the amount of released MBT shows a tendency to increase with an increasing purge gas flow. This might be explained by an increased air exchange which, as shown above, could promote the decomposition of the DBT carbonate type of stabilizer into monobutyltin chloride. The fluctuations of the purge gas flow at our set-up did not exceed 20% which could not affect the obtained results at these amounts.

4. Conclusions

This work shows that organotin compounds are released from PVC at elevated temperatures. Using the described experimental set-up, a reproducible release of the target compounds was achievable. The choice of the adsorption layers was found to be important for complete retention and effective extraction. The amounts of released dibutyltin stabilizer might possibly imply a need to monitor the work environment where PVC is processed and installed. Further investigations in this direction should consider diverse surface characteristics of differing PVC materials. Of additional interest could be a monitoring of organotin emissions from PVC at temperatures below 100°C and the development of a matching analytical method for this purpose to determine possible long-term emissions from thermally stressed thermoplasts. The GC–AED technique provides excellent determination capabilities for this purpose.

Table 8
Dependence of the release of butyltin compounds on the gas flow-rates

Flow-rate (ml min^{-1})	MBT (mg g^{-1})	DBT (mg g^{-1})	TBT (mg g^{-1})
50	0.33	4.68	0.14
100	0.27	4.35	0.14
200	0.60	4.96	0.10

Conditions as in Table 4

Acknowledgments

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SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

Attachment 1 to the Governing Board Resolution for Proposed Amended Rule 1168 – Adhesive and Sealant Applications:

Statement of Findings and Statement of Overriding Considerations

SCAQMD No. 121101BAR

May 2002

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TABLE OF CONTENTS

INTRODUCTION 1-1

SUMMARY OF THE PROPOSED PROJECT 1-1

SIGNIFICANT ADVERSE IMPACTS THAT
CANNOT BE REDUCED BELOW A SIGNIFICANT LEVEL 1-1

STATEMENT OF FINDINGS 1-1

STATEMENT OF OVERRIDING CONSIDERATIONS 1-2

MITIGATION MONITORING PLAN 1-4

ATTACHMENT 1

Introduction

Summary of the Proposed Project

Potential Significant Adverse Impacts Mitigated Below a Significant Level

Potential Significant Adverse Impacts that Cannot Be Reduced Below a Significant Level

Statement of Findings

Statement of Overriding Considerations

Mitigation Monitoring Plan

INTRODUCTION

Proposed amended Rule 1168 – Adhesive and Sealant Applications (PAR 1168), is a "project" as defined by the California Environmental Quality Act (CEQA) (California Public Resources Code §§21000 et seq.). The South Coast Air Quality Management District (SCAQMD) is the lead agency for the proposed project and, therefore, has prepared an Environmental Assessment (EA) pursuant to CEQA Guidelines §15252 and SCAQMD Rule 110. The purpose of the EA is to describe the proposed project and to identify, analyze, and evaluate any potentially significant adverse environmental impacts that may result from adopting and implementing the proposed project. The Draft EA was circulated to the public for a 45-day review and comment period from March 5, 2002, to April 19, 2002. The SCAQMD did not receive any comments during the 45-day public review and comment period.

SUMMARY OF THE PROPOSED PROJECT

The SCAQMD is proposing the following amendments to Rule 1168: establish an interim limit of 540 grams per liter of VOC, less water and exempt compounds for top and trim adhesives used in the automotive and marine top and trim industry effective upon adoption of the proposed amendments until January 1, 2004 when the VOC limit will be reduced to 250 grams per liter; extend the compliance date for polyvinyl chloride (PVC) and other specialty applications of plastic welding products until January 1, 2005; extend the exemption of shoe repair adhesives until July 1, 2008 when the VOC limit will be established at 250 grams per liter; exempt the use of high VOC adhesives used in the fabrication of prostheses and orthotics; prohibit the sale and use of adhesives, sealants and adhesive and sealant primers containing chloroform, ethylene dichloride, methylene chloride or perchloroethylene on and after January 1, 2004; remove the interim compliance date of January 1, 2003 to permanently exempt adhesives used for thin metal laminations provided that the VOC content is less than 780 grams per liter; and, in addition to the proposed compliance dates elsewhere in the rule, and allow a one-year sell through and use of previously compliant adhesives and sealants for shoe repair and top and trim adhesives plus products containing methylene chloride.

POTENTIAL SIGNIFICANT ADVERSE IMPACTS THAT CANNOT BE REDUCED BELOW A SIGNIFICANT LEVEL

The primary effect of the proposed amendments is expected to be the loss of anticipated interim VOC emission reductions from top and trim adhesives totaling 1,078 pounds per day between September 1, 2001 and January 1, 2004 and from shoe repair adhesives totaling 413 pounds per day between September 1, 2001 and July 1, 2008. The estimated amount of permanent emission reductions foregone from exempting adhesives used in fabricating orthotics and prosthetics is approximately four pounds of VOC per day. In addition, the estimated amount of permanent emission reductions foregone beginning January 1, 2003 for thin metal lamination applications is 2.7 pounds of VOC per day. Further, anticipated VOC emission reductions of 1,700 pounds per day from plastic pipe cements and primers would be delayed two years, from January 1, 2003 to January 1, 2005. Both interim and permanent VOC emission reductions foregone and VOC emission reductions

delayed would exceed the SCAQMD's VOC significance threshold of 55 pounds per day. Therefore, it is concluded that PAR 1168 has the potential to generate significant adverse air quality impacts. Rule 1168 is being amended because compliant products are currently not available. Consequently, there are no measures available to mitigate significant adverse air quality impacts from the proposed project.

STATEMENT OF FINDINGS

Public Resources Code §21081 and CEQA Guidelines §15091(a) state that "No public agency shall approve or carry out a project for which an EIR has been completed which identifies one or more significant adverse environmental effects of the project unless the public agency makes one or more written findings for each of those significant effects, accompanied by a brief explanation of the rationale for each finding." Additionally, the findings must be supported by substantial evidence in the record (CEQA Guidelines §15091(b)). As identified in the Final EA and summarized above, the proposed project has the potential to create significant adverse air quality impacts as a result of future emission reductions foregone. The SCAQMD Governing Board, therefore, makes the following findings regarding the proposed project. The findings are supported by substantial evidence in the record as explained in each finding. This Statement of Findings will be included in the record of project approval and will also be noted in the Notice of Determination. The Findings made by the SCAQMD Governing Board are based on the following significant adverse impacts identified in the Final EA.

Potential VOC emission reductions foregone exceed the SCAQMD's significance thresholds and cannot be mitigated to insignificance.

Finding and Explanation: The air quality analysis concludes that the potential loss of anticipated interim VOC emission reductions from top and trim, shoe repair, and thin metal laminating adhesives, and the delay of VOC emission reductions from plastic pipe cements and primers may result in emissions of VOC that exceed the SCAQMD's daily CEQA significance threshold of 55 pounds per day.

The Governing Board finds that no feasible mitigation measures have been identified to eliminate or minimize the potentially significant adverse impact to air quality. CEQA defines "feasible" as "capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social, and technological factors" (Public Resources Code §21061.1).

The Governing Board finds further that a Mitigation Monitoring Plan (pursuant to Public Resources Code § 21081.6) need not be prepared since no feasible mitigation measures were identified.

The Governing Board finds further that aside from the No Project Alternative, the Final EA considered alternatives pursuant to CEQA Guidelines §15126.6, but no project alternatives would reduce to insignificant levels the significant air quality

impacts identified for the proposed project and still achieve the objectives of the proposed project.

STATEMENT OF OVERRIDING CONSIDERATIONS

If significant adverse impacts of a proposed project remain after incorporating mitigation measures, or no measures or alternatives to mitigate the adverse impacts are identified, the lead agency must make a determination that the benefits of the project outweigh the unavoidable adverse environmental effects if it is to approve the project. CEQA requires the decision-making agency to balance, as applicable, the economic, legal, social, technological, or other benefits of a proposed project against its unavoidable environmental risks when determining whether to approve the project (CEQA Guidelines §15093 [a]). If the specific economic, legal, social, technological, or other benefits of a proposed project outweigh the unavoidable adverse environmental effects, the adverse environmental effects may be considered "acceptable" (CEQA Guidelines §15093 [a]). Accordingly, a Statement of Overriding Considerations regarding potentially significant adverse air quality impacts resulting from the proposed project has been prepared. This Statement of Overriding Considerations is included as part of the record of the project approval for the proposed project. Pursuant to CEQA Guidelines §15093(c), the Statement of Overriding Considerations will also be noted in the Notice of Determination for the proposed project.

Despite the inability to incorporate changes into the project that will mitigate potentially significant adverse air quality impacts to a level of insignificance, the SCAQMD's Governing Board finds that the following benefits and considerations outweigh the significant unavoidable adverse environmental impacts:

1. The analysis of potential adverse environmental impacts incorporates a "worst-case" approach. This entails the premise that whenever the analysis requires that assumptions be made, those assumptions that result in the greatest adverse impacts are typically chosen. This method likely overestimates the actual emission reductions foregone from the proposed project.

2. The long-term effect of PAR 1168, other SCAQMD rules, and AQMP control measures is the reduction of emissions district-wide, contributing to attaining and maintaining the state and federal ambient air quality standards. Rule 1168 will continue to reduce emissions from adhesive and sealant applications, albeit over a longer period of time. The amendments will not increase emissions, but rather would delay originally anticipated emission reductions from sources subject to the rule. The long-term effect of the proposed amendments is a permanent loss of anticipated VOC emission reductions of less than seven pounds per day, which does not exceed the SCAQMD's VOC significance threshold of 55 pounds per day.

3. Overall emission reductions achieved by implementation of Rule 1168, other SCAQMD rules and regulations, and future AQMP control measures would ensure the potential emission reductions delayed and foregone as a result of PAR

1168 would not result in significant adverse cumulative air quality effects. Additionally, PAR 1168 provides human health benefits by reducing toxic emissions from sources using adhesive and sealant applications over time. In particular, PAR1168 would prohibit the use of products containing chloroform, ethylene dichloride, methylene chloride, perchloroethylene, and trichloroethylene.

The SCAQMD's Governing Board finds that the above-described considerations outweigh the unavoidable significant effects to the environment as a result of the proposed project.

MITIGATION MONITORING PLAN

When making findings as required by Public Resources Code §21081 and CEQA Guidelines §15091, the lead agency must adopt a reporting or monitoring program for the changes to the project which it has adopted or made a condition of project approval in order to mitigate or avoid significant effects on the environment (Public Resources Code §21081.6 and CEQA Guidelines §15097[a]).

The Governing Board finds that, in the case of PAR 1168, a Mitigation Monitoring Plan need not be prepared since no feasible mitigation measures were identified.

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Frequently Asked Questions

1.What is the difference between pipe cleaner, primer/c and primer?

All pipe surfaces should be thoroughly cleaned with pipe cleaner. cleaner is formulated to remove surface dirt and any oils or grease on the pipe from the manufacturing process. Primer/Cleaner and P contain more aggressive solvents and will soften the pipe surface t solvent cement to penetrate more effectively. Primer is often requi plumbing code and sometimes a purple colored primer is needed.

2. What temperature should solvent cements be applied

While we recommend that the cement be applied between 40-100 weather conditions may not make this feasible. A strong solvent w can be made at temperatures below freezing, as long as the cement cure times are extended and other handling precautions are follow

3. What is the difference between PVC, CPVC and AB

These are three different types of plastic pipe used in plumbing ap PVC is Poly(Vinyl) Chloride, CPVC is Chlorinated Poly(Vinyl) C and ABS is Acrylonitrile-Butadiene-Styrene. PVC and ABS pipe a normally used for Drain, Waste and Vent (DWV) systems, while C used for water distribution systems. It is important to choose the c solvent cement based on the type of plastic pipe being used.

4. What is the recommended cure time?

The cure time is dependent on several factors. The pipe size, socke ambient temperature, relative humidity, solvent cement used and t operating pressure should all be considered when determining cur The following chart can be used as a guideline to determine joint c

Pipe Size Movement of Joint 10% of Rated Pipe Pressure
100% of Rated Pipe Pressure HOT WEATHER- 90 to
150 degree F Surface Temperature

1/2 thru 1-1/4"	1/4 hr.	1 hr.	4 hrs.
1-1/2 thru 2-1/2"	1/2 hr.	1-1/2 hrs.	6 hrs.
2-1/2 thru 4"	3/4 hr.	2-3/4 hrs.	8 hrs.

Over 4" 1 hr. 3-1/2 hrs. 10 hrs. MILD WEATHER- 50-90

degree F Surface Temperature

1/2 thru 1-1/4"	1/3 hr.	1 hr.	5 hrs.
1-1/2 thru 2-1/2"	3/4 hr.	1-3/4hrs.	8 hrs.
2-1/2 thru 4"	1 hr.	3-1/2 hrs.	15 hrs.

Over 4" 1-1/2 hrs. 4 hrs. 20 hrs. COLD WEATHER- 0-50 degree F Surface Temperature

1/2 thru 1-1/4"	1/2 hr.	1-3/4 hrs.	7 hrs.
1-1/2 thru 2-1/2"	3/4hr.	3 hrs.	10 hrs.
2-1/2 thru 4"	1-1/3 hrs.	6hrs.	18 hrs.
Over 4"	2-1/2 hrs.	12 hrs.	30 hrs.

5. What type of applicator should be used to apply the s cement?

Each of our cements (excluding gallon sizes) have a dauber includ can. This dauber can be used to apply cement to pipe sizes up to 3 3" diameter, we recommend the applicator (brush, roller, etc) to be pipe diameter.

6. Should a gelled or lumpy cement be used?

We do not recommend attempting to thin solvent cements. The sol the can will evaporate if left open for extended periods of time, ca product to thicken or gel. Do not use gelled or thickened cements pipe.

7. What cement should be used for PVC, CPVC and AI

It is important to carefully select the proper solvent cement for yo application. Oatey manufactures several varieties of solvent cemer cements should be used for PVC pipe and fittings, CPVC cements used for CPVC pipe and fittings and ABS cement should be used pipe and fittings. We also manufacture specialty cements such as Flexible and All Purpose Cements.

8. Should primer or primer/cleaner be allowed to dry b applying solvent cement?

Because the primers will soften the pipe surface, it is important to cement to the pipe and fittings while the primer is still wet for ma bond strength.

9. How can purple primer stains be removed?

The pigments or dyes in Oatey Purple Primer and Purple Primer/C permanent. Depending on the type of material stained and its poro

the length of time the stain has set, it may be possible to remove o the stain. We recommend blotting a clean, dry towel with Oatey C Cleaner to attempt to remove the stain. It may not be possible to re colorant from particular fabrics or surfaces. The finish and/or colo fabrics or materials may be dulled or discolored when in contact w solvents in our Clear Cleaner. You may want to try the cleaner on inconspicuous spot before using on the stained area. Please use ou primers and colored cements with caution.

10. Can Oatey No-Calk Flashings be used on Type B ve

Yes, All No-Calk Flashings are rated for use on Type B vents.

11. Is there a roof flashing that can be used on a steep r (i.e. above 40 degree pitch)?

Yes, Oatey manufactures a flashing that can be used on roofs with degrees pitch. Our HighRise No-Calk Flashings are products #119 #11931.

12. Is there a roof flashing for corrugated roofing?

Yes, Oatey carries MasterFlash which can conform to most roof p

13. Is there a standard height that the washing machine box should be mounted?

42° from floor to the bottom of the box is average. The box shoulc installed below the height of the washing machine.

14. How should the DWV drain pipe be solvent cemented to th opening?

The box is made of High Impact Polystyrene and can be solvent w either ABS or PVC cement. A PVC cement should be used when pipe and an ABS cement should be used when using ABS pipe.

The REP CORNER

OATEYSCS®

MATERIAL SAFETY DATA SHEET
This Material Safety Data Sheet complies with
the U.S. OSHA Hazard Communication
Standard 29CFR 1910.1200

CODE: M/L 1134

PRODUCT: DUTCH BOY® PASTE FLUX

TARACORP

NFPA/HMIS HAZARD CODES: HEALTH: 1/1 FIRE: 0/0 REACTIVITY: 0/0 SPECIAL: NA

0 = Minimal 1 = Slight 2 = Moderate 3 = Serious 4 = Severe

SECTION I

MANUFACTURER: Taracorp
ADDRESS: 1690 Lowery Street
Winston-Salem, NC 27101
PHONE: (336) 777-8600

ISSUE DATE: October 2004

SECTION II HAZARDOUS INGREDIENTS

INGREDIENTS	CAS NO.	PERCENT	OSHA PEL	ACGIH TLV
Petrolatum	08002059	70.8	N/A	N/A
Zinc Chloride	07646857	25.3	1mg/m3	1mg/m3
Moisture, as water		3.9		

SECTION III PHYSICAL/CHEMICAL CHARACTERISTICS

APPEARANCE AND ODOR: Amber colored jelly
BOILING POINT: 74° C
VAPOR PRESSURE: 10MM Hg
VAPOR DENSITY: NA
SOLUBILITY IN H2O: NO
SPECIFIC GRAVITY: 0.9
MELTING POINT: 67° C
EVAPORATION RATE: NA

SECTION IV FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: 180°C
FLAMMABLE LIMITS: NA
AUTO IGNITION TEMPERATURE: NA
EXTINGUISHING MEDIUM: No Preference
SPECIAL FIRE FIGHTING PROCEDURES: None
UNUSUAL FIRE & EXPLOSIVE CONDITIONS: None

SECTION V REACTIVITY DATA

STABILITY: Stable
CONDITIONS TO AVOID: NA
INCOMPATIBILITIES: None
HAZARDOUS DECOMPOSITION: None
HAZARDOUS POLYMERIZATION: Will not occur.

SECTION IV HEALTH HAZARD DATA

ROUTES OF ENTRY: inhalation (fume), ingestion, dermal.
SYMPTOMS & EFFECT OF OVEREXPOSURE:
Acute: Inhalation can cause irritation & damage to eyes, lungs, mucous & mucous membranes. Skin contact can cause ulceration of the skin.
Chronic: Irritation of the eyes, skin and mucous membranes.
MEDICAL CONDITIONS GENERALLY AGGRAVATED BY EXPOSURE: Skin conditions or respiratory problems.
CARCINOGENICITY: Not listed.
EMERGENCY AND FIRST AID PRCEDURES:
EYES: Flush with water for 10 minutes. Obtain immediate medical attention.
SKIN: Wash thoroughly with water; If irritation develops, obtain medical attention.
ACUTE INHALATION: Remove to fresh air. Obtain immediate medical attention.
INGESTION: Give water; Obtain immediate medical attention.

SECTION VII PRECAUTIONS FOR SAFE HANDLING AND USE

STEPS TO BE TAKEN IN CASE THIS MATERIAL IS RELEASED OR SPILLED:	Normal clean-up procedures are sufficient. Protect skin from exposure during the procedure.
WASTE DISPOSAL METHOD:	Permitted landfill, check local ordinances.
PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING:	Store below melting temperature: do not expose to heat in storage.
OTHER PRECAUTIONS:	None

SECTION VIII CONTROL MEASURES

RESPIRATORY PROTECTION:	NIOSH Approved Respirator
VENTILATION:	Good general dilution ventilation
PROTECTIVE GLOVES:	Recommended for prolonged contact/heat.
EYE PROTECTION:	Safety glasses or goggles are recommended.
OTHER PROTECTIVE EQUIPMENT:	Safety equipment should be worn as appropriate for the work environment; includes, apron, safety goggles.
WORK/HYGIENIC PRACTICES:	Wash hands thoroughly after use to prevent exposure to the eyes or skin.

SECTION IX UNITED STATES SARA TITLE III INFORMATION

This product/mixture contains the following toxic chemical(s) subject to the reporting of Section 313 of the Title of the U.S. Superfund Amendments and Reauthorization Act (SARA) of 1986 and 40 CFR part 372. Percent by weight of each toxic chemical abstract system (CAS) number are to be found in Section II of this Material Safety Data Sheet.

CHEMICAL NAME	EHS RQ (LBS)	EH TPQ (LBS)	SEC. 313	313 CATEGORY	311/312 CATEGORIES
	*1	*2	*3	*4	*5
Zinc Chloride	1,000	1,000	yes	yes	H-1

*1=Reportable quantity of extremely hazardous material substance, Section 302
*2=Threshold planning quantity, extremely hazardous substance, Section 302
*3=Toxic chemical list, Section 313.
*4=Chemical category as required by Section 313 (40 CFR 372.42). Subject to annual release reporting requirements.
*5=Hazard category as required by SARA Section 311/312 reporting:

Health	H-1=Immediate (ACUTE) Health Hazard	Physical	P-3= Fire Hazard
	H-2=Delayed (CHRONIC) Health Hazard		P-4= Sudden Release of Pressure Hazard
			P-5= Reactive Hazard

SECTION X TRANSPORTATION AND DISPOSAL CONSIDERATIONS

D.O.T. PROPER SHIPPING NAME:	Non-hazardous
WASTE DISPOSAL METHOD:	Dispose of in accordance with EPA regulations

SECTION XI OTHER INFORMATION

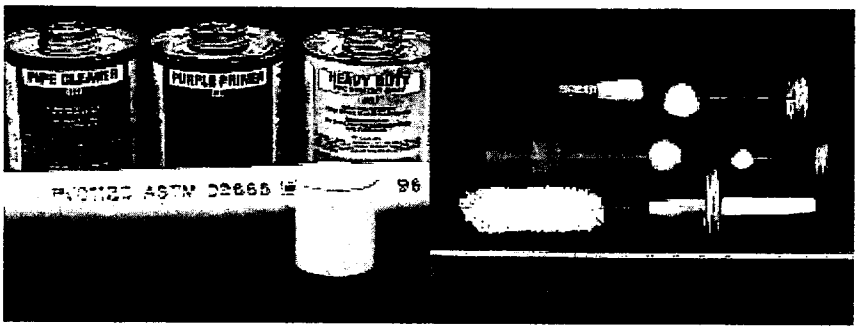
This Material Safety Data Sheet is offered solely for your information, consideration and investigation. Taracorp, Inc. provides no warranties, either express or implied, and assumes no responsibilities for the accuracy or completeness of the data contained in this document. The data in this Material Safety Data Sheet relates only to this product and does not relate to use in combination with any other material or in any process.

AOL Hometown

Someone special is waiting to meet you! See for yourself.

E-Z WELD TECHNICAL NOTE

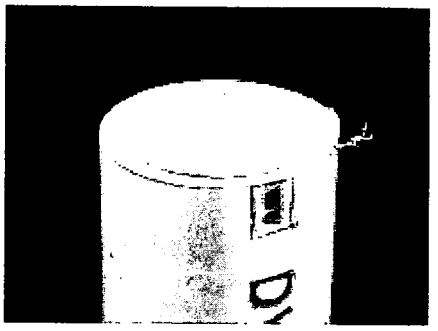
Proper Solvent Cement Procedures



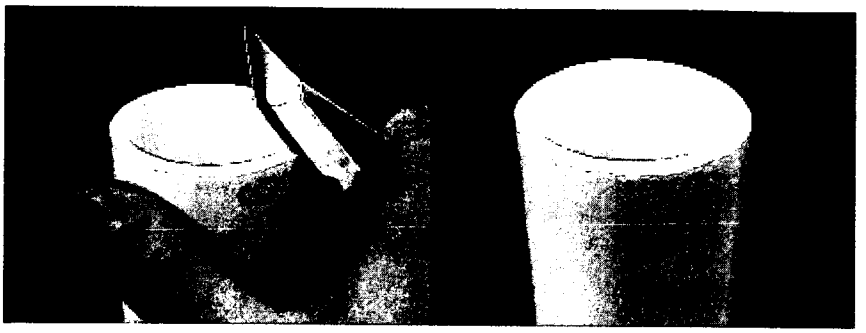
Translate this page automatically.

Select the proper cement for the work to be done and also obtain pipe cleaner and primer. Obtain any needed safety equipment (gloves, eye protection, etc.) prior to starting work. Make sure you are following local plumbing codes regarding cement and primers. If job conditions are unusual, for example, freezing, or hot and windy, additional precautions should be taken. Choose a dauber that is sized properly for the work to be done. Daubers should be 1/2 the diameter of the fittings being joined. This reduces the time required to apply the cement, resulting in better joints.

For small diameters of plastic pipe, cutters are available to product easy straight cuts. Larger pipes should be cut with a tool producing square cuts.

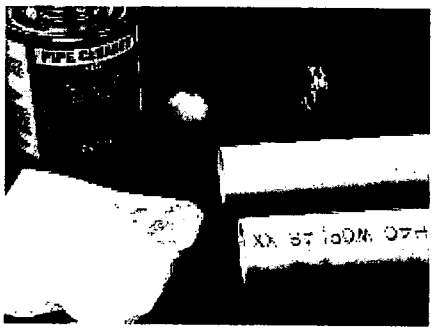


Cut the pipes neatly and square - this is very important as most of the joint strength is obtained at the bottom of the tapered pipe fittings. Straight cuts ensure that the pipe can bottom out properly in the fitting, producing the strongest possible joints. Pipes must also be deburred before assembly.



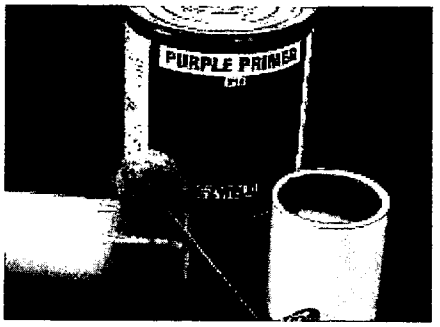
Deburr the pipe, inside and out. - Burrs left from cutting can act to scrape needed cement out of the joint, which can cause leaks. Use of a blade or file is recommended to deburr the pipe ends. As the fittings are tapered, a clean and even cut is essential so that applied cement is not scraped from the joint during assembly. Do not sand or abrade the walls of the pipe or fitting - this may change the dimensions of the pipe. Plastic pipe and fittings are manufactured with very close tolerances.

Check the dry fit of the pipe and fitting. Interference fits on normal pipe should be felt ½ to 2/3 of the fitting socket depth.



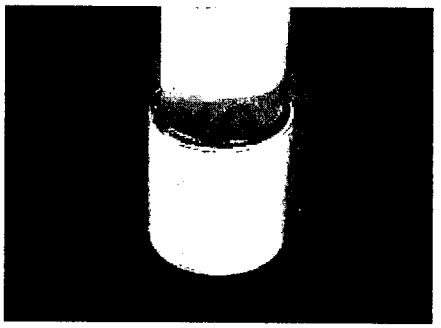
Use pipe cleaner to remove any inks, grease, dirt, waxes and/or oils from the pipe surfaces.Wipe pipe and fitting with cleaner, using a clean rag on larger pipe sizes.

This is done to ensure that oils, inks, dirt and/or grease are removed and are not incorporated into the joint.

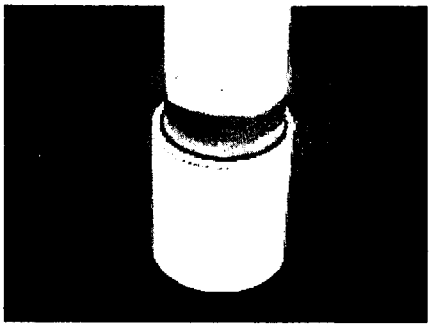


Use a primer to soften both pipe and fitting prior to cement. Apply a coat of primer to start the softening of the pipe and fitting. Primer may not required in pipes under 3" nor is recommended for thin wall, styrene or ABS pipe. Check your local codes.

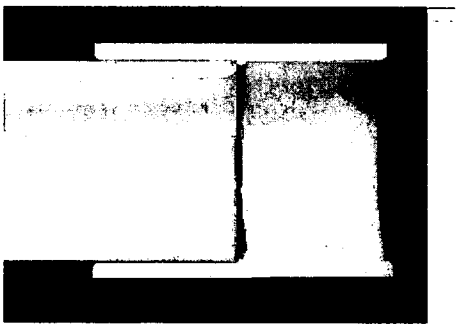
While the primer is still wet, use a proper sized applicator to quickly and evenly coat the cement to the pipe and fitting. Best results are had when the cement is "flowed" on the pipe surface - not thinly brushed.



Working quickly, insert the pipe into the fitting until it bottoms, giving the pipe a ¼ turn to help evenly distribute the cement. The cement on both the pipe and fitting must be fluid at this time or a failure may occur later. The pipe and fitting must now be compressed tightly for 15 seconds to 3 minutes as the swelling action of the tapered fitting tends to push-off the pipe. Assistance or mechanical means may be required on larger pipe sizes. The cement should appear to "wet" the surfaces of the pipe and fitting when assembled.



Wipe away excess cement that is pushed out of the joint with a dry rag. A wet bead of cement on the outside of the fitting is a good sign, as it indicates that sufficient cement has been used, and that the cement was fluid when assembled. Excess cement on the outside of a pipe can, however, weaken it, so it must be removed. When working with bell end pipe caution must be used to ensure that excess cement does not puddle in the end of the socket. A large puddle of cement can weaken the pipe wall. This excess cement can cause leaks or breaks to form in the sidewalls of thin schedual and bell end pipes.



Notice the close fit of pipe and fitting in a good joint

The set joint must be treated carefully during the initial curing time, and not mechanically disturbed. Allow the cemented joint to cure according to the following guide before pressure testing pipe. Do not use compressed gas to test pipe as a failure may have explosive force. Allow the pipe interiors to vent the solvent vapors, **and avoid using sparking or open flame equipment (power drills or torches) near** areas where solvent vapors may exist - an explosion could occur. In conditions where enough vapors exist to ignite, such as a spill, have no electronics - cell phones, etc, or static prone equipment in the area.

Cure times are variable, and can be difficult to exactly predict. The cure time depends on the cement used, the size and tolerance of the pipe and fitting, the air temperature and the test pressure. For a guide to cure times, click here.

Tighten the caps after completion of the job. The cleaners, primers and cements will last much longer. Flush the installed pipes after hydrostatic testing to purge system of solvent vapor traces.

Back to Home Page

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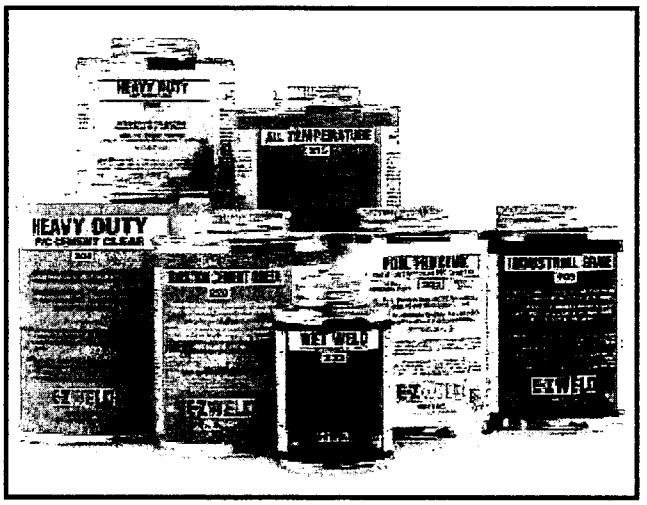
E-Z WELD TECHNICAL NOTE

E-Z Weld Solvent Cementing FAQ

Translate this page automatically.

What is pipe cleaner?
What is primer?
What is a solvent cement?
How does solvent welding work?
How long will it take to set?
How long does the cure take?
How do I chose a cement for a job?
Why are there so many kinds of cement?
How do I choose an applicator for a job?
The cement on the outside of the joint is still soft, is this glue still working?
This cement has become thick/lumpy/dry, what can I do?
My cement froze, what can I do?
I spilled purple primer, what can I do?
What problems are reported in the field?
What is a "dry joint?"
What are the safe precautions for working with these products?
Is solvent welding capable of high strength?
What if the joint leaks?



What is pipe cleaner? - Pipe cleaner is a non-aggressive mix of solvents used to remove contamination from joints and pipes prior to cementing. It will remove inks, dirt, oils and grease that could affect joint quality - and will not carry them into the plastic - as would primer. Pipe cleaner should NOT be used as a hand cleaner.

BACK TO TOP

What is primer? - A primer consists of special solvents to soften, or etch the pipe prior to use of a cement. Available in clear or purple for identification purposes, primer is critical for good joints, especially in larger diameter pipes. It is often required in plumbing codes. Primer or cleaner should NOT be used as a hand cleaner.

BACK TO TOP

What is a solvent cement? - A solvent cement is a mixture of plastic resins, solvents and other additives used to physically weld specific plastics into one piece. Solvent cements are NOT glues, epoxies or silicones. They are a class onto themselves. They come in many viscosities, colors and levels of aggressiveness depending on the end use. Selecting the proper cement is important.

BACK TO TOP

How does solvent welding work? - The solvents in the cleaner remove residues that may be on the pipe, leaving a good clean surface. Then, primer solvents begin the softening process, "etching" or penetrating the pipe. By doing so, the plastic begins to soften and swell. Cement is similar to primer, but contains higher concentrations of active solvents and dissolved resin, similar to the plastics in the pipe and fitting being welded. The pipe and fitting are both coated, connected and bottomed out, and given a 1/4 turn to ensure an even distribution of the cement. The swelling and the tapered shape of the fitting will cause the pipe to attempt to "push-off" of the fitting, so some resistance must be applied until the cement takes a "set". The set usually only takes a minute or two to allow for gentle handling of the joint. The "cure" is the slow increase in strength of the joint. This process involves the evaporation of solvent out of the joint, completing the weld.

BACK TO TOP

How long will it take to set? - Set times are usually under 2 minutes for small pipe sizes. After insertion, and a 1/4 turn to distribute cement evenly, you will need to hold the joint firmly to prevent "push-off" caused by the swelling of the pipe and tapered fittings. Once set, it can be released gently and allowed to cure.

BACK TO TOP

How long does the cure take? - The cure time really depends on several things; the temperature, cement body, pipe size and what pressures the system needs to handle when tested. Cure is the diffusion and evaporation of the solvents away from the joint. The material outside the joint may remain flexible for weeks - this is normal. Safe cure times range from 30 min. for 1/2" pipes under low pressure to 8 days for 8" high pressure main lines constructed under freezing weather conditions. Ultimate joint strength develops in most systems after 30 days of cure. The chart below is offered only as a guide for medium and regular cements.

BACK TO TOP

Joint Curing Guide - < 65% Humidity

	1/2-1 1/4"	1/2-1 1/4"	1 1/2-3"	1 1/2-3"	3 1/2-8"	3 1/2-8"
Temperature	<180 psi	180 to 370 psi	<180 psi	180 to 370 psi	<180 psi	180 to 370 psi
60 to 100 F	1 hr.	6 hr.	2 hr.	12 hr.	6 hr.	24 hr.
40 to 60 F	2 hr.	12 hr.	4 hr.	24 hr.	12 hr.	48 hr.
10 to 40 F	8 hr.	48 hr.	16 hr.	96 hr.	48 hr.	8 days

BACK TO TOP

How do I chose a cement for a job?

1 - You need to know the pipe material - example PVC, ABS or CPVC.

2 - You need to determine pipe diameter - example 6"

3 - Consult Product Listing

BACK TO TOP

Why are there so many kinds of cement? - There are many types of solvent cement depending on end use, conditions, local codes and contractor requirements. While they all work in a similar manner, special circumstances do exist where benifits can be had using a specialty product, such as All-Temperature in sub freezing condtions, Wet Weld for quick curing strength, or Super Duty cements for large pipe diameters.

BACK TO TOP

How do I choose an applicator for a job? - The applicator dauber, roller, brush or mop should be 1/2 the pipe diameter. This is to ensure that primer and cement application is done fast enough to avoid dry joints. You cannot use a small can dauber on sizes over 2" and *always* obtain a good joint - it simply takes too long to coat the pipe and fitting. When you consider the costs of large fittings, the cost of daubers, primer and cement used are insignificant - do it right the first time!

BACK TO TOP

The cement on the outside of the joint is still soft, is this glue still working? - The way solvent cement works is by fusing or welding the two plastics into a single unit. The actual thickness of the cement layer in a well made joint is very thin. Excess material on the outside of the pipe will take a very long time to cure to the hardness

of the pipe, and for that matter, may soften the pipe itself. Excess cement is to be removed when making a joint for that reason.

BACK TO TOP

This cement has become thick/lumpy/dry, what can I do? - NEVER THIN SOLVENT CEMENT. The can may have been left open, and solvents have evaporated away. Given the complex nature of the cement, it cannot be recovered. Attempts to recover the cement by adding primer of cleaner are likely to cause failures in the job being assembled and are NOT worth the risk. The cement must be disposed of properly according to local, state and federal regulations. Keep the cans closed whenever possible - tighten can lid with pliers before any long term storage. Finger-tight is not tight enough to prevent evaporation.

BACK TO TOP

My cement froze, what can I do? - Solvent cement has better resistance to cold than many adhesives, but overnight or longer storage at a job site with conditions that are sub-freezing can cause the cement to thermally jell or substanitally thicken - much like "Jell-O" brand gelatin. This behavior tends to effect cements with heaver bodies and higher resin concentrations. Often, product exposed to freezing can be made to return to normal by bringing the jelled product into a warm area for several hours. Recommended storage for these products are between 40 - 90 F. Room temperature is best. Producing joints in sub freezing conditions is possible, but requires additional cure time.

BACK TO TOP

I spilled purple primer, what can I do? - Purple primer is designed to permanently mark PVC pipe for code inspection. Many other household items, such as common plastic floor surfaces, tiles and grout, will also be permanently marked by purple primer, or other cement products. Work carefully!

BACK TO TOP

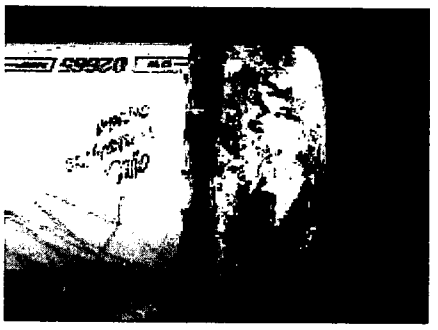
What problems are reported in the field? - The most often heard of problem is contractors jumping from 1-3" PVC pipe jobs to 8-24" installations with no change in procedures. The techniques, applicators, and prior set-up required in such a case are often overlooked with serious consequences. Using the can dauber on pipes over 4" is hopeless, as the cement begins to dry well before the pipe is coated. Attempting to insert the pipe into the fitting then results in the dried cement coating tearing in places and may make bottoming the fitting impossible - resulting in a dry joint with poor strength, and many leaks. The cement must be fluid to ensure several things; it acts as a lubricant, making insertion easier, it fills gaps in the pipe, preventing leaks and it allows the plastics to weld into a single unit. More than one person is required for larger sizes of pipe, to complete the job in reasonable time and mechanical assistance may be required as well. PVC joints contaminated by debris, sand and materials from the jobsite are also common. Because this material prevents the fitting from being bottomed out, leaks occur. Improper storage of cements can cause failures. Keep the cements from extreme temperatures of hot and cold. Store indoors when possible between 40-90 F. Lids must be kept tight during storage to lessen evaporation. Stir before use, and manufacture a test joint to ensure your ability to produce a quality joint with the jobsite materials. Some may attempt to "salvage" a bad joint by sanding a pipe or fitting for reuse - making a future failure possible. It is poor practice, and may be more expensive to repair later.

BACK TO TOP

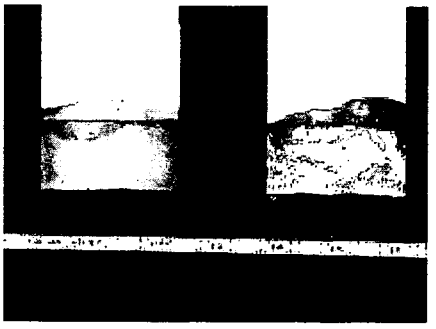
"Dry Joints"

A typical failure of large plastic pipe jobs occurs when a dry joint is made. When the pipe assembly is delayed, by using a small dauber, or other causes, the cement will "flash-off" its solvents and fail to weld the plastics, producing a dry joint. The active solvents are very quick to evaporate, and are required for the cement to work properly. You have no additional time to produce a large joint than a small one - Work quickly!

A dry joint has this appearance:



One can see that the cement layer is thick, uneven and torn, and that no weld was achieved. A common additional problem with dry joints is the semi-fluid cement makes bottoming the pipe difficult, if not impossible. As a result, the joint is likely to fail. In this case, the small can dauber was used on a 8" PVC joint, and a failure occured.

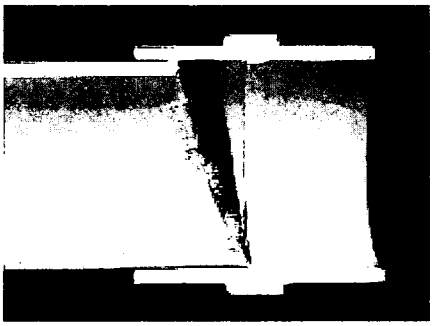


In the above example, a good joint was made, including primer, purposefully cut

and broken for analysis before cure. A second joint was made, cement only, and delayed to produce a classic dry joint. The proper joint has only a thin layer of cement inside the actual joint, with a majority toward the open end of the tapered fitting. The dry joint has the typical poor distrubution of torn unbonded cement.

A typical failure of poorly installed plastic pipe is caused by poorly prepared pipe - pipe cut at odd angles, and/or not deburred.

A poor joint can have this appearance:



The cut made above produces a joint that may sustain initial pressure testing, but leak later on. Under stress, the pipe could break away. In some cases, the burrs left on the pipe will scrape needed cement out of the joint, producing a pathway for a slow leak. The slow leak may over time grow through erosion.

BACK TO TOP

What are the safe precautions for working with these products? - The solvents used in the products are flammable and quickly evaporating. Use precautions to prevent fire or explosion. Keep sources of ignition away from storage and work areas. Vapors can travel and may persist if ventilation is not used. Local exhaust or fans may be required to work in confined spaces, or an approved respirator may be used if solvent fumes exceed limits. Ventilation must be chosen with respect to the flammability of the materials. Wear gloves that are impervious to the solvents in the materials. Eye protection - chemical goggles or face shields should also be used where the risk of eye contact exists. Consult the MSDS and ASTM 402 for more important safety information.

BACK TO TOP

Is solvent welding capable of high strength? - Yes! Lap shear testing, as required by ASTM standards, determines the weld strength over time on flat samples of PVC plastic. Joint strength is +250 lbs/in^2 in two hours and slowly approaches the strength of the plastic in the pipe. The required end PVC strength is 900 PSI and the cure strength will often go much higher.

BACK TO TOP

What if the joint leaks? - Start over. Plastic pipe and fittings with bad joints are non-repairable. You may stop the leak, but it will eventually return. A temporary fix is not worth the risk of a future leak.

BACK TO TOP

COOKSON

BFGoodrich CORZAN INDUSTRIAL SYSTEMS

Joining Corzan Pipe and Fittings – Solvent Cementing

Cutting
Corzan pipe can be easily cut with a ratchet cutter, wheeltype plastic tubing cutter, power saw, or fine-toothed saw.To ensure the pipe is cut square, a mitre box must be used when cutting with a saw. Cutting the pipe as squarely as possible provides the maximum bonding surface area.

Deburring
Burrs and filings can prevent proper contact between the pipe and fitting and may put undue stress on the pipe and fitting assembly. Burrs and filings must be removed from the outside and inside of the pipe. A chamfering tool or file is suitable for this purpose. A slight bevel should be placed at the end of the pipe to ease entry of the pipe into the socket and minimize the chances of wiping solvent cement from the fitting.

Fitting Preparation
Loose dirt and moisture should be wiped from the fitting socket and pipe end with a clean, dry rag. Moisture can slow the curing, and at this stage of assembly excessive water can reduce the joint strength. The dry fit of the pipe and fitting should be checked. The pipe should enter the fitting socket easily 1/4 to 3/4 of the depth. If the pipe bottoms in the fitting with little interference, extra solvent cement should be used to prepare the joint.

Primer Application
Primer is needed to prepare the bonding area for the addition of the cement and subsequent assembly. It is important that a proper applicator be used. A dauber or paintbrush approximately half the size of the pipe diameter is appropriate. A rag should not be used. Primer is applied to both the outside of the pipe end and inside of the fitting socket, redipping the applicator as necessary to ensure that the entire surface is tacky.

Solvent Cement Application
Solvent cement must be applied when the pipe surface is tacky, not wet, from primer. Joining surfaces must be penetrated and softened. Cement should be applied with a natural bristle brush half the size of the pipe diameter. A dauber may be used to apply cement on pipe sizes below 2 inches. A heavy, even coat of cement should be applied to the outside of the pipe end, and a medium coat should be applied to the inside of the fitting socket. Pipe sizes greater than 2 inches should receive a second coat of cement on the pipe end.

Assembly
After cement application, the pipe should immediately be inserted into the fitting socket and rotated 1/4 turn. The fitting should be properly aligned for installation at this time. The pipe must meet the bottom of the fitting socket. The assembly should be held in place for 10 to 15 seconds to ensure initial bonding. A bead of cement should be evident around the pipe and fitting juncture. If this bead is not continuous around the socket shoulder, it may indicate that insufficient cement was applied. In this case, the fitting should be discarded and the joint reassembled. Cement in excess of the bead may be wiped off with a rag.

Set and Cure Times
Solvent cement set and cure times are a function of pipe size, temperature, relative humidity, and tightness of fit. Drying time is faster for drier environments, smaller pipe sizes, high temperatures, and tighter fits. The assembly must be allowed to set, without any stress on the joint, for 1 to 5 minutes depending on the factors just discussed. Following the initial set period, the assembly can be handled carefully avoiding significant stresses to the joint. Refer to the following table for minimum cure times prior to testing.

Extra care should be exercised when systems are assembled in extreme temperature conditions. Extra set and cure times should be allowed when the temperature is below 40°F (4°C). When the temperature is above 100°F (38°C), the assembler should ensure that both surfaces to be joined are still wet with cement before joining them.

Technic Data

HERSHEY VF

Piping Systems

1. What is Cozan CPVC ?
2. Basic Physical Properties
   * Tensile Strengh
   * Tensile Modulus
   * Flexural Strength
   * Flexural Modulus
   * Compressive Strength
   * Compressive Modulus
   * Izod Impact
   * Specific Heat
3. Fier Performance Characteristics
4. Weatherabililty
5. Abrasion Resistance
6. Biological Resistance
7. Long-Term Performance Under Pressure
8. Design Properties of Pipe
   * Schedule 80
   * Schedule 40
9. General Specification
   * Applicable Standards
10. Dimensions and Pressure Ratings
   * Max. Working Pressure vs. Temperature - Schedule 80
   * Max. Working Pressure of 6 Inch Diameter - Schedule 80
   * External Pressure Rating (PSI)
11. Fluid Handling Characteristics
12. Carrying Capacity and Friction Loss - Schedule 80 Pipe
13. Carrying Capacity and Fruction Loss for Schedule 40 Pipe
14. Thermal Expansion and Thermal Stresses
15. Typical Recommended Maximum Support Spacing
   * Schedule 80 Corzan Piping Nominal Pipe Size
   * Support Spacing for 6 Inch Diameter - Schedule 80
   * Schedule 40 Corzan Piping Nominal Pipe Size
   * Pipe Managers, Clamps, & Supports
16. Thermal Conductivity of Corzan CPVC
   * Estimated Pipe Surface Temperature vs. Internal Fluid Ter

17. General Installation Guidelines
18. Joining Pipe and Fittings Solvent Cementing
19. Threading of Corzan Schedule 80 Pipe
20. Flanging of Corzan Pipe
21. Back-Welding of Pipe Joints
22. Underground Installation Guidelines

MATERIAL SAFETY DATA SHEET
This Material Safety Data Sheet complies with the U.S. OSHA Hazard Communication Standard 29CFR 1910.1200

CODE: M/L136

PRODUCT: TARAMET STERLING® WATER SOLUBLE FLUX

TARACORP

NFPA/HMIS HAZARD CODES: HEALTH: 1/1 FIRE: 0/0 REACTIVITY: 0/0 SPECIAL: NA

0 = Minimal 1 = Slight 2 = Moderate 3 = Serious 4 = Severe

SECTION I IDENTIFICATION

MANUFACTURERS NAME: Taracorp
1690 Lowery Street
Winston-Salem, NC 27101
336-777-8600

ISSUE DATE: October 2004

SECTION II COMPOSITION INFORMATION

INGREDIENT	CAS NO.	US OSHA PEL	%
Hydrochloric Acid	7647-01-0	5PPM	3-6
Zinc Chloride	7646-85-7	1PPM	1-3

SECTION III HEALTH HAZARDS

EYES: Flush with water for 10 minutes. Obtain immediate medical attention.
SKIN: Wash thoroughly with water. If irritation develops, obtain medical attention.
ACUTE INHALATION: Remove to fresh air or administer oxygen. Obtain immediate medical attention.
INGESTION: Give water or milk. Obtain immediate medical attention.
PRIMARY ROUTES OF ENTRY: Fume inhalation, ingestion, skin and eyes.
SYMPTOMS OF OVEREXPOSURE: Salivation, coughing, choking, chills, may cause weight loss, brittle bones, anemia, and stiff joints.
MEDICAL CONDITIONS GENERALLY AGGRAVATED BY OVEREXPOSURE: Any weakness of the lungs, kidneys or liver will be aggravated.

CHEMICAL LISTED AS A CARCINOGEN OR POTENTIAL CARCINOGEN: None

SECTION IV FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: N/A
FLAMMABLE LIMITS: N/A
EXTINGUISHING MEDIA: Not needed
AUTO IGNITIOIN TEMPERATURE: None
SPECIAL FIRE FIGHTING PROCEDURES: None
UNUSUAL FIRE & EXPLOSION HAZARDS: Fluoride fumes

SECTION V ACCIDENTAL RELEASE MEASURES

STEPS TO BE TAKEN IN CASE MATERIAL IS SPILLED:
Clean up paste and dilute/flush remaining materials with excess of water.

SECTION VI HANDLING AND STORAGE

STORAGE REQUIREMENT: Store in plastic containers in cool area, away from heat. Do not store in glass or porcelain container. Wash thoroughly after use.
HANDLING PRECAUTIONS: Safe precautionary practices - avoid spills and exposure to skin and fume.

SECTION VII CONTROL MEASURES

RESPIRATORY PROTECTION (TYPE):	NIOSH Approved Respirator
MECHANICAL (GENERAL):	Yes
EYE PROTECTION:	Safety glasses/goggles
PROTECTIVE GLOVES:	Recommended
OTHER PROTECTIVE CLOTHING OR EQUIPMENT:	Optional to user's preference.
VENTILATION:	Yes
LOCAL EXHAUST:	Yes

SECTION VIII PHYSICAL AND CHEMICAL CHARACTERISTICS

BOILING POINT:	104°C	**SPECIFIC GRAVITY (WATER=1):**	.97
VAPOR PRESSURE (mm Hg):	N/A	**PERCENT VOLATILE BY VOLUME:**	64%
VAPOR DENSITY (AIR=1):	N/A	**EVAPORATION RATE (BUTYL ACETATE=1):**	0.6
MELTING POINT:	0°C	**SOLUBILITY IN WATER:**	Moderate
REACTIVITY IN WATER:	None	**APPEARANCE AND ODOR:**	White, odorless paste

SECTION IX STABILITY AND REACTIVITY

STABILITY:	Product is stable
(CONDITIONS TO AVOID):	Metals
INCOMPATIBILITY:	Alkaline, strong oxidizing or reducing materials, cyanides or combustible materials.
HAZARDOUS DECOMPOSITION PRODUCTS:	HCl, zinc chloride, zinc oxide, ammonium fume
HAZARDOUS POLYMERIZATION:	Will not occur
(CONDITIONS TO AVOID):	Excessive heat or cold

SECTION X TRANSPORTATION AND DISPOSAL CONSIDERATIONS

D.O.T. PROPER SHIPPING NAME:	Non-hazardous
WASTE DISPOSAL METHOD:	Dispose of in accordance with EPA regulations

SECTION XI OTHER INFORMATION

This Material Safety Data Sheet is offered solely for your information, consideration and investigation. Taracorp, Inc. provides no warranties, either express or implied, and assumes no responsibilities for the accuracy or completeness of the data contained in this document. The data in this Material Safety Data Sheet relates only to this product and does not relate to use in combination with any other material or in any process.

Main >> Business Park >> Plumbing

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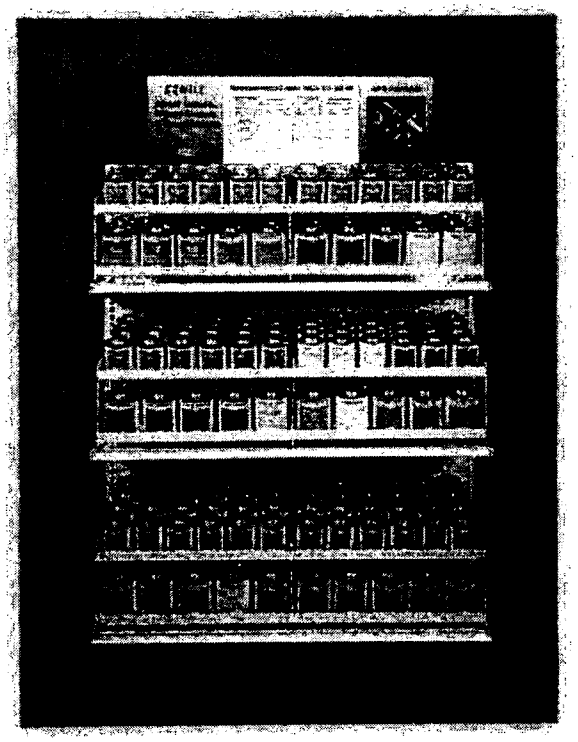
E-Z Calc

...makes buying E-Z Weld® easier!

E-ZWELD®



Quantity by Joint			E-Z Weld® Used	
½" joints ×	1000	=	3.096	quarts
¾" joints ×	1000	=	4.444	quarts
1" joints ×	1000	=	6.452	quarts
1¼" joints ×		=		quarts
1½" joints ×		=		quarts
2" joints ×		=		quarts
2½" joints ×		=		quarts
3" joints ×		=		quarts
4" joints ×		=		quarts
5" joints ×		=		quarts
6" joints ×		=		quarts
8" joints ×		=		quarts
10" joints ×		=		quarts
12" joints ×		=		quarts
14" joints ×		=		quarts
16" joints ×		=		quarts
18" joints ×		=		quarts
	TOTAL	=	14	quarts
			- OR -	
			4	gallons

Instructions: Enter number of joints on appropiate line, click on next box to get data.

The E-Z Calc tool is designed to assist the plumbing industry professional in quickly determining cement quantities to order per specific jobs. It answers the question, "How much solvent cement do I need to buy for a job with this many joints?" The data behind the engine has been averaged from many solvent cement industry sources and is believed to be the most accurate information available. Your usage, however, may vary depending on application, conditions and other factors. For primer and/or pipe cleaner, order 1/3 of the total volume of cement. Consult the product listing to ensure that the cement chosen is suitable for the pipe diameter being welded. Also note that many jobs require or may be best done with several

types of cement and not a single type.

Back to Home Page

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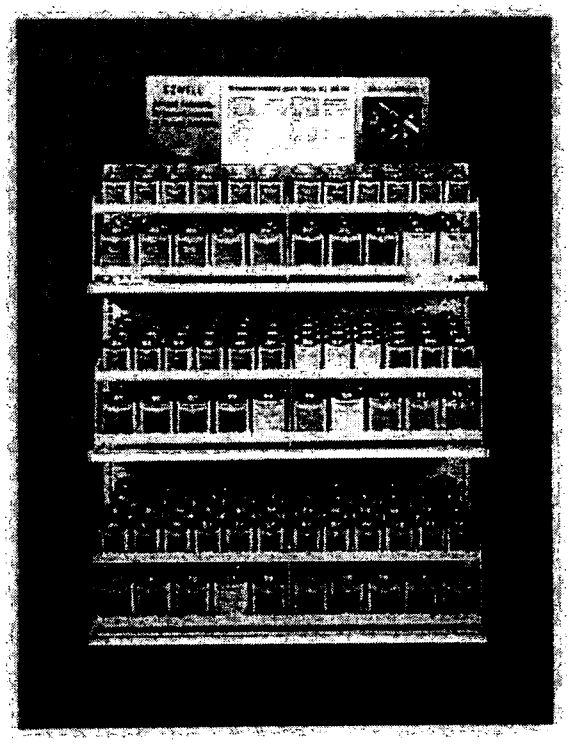
E-Z Calc

...makes buying E-Z Weld® easier!

E-ZWELD®



Quantity by Joint			E-Z Weld® Used	
½" joints ×	209	=	0.647	quarts
¾" joints ×	206	=	0.916	quarts
1" joints ×	54	=	0.348	quarts
1¼" joints ×		=		quarts
1½" joints ×		=		quarts
2" joints ×		=		quarts
2½" joints ×		=		quarts
3" joints ×		=		quarts
4" joints ×		=		quarts
5" joints ×		=		quarts
6" joints ×		=		quarts
8" joints ×		=		quarts
10" joints ×		=		quarts
12" joints ×		=		quarts
14" joints ×		=		quarts
16" joints ×		=		quarts
18" joints ×		=		quarts
	TOTAL	=	2	quarts
			- OR -	
			1	gallons

Instructions: Enter number of joints on appropiate line, click on next box to get data.

The E-Z Calc tool is designed to assist the plumbing industry professional in quickly determining cement quantities to order per specific jobs. It answers the question, "How much solvent cement do I need to buy for a job with this many joints?" The data behind the engine has been averaged from many solvent cement industry sources and is believed to be the most accurate information available. Your usage, however, may vary depending on application, conditions and other factors. For primer and/or pipe cleaner, order 1/3 of the total volume of cement. Consult the product listing to ensure that the cement chosen is suitable for the pipe diameter being welded. Also note that many jobs require or may be best done with several

types of cement and not a single type.

Back to Home Page

A Cookson Company

Solvent Cement, Primer and Cleaner - How to Use

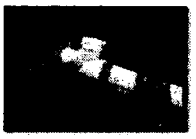
Before Beginning:

1. Verify the cement is the same as the pipes and fittings being used.
2. Check the temperature where the cementing will take place.
   - Cements take longer to set up in cold weather. Be sure to allow extra time for curing. Do not try to speed up the cure by artificial means - this could cause porosity and blisters in the cement film.
   - Solvents evaporate faster in warm weather. Work quickly to avoid the cement setting up before the joint is assembled. Keep the cement as cool as possible. Try to stay out of direct sunlight.
3. Keep the lid on cements, cleaner, and primers when not in use. Evaporation of the solvent will affect the cement.
4. Stir or shake cement before using.
5. Wear rubber gloves when using solvent cement.
6. Wear goggles or safety glasses with side shields when using solvent cement.
7. Ensure adequate ventilation to prevent build up of solvent fumes. If adequate fumes can not be achieved, wear a NIOSH approved respirator for organic solvents. If using a fan for ventilation be sure the fan motor and electrical hook-up do not cause a solvent-fume fire hazard.
8. Use 3/4" dauber on small diameter pipes, 1 1/2" dauber up through 3" pipe, and a natural bristle brush, swab, or roller 1/2 the pipe diameter on pipes 4" and up.
9. DO NOT mix cleaner or primer with cement.
10. Do not use thickened or lumpy cement. It should be the consistency of syrup or honey.
11. Do not handle joints immediately after assembly.
12. Do not allow daubers to dry out.
13. Maximum temperature allowable for CPVC pipe is 180 F and PVC is 140 F.
14. All colored cements, primers, and cleaners will leave a permanent stain. There is no known cleaning agent.
15. Use according to the step outlined in ASTM D-2846, joining of pipe and fittings.

Number of joints per pint - gallon of cement by pipe size

Pipe Diameter	Joints/Pint	Joints/Gallon	Pipe Diameter	Joints /Pint	Joints/Gallon
1/2"	175	1400	6"	12	96
3/4"	150	1200	8"	3	24
1-1/2"	75	600	10"	2	16
2"	40	320	12"	1	8
2-1/2"	35	280	14"	1	6
3"	30	240	16"	1/2	5
4"	25	200	18"	1/2	4

Application:



Cut pipe square and remove all burrs.

1. Check dry fit for interference fit. Pipe should push at least 1/3 of the way into the fitting. If pipe bottoms, it should be snug.
2. Clean pipe and fitting with a Purple Primer or cleaner as required by local regulations. If approved, Oatey one-step cements can skip this step. ABS should be cleaned with a cleaner only - do not use primer.
3. Stir or shake cement before using. If "jelly-like" do not use.
4. Use 3/4" dauber on small diameter pipes, 1 1/2 " dauber up through 3" pipe, and a natural bristle brush, swab, or roller 1/2 the pipe diameter on pipes 4" and up.
5. Apply a thin coat in the socket. Then, evenly coat the pipe end to the socket depth. Avoid puddling - especially on thin walled pipe.
6. Assemble parts quickly. Cement must be fluid, if not, recoat both parts.
7. Assemble the joint by twisting the pipe 1/4 turn while pushing to the socket depth. Hold for 30 seconds to avoid push-out.
8. Wipe off any excess cement remaining between the socket and pipe with a clean dry rag.

Physical Properties:

For Set-up time and pipe size see individual cement information sheets.
Shelf life - 2 years from date of mfg. (stored @ 80F in unopened cans).

LINE PRESSURE:	– 150 psi –	– 300 psi –
100 Degrees	2 hours	4 hours
60 Degrees	2 hours	6 hours
40 Degrees	4 hours	8 hours
20 Degrees	8 hours	48 hours

The pressure shown above represents the bond strength relative to time and ambient temperatures. Consult local codes for appropriate test relative to water service or DWV installations.

Lo-VOC Cements

Southern California

The South Coast Air Quality Management District (SCAQMD) has issued Rule #1168 requiring reduced solvent emissions from plastic pipe cements and primers. After January 1, 1994, only cements and primers that meet the new standard for low Volatile Organic Compound (VOC) emission will be allowed in the District. The exception is 4 oz containers.

The California counties in the SCAQMD are: Los Angeles, San Bernardino, Orange, and

Riverside.

Northern California

The Bay Area Air Quality Management District (BAAQMD) has issued Rule #59 requiring reduced solvent emissions from plastic pipe cements and primers. After January 1, 1997, only cements and primers that meet the new standard for low Volatile Organic Compound (VOC) emissions will be allowed in the District.

The California counties in the BAAQMD are: Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Sonoma (Southern portion only), Santa Clara, and Solano.

Oatey Lo-VOC cements and primers are carefully designed to be used with the same technique as the rest of our product line.

Cure times, lap shear values, and hydrostatic burst strengths are comparable to our existing products. The Lo-VOC product line provides the same dependable performance as the rest of the Oatey product line.

Requirements for the SCAQMD Rule 1186 (Method 316A) and BAAQMD Rule 51 are as follows:

	SCAQMD	Oatey Lo-VOC	Oatey Cements
ABS	350	=<350	650
CPVC	450	=<450	850
PVC	450	=<450	850
Primers	850	=<850	850

ARROW ADHESIVES COMPANY

HOW ARROW PLASTIC PIPE SOLVENT CEMENTS WORK *and* WHY THEY ARE TROUBLE-FREE WHEN PROPERLY USED

BASIC FACTS ON HOW ARROW CEMENTS WORK

(1) Arrow plastic pipe solvent cements work by solvent action.

(2) When cement is applied, solvent action softens (dissolves) the pipe and fitting surfaces, preparing them for joining. (See Figure 2 below)

(3) A few seconds after joining, the interference section fuses together. The non-interference section is bonded together. (See Figure 3 below)

(4) The joint cures by evaporation of the cement solvents. If possible, allow 24 hours.

Also see Frequently Asked Questions and Abnormal Conditions for more information.

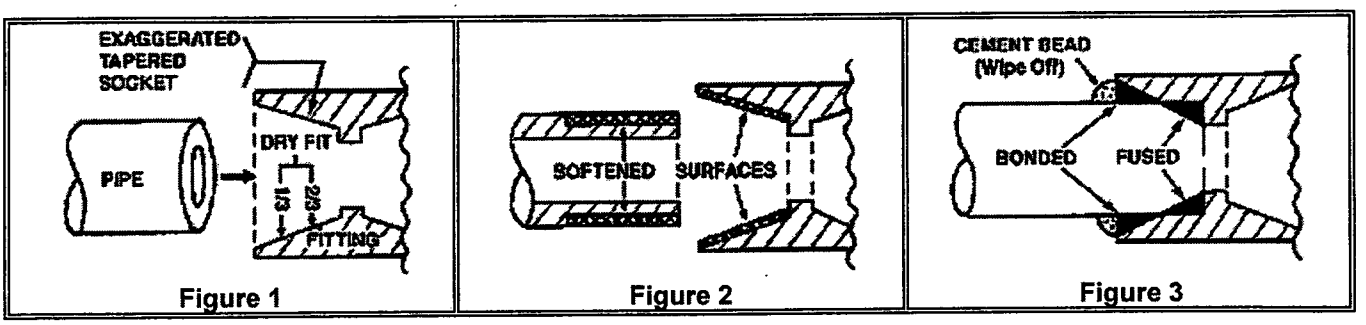


Figure 1 Figure 2 Figure 3

IMPORTANT POINTS FOR TROUBLE-FREE USE

Interference Fit	• Required for proper solvent action. • 1/3 to 2/3 dry fit is best. (See **Figure 1**) • If pipe fully inserts in fitting, it should be snug. Avoid loose fits.
Pipe Cut	• Cut pipe square and remove burrs to avoid leaks.
Proper Cleaning	• Remove all dirt, oil, moisture and surface gloss for best results. • Best to use **Arrow** Primer (PVC,CPVC) or Cleaner (ABS,PVC,CPVC)
Proper Cement	• Check that cement is recommended for pipe size used. • Make sure cement is free-flowing and not gelled.
Apply Cement	• Apply a heavy coat of cement to pipe, a light coat to fitting socket and another coat to pipe.
Join Pipe and Fitting	• Use a slight twisting motion to insert pipe into fitting and hold for a few seconds to prevent pipe from pushing out. • A joint should fuse ('Grab') shortly after joining pipe and fitting. If not, avoid using as it may pull out or leak.
Cement Bead	• A cement bead will appear at interface if enough cement was used.

- Wipe off bead to speed joint curing.

Curing

- Allow sufficient curing time (24 hours is best) to assure a strong joint.

ARROW products are **TROUBLE-FREE** when **PROPERLY USED**

ARROW ADHESIVES COMPANY

FREQUENTLY ASKED QUESTIONS ABOUT PLASTIC PIPE CEMENTS

What are plastic pipe cements and how do they work?

A plastic pipe cement is a mixture of plastic resin dissolved in solvents. The cement works by solvent action on the plastic surfaces. See **Arrow** "**How and Why**" sheet for additional information.

How strong is a solvent-cemented plastic pipe joint?

Plastic pipe cements are designed to make a plastic pipe joint which is as strong or stronger than the pipe being used. See **Arrow Products** section for strength data.

What are the main installation problems to avoid? (Also see "Abnormal Conditions")

Loose-Fitting Joints	1/3 to 2/3 dry fit is recommended. Dry fit is the fraction that the pipe can be pushed into dry fitting without cement.
Improper Cement Selection	Follow guidelines on can or data sheet for proper pipe diameter and cement selection. Do not mix plastic types.
Pipe Burrs	After cutting the pipe, remove any burrs to avoid a leak.
Insufficient Cleaning	For best results, use **Arrow** Primer, S-911, for pressure applications, and **Arrow** Cleaner, S-901, for non-pressure.
Not Enough Cement Used	After cementing, a properly made joint will show a bead of cement completely around the pipe/fitting interface. Wipe off the bead for faster curing.

Is there a way I can tell if I have made a good joint?

Check the above main installation problems prior to cementing. During installation, you can get an indication of a good joint if the pipe "grabs" (i.e. fuses) the fitting a few seconds after joining and becomes a firm union. If the pipe is wobbly in the fitting after cementing, it indicates a loose-fitting joint and should not be used. The use of a primer prior to cementing overcomes some installation problems and will make a stronger joint. After the joint properly cures (24 hours recommended), you can pressure test the joint.

How much cement is needed?

Shown here is a chart to estimate the amount of cement needed for a job:

CEMENT USAGE DATA

PIPE SIZE	1/2"	1"	2"	3"	4"	6"	8"	12"
Ave. Joints Per Pint	175	90	40	20	15	6	2	1
Ave. Joints Per Liter	375	190	85	42	32	13	4	2

If you have additional questions, search our web site or Contact Us.

Soldering Handbook

3rd Edition

by

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contaminated with base material particles and thus, must potentially be treated as a hazardous effluent.

Finally, some metal particles can present a potential fire hazard. For example, shavings and particles of Mg, Ti, or even Al can be ignited by a nearby flame or spark. These particles burn much hotter than most organic combustibles, so that their potential to burn workers (even through protective clothing) or to start ancillary fires is very high.

8.3 Fluxes

Fluxes are comprised of three primary components:

(1) the corrosive agent;

(2) the carrier or vehicle component; and

(3) surfacting agents.

The surfactants or wetting agents that enhance the spreading of the flux over the substrate surface, are generally of little consequence to the hazards associated with a flux. Rather, the corrosive agent and the flux vehicle stand to offer the greatest potential hazard to workers and the environment. An important point should be made of that potential hazard. That is, besides the flux being hazardous due to its own components, its residues pose an added concern because they are typically contaminated with substrate and solder metal atoms picked up in the course of the soldering process. Therefore, the environmental hazards associated with the flux *residues* removed from the joint after assembly are of equal concern as is those of the flux material, itself. Of course, the use of so-called "no-clean" fluxes, the residues of which, need not be removed from the substrate surface, eliminates completely the problem of disposing of cleaning solutions having the contaminated residues.

The corrosive agent of a flux presents several safety issues. The potential hazard posed by flux corrosiveness is dependent upon the level of that corrosiveness. Inorganic acid fluxes have the strongest corrosion action and hence, pose a far greater hazard to operators than would the milder, rosin-based fluxes. Besides inadvertent contact with hands and arms that can be easily prevented by the use of gloves and suitable protective clothing, is the hazard caused by spattering that is generated during the solder process as the hot iron, torch or molten solder contacts the flux coating on a substrate. In the absence of a face shield or protective glasses, spattered acid particles can do irreparable damage to an eye upon contact. In addition, spattered particles may be so small as to form an aerosol cloud about the work area; these small particulates are invisible to the eye. However, continued breathing of these fine particles by an operator can damage nose, throat, and lung tissues. Proper ventilation of the work area minimizes this hazard. However, ventilation is *not* a substitute for eye protection since the draft of the fume extraction flow is usually not sufficient to deflect the trajectory of larger flux spatter particles.

An acute hazard that accompanies fluxes is their inadvertent ingestion. Occasionally a worker reaches for a cup of coffee, becomes distracted, and instead, grabs a styrofoam cup filled with flux and drinks some before realizing his/her mistake. There have been cited cases!

The acid component of a flux can also cause environmental damage upon the release of untreated rinse solutions into the ground water. Typically, water-based rinsing solutions are used to remove the acid residue. Such effluents can be treated by their capture in closed-loop systems and subsequently being passed through water-treatment facilities prior to release into the environment (sewer drain).

The vehicle of the flux can complicate both worker safety and environmental-protection issues. This situation is best illustrated by example. Fluxes are either water-based or based upon an organic solvent such as one of the alcohols. In the latter case of organic vehicles, a potential fire hazard must be addressed with use (and storage) of such fluxes. The fire hazard is made particularly significant as a result of the formation of flux particles and aerosols that occurs during the soldering process as the vehicle evaporates or is volatilized under the action of a hot iron, torch, or molten solder. Aerosol formation can be further enhanced by automatic fluxers, e.g., foamers, used on mass soldering equipment. These aerosols can form explosive fuel-air mixtures in the work area or within the machine. Protective measures range from the provision of suitable ventilation in the immediate vicinity of the operation, to equipping mass soldering equipment with fire-retardant systems, explosion-proof panels, and electrically conductive components to reduce the likelihood of static electricity building up within the structure.

Spattering of the flux occurs in the course of most soldering operations as the substrate reaches the soldering temperature. Because of the lower boiling point of most organic vehicles, such components readily volatilize during the preheat step, prior to the actual soldering operation. Water-based vehicles require higher temperatures and greater heat input to realize volatilization and so, may not be completely eliminated from the flux coating at the time of soldering. Therefore, spattering and aerosol formation are of particular concern with the use of water-based fluxes, although such aerosols may not be a significant fire hazard.

The complication with regard to environmental concerns arises from the fact that both organic solvents, e.g., isopropyl alcohol, and inorganic solvents, e.g., water, may be needed to clean a particular part after soldering. For example, the activated rosin-based fluxes (organic)

used in many soldering processes contain an added, activator (ionic) component to boost the corrosive action. The approach used to remove such residues is to start with a solvent rinse which releases the organic (rosin) residue. This step is then followed with a water rinse to assure removal of the ionic (activator) component. As a consequence, two waste streams are generated, one for the organic solvent(s) and the other for the water-based solvent(s). Until verified by testing, it must be assumed that both are contaminated with metal elements from the substrate and/or solder materials. The situation becomes particularly hazardous should the two waste streams become combined as so-called "mixed wastes" which are much more difficult to dispose or treat.

The environmental safety and health issues brought to light with respect to fluxes should be of utmost importance when selecting a flux for a particular job. Clearly, many of the environmental aspects appear to be more pertinent to large-volume product assembly that takes place on a factory floor. However, the safety issues are as important in field assembly activities as they are in a more controlled, plant situation.

The selection of a flux as part of the development of a soldering process, should address the following technical and worker safety/environment aspects, respectively:

(1) The flux must provide a solderable surface that will support wetting and spreading by the molten alloy, resulting in a minimum number of defects;

(2) The flux must be compatible with sustained worker safety and environmental issues dealing with the disposal of the associated waste stream. The latter aspect will have to address such ancillary issues as added capital equipment cost (worker protection, equipment safeguards, waste treatment and disposal cost, etc.) and personnel investment (compliance paperwork, monitoring, on-site expertise, etc.).

8.4 Solders

Worker health and environmental concerns that have developed from the solder alloy, itself, are a result of the potential toxicity associated with their heavy-metal content. In particular, Pb and Cd components of solders have received the greatest attention in these regards. Toxicity risks to humans were identified when Sn-Pb solders were used to join potable water conduit, resulting in regulations against the use of Pb-containing solders in such applications [374]. Growing concern about the environmental risks to ground water resources from electronic assemblies that are discarded in landfills has sparked a considerable effort by solder suppliers, OEMs, and research institutions, nationally and internationally, to identify a suitable, Pb-free solder replacement for electronics applications, as well [39, 375–377].

The recently highlighted environmental toxicity of the elements Cd and Pb contained in many solders should not detract from the importance of other concerns for the health and safety of operators and assemblers. Solders also present acute (immediate) as well as chronic (long-term) dangers. The foremost acute hazard of the solder is that of *burn injuries*. The danger of *thermal burns* received from molten solder begins with contacting a hot solder pot, iron, or torch flame. In addition, the combined presence of flux and solder (especially flux cored solder wire) raises the likelihood that molten solder particles will be ejected from the work area as the flux volatilizes under the action of the heat source. Proper face and eye protection as well as thick clothing that covers the extremities prevents contact between the molten solder and the operator. Generally, solder particles do not have sufficient heat to ignite clothing; rather, the molten particle contacts clothing and generally melts the fabric or slowly burns it so as to eventually come in contact with the worker's skin underneath. Thick clothing causes the ejected particle to lose heat before it burns through the fabric and contacts the skin. When a molten solder droplet contacts unprotected skin it often "freezes" to the skin. Burn wounds from solder can be particularly serious because of the potential of an acid burn from accompanying flux droplets (*chemical burns*). Therefore, a burn should also be treated by rinsing with copious amounts of water in order to flush away harmful flux.

Chronic health problems arise from prolonged exposure to the heavy-metal contents of solder. Often, such exposures are not well appreciated by personnel, primarily because the hazard is not visible to those individuals. Although the precept, "nobody intentionally eats a bar of solder," is quite accurate, an operator can inhale and/or ingest (from nearby food products) very small, unseen solder particles arising from a soldering process. Over time, these seemingly small amounts of metal accumulate to dangerous levels in the blood stream and body tissues, resulting in chronic health problems from which, the individual may never recover.

The perspective of just how little material needs to be ingested in order that it cause a serious health concern is illustrated by the following example pertaining to Pb. Currently, health researchers contend that an individual has succumbed to Pb poisoning if their serum (blood) levels exceed 25 μg/dl (the dl being the "deciliter" or one-tenth of a liter) [378]. It has been proposed to reduce that level to 10 μg/dl. Taking the lower level of 10 μg/dl as a basis, and the fact that the human body contains 4–5 quarts of blood, this contamination level corresponds to the ingestion of a Pb particle approximately 0.55 mm/ 0.021 in. in diameter. A Sn-Pb eutectic solder

FIRE

Combustion Products from Vinyl Chloride Monomer

M. M. O'MARA, L. B. CRIDER, and R. L. DANIEL

B. F. Goodrich Chemical Company, Avon Lake, Ohio, and The Dow Chemical Company, Freeport, Texas

By means of a variety of analytical techniques, the combustion profile of vinyl chloride monomer (VCM) has been determined. This profile includes flame temperatures, soot content, and a combustion gas analysis. Depending on the amount of VCM-air premixing prior to combustion, the temperature of a VCM flame ranges from 950° to 1466°C. Similarly, the soot or unburned carbon content of a VCM flame varies from 3 to 6 weight percent. An analysis of the combustion gases from VCM reveal the following composition: HCl 27,000 ppm; CO^2 58,100 ppm; CO 9500 ppm; phosgene 40 ppm; and VCM trace. From a hazard standpoint, the gross quantity of hydrogen chloride is the main source of danger in a VCM fire.

Introduction

THE COMBUSTION PRODUCTS from chlorinated hydrocarbons are of considerable importance from a toxicological standpoint. This class of organic compounds, when burned or thermally degraded in an oxidizing atmosphere, can produce carbon monoxide, hydrogen chloride, and phosgene. The highly chlorinated hydrocarbons (carbon tetrachloride, etc.) have been well characterized in this respect. For example, Sjoberg[1] has determined the amount of phosgene and hydrogen chloride released from a series of chlorinated hydrocarbons when brought into contact with hot metal surfaces, glowing charcoal, and an open flame. The results of this study showed that, at temperatures above 600°C, the major combustion product was hydrogen chloride.

In a more recent study Jay[2] has found that, at decomposition temperatures between 600° to 700°C, the presence of phosgene from chlorinated hydrocarbons was noted only when the following empirical ratio (α) for the molecule was greater than or equal to 0.40:

$$\alpha = \frac{(\text{No. of Cl atoms}) - (\text{No. of H atoms})}{(\text{No. of C atoms})}$$

Little has been reported in the literature on comparable studies involving the combustion of vinyl chloride monomer (VCM). Kubler[3] has analyzed the combustion products from a number of halogenated aerosol propellants and has reported that, in a hot flame at 1000°C, 100 gm of VCM will generate the following levels (for a room having a 50-m^3 volume): CO 63.2 ppm; $COCl_2$ 0.05 ppm; and HCl 126 ppm. Under these specific conditions, HCl would seem to contribute the greatest to the overall toxicity of the combustion products. (Recent work on the toxicity of the combustion products from polyvinyl chloride has shown that carbon monoxide and not HCl is of major toxicological importance under some conditions.[4])

Current interest in the combustion products from large amounts of VCM has prompted the present study. Kubler's results on the combustion of VCM is of limited use in this respect owing to the fact that, in his study, VCM was decomposed in an external fire. Our interest was in the self-ignition and combustion of VCM in the absence of an external fuel. In this respect, we have determined the

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This laboratory and analytical procedure development work was done in conjunction with joint studies of the Safety and Fire Protection Committee of the Manufacturing Chemists' Association.

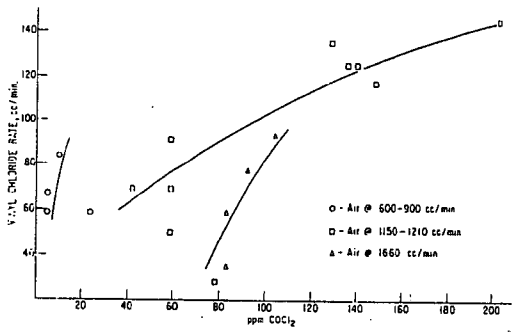


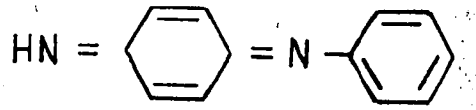
FIGURE 1. Effect of feed composition and burning rate on phosgene production.

combustion products from VCM under both diffusion and premixed flame conditions. The temperature of the flame and the amount of soot generated in a VCM flame was also measured.

Phosgene Determinations

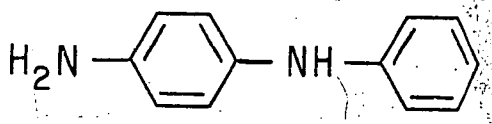
Linch *et al.*[5] have reviewed a number of methods for carrying out an analysis of phosgene in air. Many of the colorimetric methods listed are so sensitive to HCl that they were of little use in the current study. While attempting to determine phosgene in a VCM flame with the colorimetric detector 4,4-bis-(diethylamino)benzophenone, we found that the combustion gases from VCM convert this reagent to a form (probably the HCl salt) that is totally insensitive to pure phosgene.

Phosgene analyses by the aniline method described by Crummett[6] were also attempted. In this method, the combustion gases were scrubbed in an aqueous aniline trap; any phosgene present is converted into 1,3-diphenylurea which then can be determined spectrophotometrically. In carrying out this analysis, we found that, when the combustion products from VCM were directed into this solution, a precipitate was formed. The ultraviolet spectrum of this material in methanol exhibited an absorption at 254.5 mμ, indicating it to be 1,3-diphenylurea. The mass spectrum of this material, however, unequivocally showed that not even trace amounts of 1,3-diphenylurea were present. Rather the composition of this precipitate consisted of materials that result from the oxidative coupling of aniline. We have identified the following components:



M/E = 182

and



M/E = 184

and polymeric forms thereof.

The high level of HCl in the combustion gases is the cause of this oxidative coupling of aniline. Indeed, aniline can only undergo oxidation when present in the form of a salt (that is, aniline hydrochloride).[7] Additional evidence further points up the inadequacy of the aniline method for determining phosgene in the presence of large amounts of HCl. It has been shown that the conversion of phosgene to 1,3-diphenylurea is pH-sensitive and that, at pH = 1.97, the efficiency of this reaction is only 9.3%.[8]

To circumvent these problems, a gas chromatographic analysis of the combustion gases, aimed at determining phosgene, was devised. For this particular analysis, either of two chromatographic columns was used. Chromatographic conditions are summarized in Table I. In addition to these analyses, phosgene determinations were also carried out with a Model 21/31 Drager multi-gas detector equipped with CH283 Drager tubes.

Phosgene analyses were made on VCM flames under a number of experimental conditions. The following flames were probed: microburner, copper tubing burner containing VCM and air feed lines, glass tubing burner, VCM burning in a watch glass and VCM burning in a ruptured 1-liter metal cylinder. In each case, low levels (15 to 150 ppm) of phosgene were detected. Extensive data collected, using the all-glass burner, indicate that an optimum air/VCM ratio is required for the production of phosgene; ratios above or below this optimum tend to

TABLE I
Gas Chromatographic Conditions for Phosgene Determination

Safflower oil column:	15 % safflower oil on 30/60 CHR W, non a.w.; 12′ × ¼″ copper column; detector, t.c., 36°C carrier gas, helium, 40 cc/min.
Silicone oil column:	20% Dow Corning silicone oil 703 on 60/80 CHR W, non a.w.; 12′ × ¼″ copper column; detector, thermal conductivity, 58°C; carrier gas, helium, 94 cc/min.

TABLE II
Chromatographic Parameters for CO and CO_2 Analysis

Porapak column:	6′ × ¼″ s.s. Porapak S, 80/100 mesh; detector, thermal conductivity, carrier gas: helium
Molecular sieve:	1′ × ¼″ s.s. molecular sieve 5A, 45/60 mesh; all other chromatographic parameters identical to above (see text for further information)

suppress phosgene formation. The relationship of the rate of feed of VCM to the burner, the rate of air feed, and the amount of phosgene produced is illustrated in Figure 1.

Air samples above a watch glass and above a ruptured metal tank containing burning VCM were collected and analyzed for phosgene. These samples were of special significance in that they simulated actual burning conditions. The air sample obtained above the watch glass contained 15 to 20 ppm of phosgene, and that above the ruptured metal cylinder contained 40 ppm of phosgene.

The Drager detector was insensitive to phosgene in these experiments due to the high level of HCl in the combustion gases. However, this problem was easily circumvented by attaching an HCl scrubber to the tube. This scrubber consisted of a small section of glass tubing containing 20-mesh granular zinc. The Drager tube values varied ±25% from the gas chromatographic values. The Drager tube when equipped with the zinc scrubber would be a valuable monitoring device for use at the site of a vinyl chloride fire.

VCM Flame Temperature

The temperature of a vinyl chloride flame was measured under diffusion and premixed conditions. Under diffusion conditions, only VCM was fed to the burner (65 to 90 cc/min). Ambient air was the only source of oxygen. For a premixed flame, air (120 to 190 cc/min) and VCM (65 to 90 cc/min) were both fed to the flame; ambient air was also available to sustain combustion. Temperature measurements were made with a Platinel[9] thermocouple (0.008 inch in diameter). For a VCM diffusion flame, the highest temperature recorded was 950°C, while for a premixed flame, the highest temperature recorded was 1466°C. The diffusion flame best simulates an actual VCM fire in that there is little premixing of air and VCM in the pre-ignition step of a flame.

The fact that a VCM fire has a characteristic "cold" flame is evident from the amount of soot generated. From a number of experiments on VCM diffusion flames, it appears that the amount of soot produced during combustion ranges from 3 to 6% of the VCM consumed. This range corresponds to 7 to 15% of the available carbon in the VCM molecule.

HCl from Burning VCM

Initial studies with phosgene determinations indicated that the combustion gases from VCM contained a high level of HCl. In order to better quantify this value, the combustion gases from a VCM flame were directed into a standardized NaOH solution. Back titration of this solution afforded the quantity of HCl produced during VCM combustion. In terms of the amount of VCM burned, this level of HCl is approximately 52%. Although a theoretical yield of 58% is expected, the above analysis did not account for the HCl lost on the walls of the combustion apparatus or for the VCM that escaped combustion.

CO/CO_2 in VCM Combustion Gases

This analysis was carried out through the use of two chromatographic columns. (Column parameters are summarized in Table II). Briefly, the separation is achieved by placing a 6-foot Porapak S in series with a 1-foot 5A molecular sieve column. The air sample is injected into this two-column system; after elution of oxygen, the sieve column which contains the nitrogen and CO com-

TABLE III
CO/CO_2 Analysis of VCM Combustion Gases

Component	Volume %
O_2	14.71
CO_2	5.81
N_2	78.53
CO	0.95

ponents is isolated by means of a 6-port valve. The Porapak column is then heated to 245°C, resulting in the elution of CO_2, ethylene, and VCM. On completion of this analysis, the molecular sieve column is put back in series and heated until the CO and N_2 elute. In this way, a complete separation and analysis of CO, CO_2, N_2 and O_2 are obtained. Response factors were obtained for each of these components so that the analysis could be expressed on a volume basis.

Air samples were also obtained above a VCM diffusion flame; Table III contains a summary of a typical analysis. It should be noted that this analysis has not been corrected for HCl or combustion water content. It is also recognized that the results of each of these analyses (except the HCl analysis) are dependent on the actual conditions employed. For example, the relative levels of phosgene, CO, and CO_2 would be different in a fire where oxygen depletion is a factor. However, oxygen depletion would tend to suppress the formation of $COCl_2$ and CO, so the values cited herein represent near maximum concentrations.

Total Combustion Analysis

The various analyses cited in this paper can be combined to give an overall combustion profile for VCM. Based on the CO/CO_2 and phosgene gas analyses and on the hydrogen chloride determination (52% of the monomer), an approximate analysis of an air sample obtained immediately above a VCM flame would be, in ppm): HCl 27,000 ppm; CO_2 58,100 ppm; CO 9,500 ppm; phosgene 40 ppm; and VCM trace.

Conclusions

It is felt that, from a hazard standpoint, the gross quantity of HCl in the combustion gases from VCM is the main source of danger. While it is recognized that, in the very near vicinity of a VCM fire, dangerous amounts of phosgene may be present, it is noted that at this point the atmosphere will already have been rendered insupportable by the high concentration of HCl.

The pungent odor of HCl would also act as a warning device to clear the area or to obtain the necessary breathing apparatus to deal with the fire.

Acknowledgments

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HEALTH HAZARD ASSESSMENT OF PHOSGENE FORMATION IN GASES OF COMBUSTION OF POLYVINYL CHLORIDE USING A SIMPLIFIED METHOD OF MATHEMATICAL MODELLING

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Abstract—The unresolved question of formation of phosgene in dangerous amounts in the gases evolved by combustion of PVC, e.g. in a fire, has been investigated by mathematical modelling.

Formation of considerable amounts of phosgene is shown to be possible, thermodynamically, below 850 K (600°C), but the rates of the involved homogeneous reactions are very slow in this temperature region. If, by chance, the gases come into contact with copper or iron and elementary carbon, the rates may be strongly enhanced through a catalytic action. Under certain extreme conditions with respect to composition, temperature and cooling rate of the combustion gases, dangerous concentrations of phosgene may then be reached within a fraction of a minute. The conditions favouring phosgene formation are specified and the practical applications of the results discussed.

INTRODUCTION

POLYVINYLCHLORIDE (PVC) is one of the chloro-organic compounds manufactured in the largest volume on a global scale. It is being used, for instance, for sheet and film, flooring, coating of electric cables and wires, for pipes and conduits, etc.

A part of the PVC produced will be destroyed by combustion under conditions ranging from municipal incinerators to fires. Many people, and firemen in particular, may be exposed to the gases thereby formed. It is therefore important to assess the health hazard of the gases evolved, taking into account all hazardous substances which may be found during the process of combustion.

Several laboratory investigations have been carried out with the purpose of a qualitative and quantitative determination of gaseous substances formed by the oxidative thermal degradation of PVC under varying conditions.

PACIOREK *et al.* (1974) analysed the volatiles being formed at 670 K (400°C) in a static experiment. The following substances were found to be present: hydrogen chloride (94% of the theoretical maximum yield of 583 mg HCl/g of PVC), carbon monoxide, carbon dioxide and aliphatic and aromatic hydrocarbons with benzene as an important example. Chlorinated hydrocarbons (including the VC monomer) and organic oxygen compounds were found to be present too, but in small amounts. The same types of compounds, except the oxygen-containing ones, were identified by WOOLLEY (1971), who has also given a summary of the somewhat diverging results of older analytical investigations.

With respect to the formation of the highly toxic compound phosgene, $COCl_2$, the divergences among past research results are rather pronounced. Whereas

PACIOREK *et al.* (1974) pass over this problem, yields up to 1.6 mg $COCl_2$/g of PVC plastic were found by BROWN and BIRKY (1980). In these experiments the combustion of PVC took place inside a closed system, the surface of which was kept at room temperature. The reaction was brought about in one of the following ways: heating of the sample in a small furnace, overloading of a wire coated with the substance and electric arc formation between electrodes partially covered with PVC. Still larger yields (reaching 3.5 mg $COCl_2$/g of PVC) were demonstrated by BALTAITIS *et al.* (1975), whereas COLEMAN and THOMAS (1954) got a yield of 0.2 mg $COCl_2$/g of PVC at 1170 K (900°C). The yield decreased with decreasing temperature. The experiments referred to so far were all of the static type. No phosgene could be detected in the gas phase in the experiments of THINIUS *et al.* (1964), TSUCHIYA and SUMI (1967), BOETTNER *et al.* (1969) and WOOLLEY (1971). These experiments, except the first one, were all flow experiments with continuous supply of air and removal of gaseous products formed.

Results from different experiments are difficult to compare and to generalize for several reasons. Each experimental group used an experimental set up of its own. In the static experiments the gas phase was thermally inhomogeneous, which means that its temperature was undefined. Another important kinetic parameter, the time available for secondary reactions, was undefined also.

On evaluating these experiments from a hygienic point of view using Threshold Limit Values (TLVs), phosgene is found to be of secondary importance relative to hydrogen chloride in all the cases investigated. The character of the underlying experiments does not permit us, however, to look at this conclusion as the final one. The existence of conditions favouring a more abundant formation of phosgene in the gases of combustion of PVC cannot be excluded. It is the purpose of this paper to investigate whether such conditions might exist and, if so, to define them. The basis of the investigation is the available information on the thermodynamics and kinetics of the processes leading to phosgene formation and decomposition.

MATERIALS AND METHODS

Toxicity of gaseous mixtures—the load L

In a previous paper (BJERRE, 1981) a load L was introduced as a tool in assessing health hazards of gaseous systems in which toxic secondary pollutants are formed from a primary pollutant through a chemical reaction. When the secondary pollutants Y_j, $j=1,2,\ldots,m$ (concentration $[Y_j]$) are formed from a number of reactants X_i, $i=1,2,\ldots,n$ (concentration $[X_i]$ and initial concentration $[X_i]_0$) in a chemical reaction:

$$\sum_{i=1}^{n} \nu_i X_i = \sum_{j=1}^{m} \nu_j Y_j \tag{1}$$

the expression for L takes the form:

$$L = \left(\sum_{i=1}^{n} [X_i]/T_i + \sum_{j=1}^{m} [Y_j]/T_j\right) \Big/ \sum_{i=1}^{n} ([X_i]_0/T_i). \tag{2}$$

ν_i and ν_j are (positive) stoichiometric coefficients of reactants and products respectively. T_i is the TLV of the substance i in ppm. L tells us how many times the toxicity of the gas phase has increased at any stage of the chemical reaction. The initial value equals unity. Additivity of toxic action has been assumed in equation (2). At present there seems to be no alternative to this crude but very well used assumption (ARBEJDSTILSYNET, 1976; ACGIH, 1982). TSUCHIYA and SUMI (1967) in their evaluation used the additivity assumption as well, but instead of the TLVs they used concentrations lethal to man after 30 min.

For the present purpose we adopt a simplified version of equation (2). When the maximum rate of reaction and, therefore, the maximum of the slope $L'(t)$ of the L-curve is found at the start of the reaction ($t=0$), an approximate L-curve may be constructed from the tangent of the L-curve at $t=0$ and the straight line $L=L_{max}$, where L_{max} is the maximum value of L:

$$L \simeq \begin{cases} L(0)+L'(0)t & 0 \leq t < t_i \\ L_{max} & t_i \leq t \end{cases} \tag{3}$$

$L(0)$ is the L-value and $L'(0)$ is the slope of L at $t=0$. t_i is the point of intersection of the two straight lines.

$$t_i = (L_{max} - L(0))/L'(0). \tag{4}$$

The approximation is illustrated in Fig. 1. The approximation yields L-values larger than the exact ones, which is reasonable for a hazard evaluation.

The slope of the L-curve has a simple connection to the rate of the chemical process (1) going on in the gaseous mixture. If the reaction rate is expressed as the rate of production $d[Y_i]/dt$ of the product Y_i, the following relation is derived by differentiating equation (2):

$$L'(0) = (c/\nu_i)\,(d[Y_i]/dt)_{t=0} \tag{5}$$

where $(d[Y_i]/dt)_{t=0}$ is the initial reaction rate and c is constant:

$$c = \left(-\sum_{i=1}^{n} \nu_i/T_i + \sum_{j=1}^{m} \nu_j/T_j\right) \Big/ \sum_{i=1}^{n} ([X_i]_0/T_i), \tag{6}$$

the constant c has the same sign as the denominator of equation (6). It is positive in the cases of hygienic interest, that is, when the reaction products are more toxic than the reactants. Using equation (3), with equation (5) and (6) instead of equation (2), mathematical modelling may be done by simply inserting the rate expression of

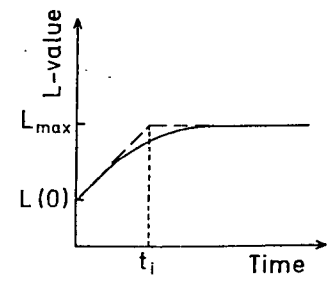


FIG. 1. Schematic graph of the quantity L [equation (2)] reflecting the change in toxicity of a gas mixture during a chemical reaction, (————) exact curve, (------) approximate curve.

reaction (1) in equation (5). A numerical integration of the rate expression to get concentrations of the components $[X_i]$ and $[Y_i]$ as a function of time is thus avoided.

The TLVs used in this paper are the Danish ones from ARBEJDSTILSYNET (1981) *viz.* HCl, 5; CO, 35; Cl_2, 0.5; and $COCl_2$, 0.05 ppm.

In the present context we regard the formation of phosgene to be significant when the increment of the load L is equal to or larger than unity. Furthermore, a unit increment of L must be reached within a minute ($L'(0) \geqq 1\ \text{min}^{-1}$).

Chemistry of phosgene formation

The basis of the present investigation is the assumption of BROWN and BIRKY (1980) of phosgene being formed through secondary reactions in the gaseous phase. An oxidation of hydrogen chloride to chlorine is followed by a reaction between chlorine and carbon monoxide:

$$2HCl + \tfrac{1}{2}O_2 = Cl_2 + H_2O \tag{7}$$

$$CO + Cl_2 = COCl_2. \tag{8}$$

Equations (7) and (8) may be described as oxychlorination of CO with gaseous, molecular chlorine as a 'chlorine carrier'. The possibility of certain nongaseous substances, e.g. chlorides of copper (DAUMAS, 1973), or of adsorbed species being able to transfer chlorine to CO should be pointed out, however. A primary formation of $COCl_2$ in the PVC phase is improbable. Studies of the kinetics of thermal oxidation of PVC (see BRAUN, 1981) has shown the first step to be a zipper-like propagating dehydrochlorination leading to cleavage of the C—Cl bonds. In the next step the polyene chains are oxidized and thermally degraded mainly to carbon oxides and hydrocarbons. Nor does a direct formation of Cl_2 in the polymer phase seem to be plausible considering the reactivity of this compound relative to the C—H and C=C bonds.

Theoretical basis of modelling

Two types of theoretical calculations are involved in the present investigation: (1) thermodynamic equilibrium calculations to decide whether the formation of a certain product (e.g. $COCl_2$) is at all possible under the given conditions, and (2) reaction rate calculations to decide whether the rate of formation of the product is large enough to ensure the formation of significant amounts within the time available.

A difficulty in applying these tools in the present case is the great variability in chemical composition, e.g. of gases formed by the combustion of PVC. For the present purpose the most satisfactory solution is to pick out the 'maximum hazard case', i.e. the case showing optimum conditions with respect to the formation of phosgene.

For the equilibrium calculations a standard computer program was used (INGRI *et al.*, 1967) in connection with thermodynamic data from the tabulation of GLUSHKO (1978). The rate expressions and rate constants to be used for the kinetic calculations are given in Table 1. Rate constants are written in the form

$$\log k = A - B/T + n \log T. \tag{9}$$

The rate data used were evaluated experimentally in systems with only the reactants and products of each process being present. We assume the processes to proceed in approximately the same way in the gaseous mixture investigated here.

TABLE 1. RATE DATA FOR GAS PHASE REACTIONS

Equation	Rate expression	Rate parameters of equation (9) (rates in mol dm^{-3} min^{-1}) n	A	B
(7)*	$d[Cl_2]/dt = k_1[HCl][O_2]$	0	11.76	11,250
(8)†	$d[COCl_2]/dt = k_2[CO][Cl_2]^{3/2}$ (homogeneous)	0	9.654	5570
(8)‡	$d[COCl_2]/dt = k_3[CO]^{3/4}[Cl_2]^{1/4}$ (heterogeneous)	1	−0.312	1400
(11)‖	$-d[COCl_2]/dt = k_4[COCl_2]^2[O_2]/([Cl_2]+k_5[O_2])$	k_4: 0	7.08	4390
		k_5: 0	−6.0	0
(12)¶	$-d[COCl_2]/dt = k_6[COCl_2][H_2O]$	0	5.58	2610

*KOCHUBEJ *et al.* (1972). Data from measurements between 850 and 1420 K in a silica vessel. Independency of the rate of the surface to volume ratio indicates a homogeneous process.

†CHRISTIANSEN (1923). Data from measurements between 650 and 780 K. Similar data were obtained by BODENSTEIN and PLAUT (1924), who showed the rate to be unchanged when oxygen is present.

‡SHAPATINA *et al.* (1976). Data from measurements between 340 and 400 K with active carbon (Bayer AKT-4) as a catalyst. The rate expression given is the limiting form valid for small phosgene concentrations. The value of the A-factor corresponds to 0.4 g of active carbon being present per dm^3 of gas. This is the maximum amount of carbon formed from incomplete combustion of a hydrocarbon C_nH_n in air.

‖ The rate expression is derived by BJERRE (1981) from experimental data of GAISINOVICH and KETOV (1969a) between 510 and 710 K in a silica vessel.

¶GAISINOVICH and KETOV (1969b). Data from measurements between 490 and 690 K in a silica vessel.

RESULTS

The methods described are applied below to the processes involved in the production of phosgene.

Combustion of PVC

The composition of the gases from combustion of PVC, optimizing the conditions of phosgene formation, is expressed by the following equation:

$$-CH_2-CHCl- + 7/4\ O_2 + 7N_2 = 2CO + HCl + H_2O + \tfrac{1}{4}\ O_2 + 7N_2. \tag{10}$$

All C atoms are transformed to CO, ensuring both a maximum concentration of this compound and the absence of hydrocarbons. Most hydrocarbons are likely to react with chlorine in a fast reaction competing with equation (8). In the gaseous mixture to be named as 'the unreacted gas mixture' [right side of equation (10)], HCl and O_2 are present in stoichiometric amounts for reaction (7). How close the composition of combustion gases from PVC might come to this extreme case is not clear. Formation of hydrocarbons is suppressed by increased temperature and an excess of oxygen, but, at the same time, the yield of CO decreases relative to that of CO_2.

The experimental investigations referred to above point towards a temperature of combustion beyond 800 K (500°C) as the optimum one for approaching equation (10).

To decide whether phosgene formation is at all possible in the unreacted gas mixture, thermodynamical calculations were carried out assuming simultaneous chemical equilibrium for reactions (7) and (8). A graph of the calculated equilibrium concentration of phosgene $[COCl_2]^*_{1,2}$ is given in Fig. 2(a). The equilibrium concentration of chlorine $[Cl_2]^*_{1,2}$ is shown as well. Indeed, for $T < 700$ K (430°C) the

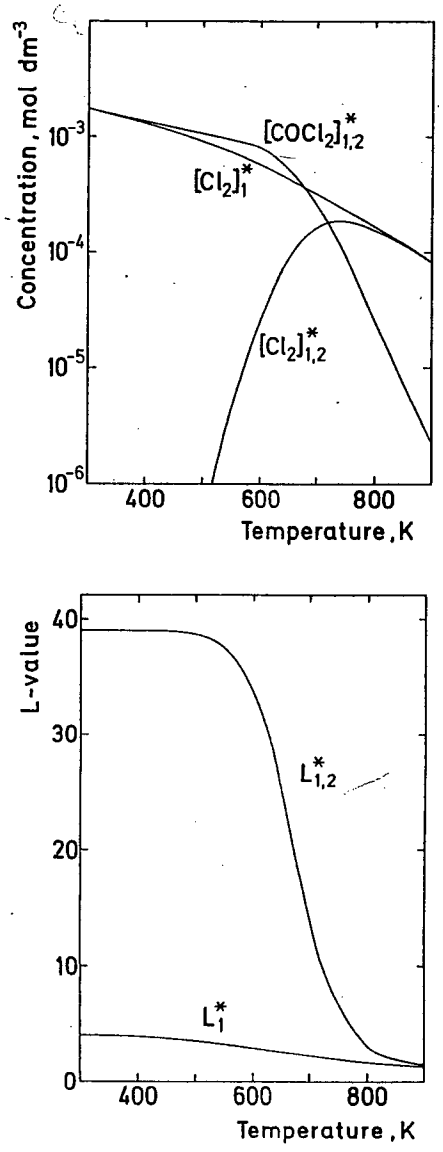


FIG. 2. Calculated concentrations and L-values versus temperature assuming the gases of combustion of PVC to go to chemical equilibrium. (a) $[COCl_2]^*_{1,2}$ and $[Cl_2]^*_{1,2}$: concentrations assuming equilibrium with respect to equations (7) and (8); $[Cl_2]^*_1$: concentration assuming equilibrium with respect to equation (7) only. (b) The corresponding graphs of the quantity L reflecting the relative toxicity of the gaseous mixture.

calculated phosgene concentration is found to be of the order of magnitude 10^{-4}–10^{-3} mol dm^{-3} or ~1000–10,000 ppm, but it decreases strongly with increasing temperature and becomes negligible above 850 K (600°C). This behaviour of the phosgene concentration is reflected in the graph of the quantity $L^*_{1,2}$ (Fig. 2(b)) being the load L calculated from equation (2) inserting equilibrium concentrations of the substances. The toxicity of the equilibrium gas mixture strongly exceeds that of the unreacted one ($L=1$) except at the highest temperatures.

Formation of chlorine

As demonstrated above, the formation of chlorine needs investigation for $T<850$ K only.

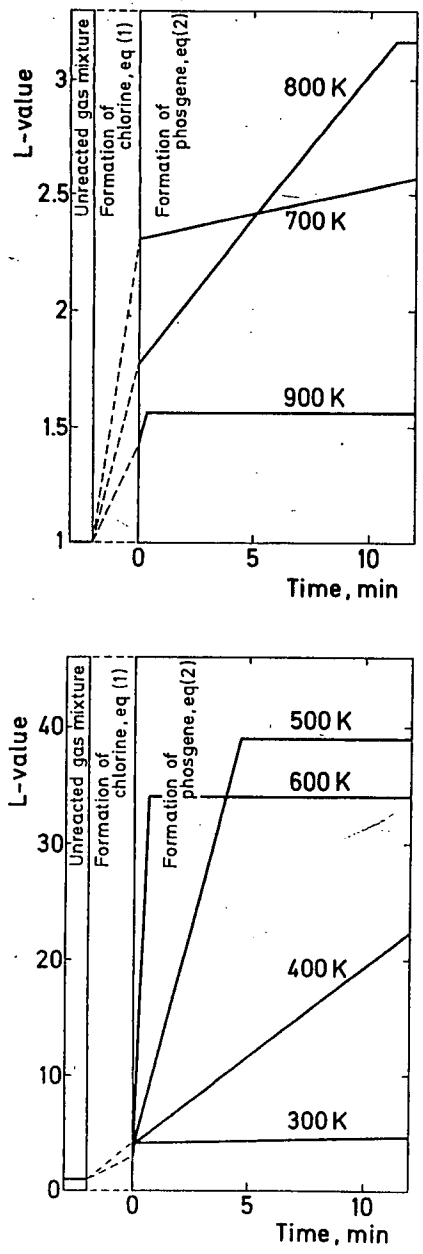
An expression for the relative reaction rate of the homogeneous process (7) can be derived using data from Table 1. The values of the concentrations of HCl and O_2 to be inserted in this expression are those of the unreacted gas mixture. A maximum value of the rate is found at $T=850$ K: $-(d[HCl]/dt)/[HCl]=1.2\times10^{-4}$ min^{-1}. The concentration of chlorine obtainable within time intervals of interest here is thus rather inconsiderable. However, in the presence of certain catalysts, e.g. chlorides of copper and iron, the rate may be speeded up enormously. In a fire the metal chlorides are most likely to be formed from the corresponding metals, when present, through a reaction with the heavily corrosive combustion gases (BROWN and BIRKY, 1980). Following Gmelins Handbook (BUSCHBECK, 1968) the rate of the catalysed reaction may be appreciable even at 670 K (400°C).

Again we avoid a rather risky prediction of the resulting chlorine concentration by going once more to the maximum hazard case. This case is characterized by the chlorine concentration showing its maximum value $[Cl_2]=[Cl_2]^*_1$ which is calculated assuming the unreacted gas mixture to be in chemical equilibrium with respect to equation (7) but not equation (8). A graph of $[Cl_2]^*_1$ is given in Fig. 2(a). The load $L=L^*_1$ of the equilibrium mixture is graphed as function of the temperature T in Fig. 2(b). It is evident from this figure that the formation of chlorine as a possible hygienic problem is much less important than that of phosgene formation.

Formation of phosgene

Inserting the chlorine concentration $[Cl_2]^*_1$ and the corresponding CO-concentration in the rate expression (Table 1) of homogeneous phosgene formation and using equations (3)–(6), the load L for the maximum hazard case was calculated as function of time t and temperature T. Graphs of L vs t are given in Fig. 3(a). Initially we have: $L=L(0)=L^*_1$. The limiting value of L for $t\rightarrow\infty$ is $L=L(\infty)=L^*_{1,2}$, in which case the maximum possible phosgene concentration has been obtained. From Fig. 3(a) the conclusion must be drawn that homogeneous phosgene formation is either too small or too slow to be of importance.

Again, the reaction rate may be strongly increased by a solid catalyst, e.g. elemental carbon, a substance present in nearly every fire as soot or carbonized material. The catalytic activity of elemental carbon depends very much on its structure. Here L-curves are calculated for the case of 0.4 g dm^{-3} of the active carbon, Bayer AKT-4, being present. This is a highly efficient industrial catalyst for the reaction (8) and certainly represents an extreme case. The calculation is done exactly as in the previous case, but now the rate expression of Table 1 for the heterogeneous reaction has to be



G. 3. Graphs of approximate L-values vs temperature reflecting phosgene formation in gases of mbustion of PVC for chlorine being initially present at its equilibrium concentration. (a) Homogeneous process. (b) Heterogeneous process with active carbon as a catalyst.

used. Figure 3(b) shows the resulting L-curves. A significant increase of the L-value within a minute may now result from about 400 K (130°C). At 600 K (330°C) a significant increase may take place within seconds.

Decomposition of phosgene

We have neglected so far the fact that phosgene is being decomposed almost completely in the presence of oxygen or water vapour through the following equations:

$$COCl_2 + \tfrac{1}{2}O_2 = CO_2 + Cl_2 \tag{11}$$

$$COCl_2 + H_2O = CO_2 + 2\,HCl. \tag{12}$$

With the rate of one or both of these processes being much larger than the rate of formation of phosgene, no build-up of this compound is taking place. Upper limits to the relative reaction rates of each of the homogeneous reactions (11) and (12) may be calculated from rate expressions and rate constants given in Table 1. The results presented in Table 2 relate to a gaseous mixture where 50% of the equilibrium yield of phosgene has been formed. Hydrolysis is seen to be the dominating process, but the rate is too small to ensure the decomposition of phosgene within a time interval of the order of magnitude of one minute, even at 800 K.

A recalculation of the L-curves of Fig. 2 and Fig. 3 with a different set of TLVs may be accomplished using information contained in this paper.

TABLE 2. FRACTION OF $COCl_2$ OXIDIZED OR HYDROLYSED IN 1 min*

T (K)	$-\frac{1}{[COCl_2]}\left(\frac{d[COCl_2]}{dt}\right)_{ox}$ (min^{-1})	$-\frac{1}{[COCl_2]}\left(\frac{d[COCl_2]}{dt}\right)_{hyd}$ (min^{-1})
400	1.7×10^{-9}	4.5×10^{-4}
600	8.1×10^{-4}	4.0×10^{-2}
800	1.0×10^{-2}	3.2×10^{-1}

*The values of the table are calculated for a composition of the gaseous mixture obtained in the following way: (1) Equilibration of the unreacted gas mixture with respect to equation (7); (2) freezing of this equilibrium; (3) formation of half the possible yield of $COCl_2$ from equation (8), that is $[COCl_2] = 0.5\,[COCl_2]^*_{1,2}$.

DISCUSSION

The dilemma met in this investigation of a gaseous reaction being thermodynamically favourable and kinetically unfavourable at low temperatures and vice versa at high temperatures has famous parallels in industrial chemistry as, for example, the reaction between nitrogen and hydrogen to form ammonia. It was not a mere coincidence that the experimental realization of this process had to await not only a search for a suitable catalyst but also a thermodynamic analysis for a careful selection of the conditions of the reaction. Noticeable yields of the product, and this is valid for the case of phosgene too, were rather improbable by using only a random selection of the parameters and other circumstances of the reaction.

We summarize the conditions favouring the formation of phosgene from the gases of PVC combustion in the following three points:

(1) The combustion of the polymer takes place in an intermediate temperature region of a probable lower limit at 800 K (500°C) and with a limited excess of oxygen;

(2) The gases of combustion keep a temperature between 600 and 850 K (330–600°C) for the longest possible period of time. Hydrolysis of the phosgene formed might be appreciable, however, near the upper temperature limit and reaction times above a minute;

(3) The gases are, at the same time, contacting catalytically active substances. The most important ones are probably metallic chlorides (formed from e.g. copper and iron) and elementary carbon in the form of soot and carbonized materials.

It was of interest to re-investigate the laboratory experiments already cited to see whether those experiments showing phosgene to be present are in better agreement with points 1–3 than those showing phosgene not to be present. In fact, this is found to be the case. Thus the decomposition temperature (when defined) was near to or exceeded 800 K (500°C) in the studies where phosgene was detected (COLEMAN and THOMAS, 1954; BALTAITIS *et al.*, 1975; BROWN and BIRKY, 1980). Enough oxygen for a full combustion of the sample was present except in a few of the experiments of BROWN and BIRKY (1980) where, however, unburnt material was sometimes left. COLEMAN and THOMAS (1954) found the phosgene yield to be larger at a decomposition temperature of 1170 K than at 870 K with no yield at 570 K. In the experiments of THINIUS *et al.* (1964), decomposing the PVC sample at 800 K, no phosgene could be detected. Here hydrocarbons were shown to be present (point 1).

The studies discussed above were all of the static type allowing prolonged contact between the gases and the heat source. Turning next to the flow experiments (TSUCHIYA and SUMI, 1967; BOETTNER *et al.*, 1969; WOOLLEY, 1971), with fast removal and cooling of the gases formed, no phosgene was found to be present (point 2).

Metallic heating coils or electrodes were in contact with the gas mixture in the studies of COLEMAN and THOMAS (1954) and in some or all of the studies of BROWN and BIRKY (1980). It is unknown whether this was the case too in the study of BALTAITIS *et al.* (1975). As regards the contact of catalytically active carbon with the gases, it seems difficult to differentiate between the experiments (point 3).

The most obvious area of application of the results presented above is health hazard assessment of gaseous mixtures from fire hazards or from incinerators burning material with a high content of PVC. A straightforward example is that a phosgene hazard is much more probable when the combustion involves PVC-coated metallic parts (e.g. electric cables and wires) than when no such parts are involved. In the case of the incineration of municipal refuse containing only a few percent of PVC the conditions of phosgene formation are still more unfavourable: the small content of hydrogen chloride decreases the rate of chlorine formation and the large concentration of water vapour present increases the rate of decomposition of phosgene.

Certainly the necessary conditions to be fulfilled for phosgene to be formed in hazardous amounts are very restrictive, but they are not prohibitive. Yet the problem still cannot be buried. How much phosgene might be formed when these conditions are fulfilled? This question has not been answered in this paper and might at present be more open to an experimental than to a kinetic investigation.

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Polyvinyl Chloride Toxicity in Fires

Hydrogen Chloride Toxicity in Fire Fighters

Robert F. Dyer, MD, Victor H. Esch, MD

• Polyvinyl chloride, of all the plastic polymers, has been implicated primarily in causing the most serious problem in fire fighting today because it releases hydrogen chloride gas when burning. One hundred seventy fire fighters who experienced symptoms from its toxicity have been studied from 1970 to 1975. One died.

(*JAMA* 235:393-397, 1976)

A RECENTLY identified hazard that is of paramount importance to practicing physicians is that of chemical injury incurred by persons exposed to fumes from fires. Specifically, such injuries are caused by the inhalation of vapors created by the thermal degradation of polyvinyl chloride, a plastic polymer. Such substances have now become widely used in the construction of homes, furnishings, office equipment, electric wire, telephone and cable covering, and vehicles. A particular hazard exists in the case of the fire fighter, although it could be equally serious in any circumstance in which an individual might be exposed to such plastic combustion products.

See also p 390.

THE FIRE

At 10:30 AM on Jan 6, 1970, an alarm sounded for a fire reported to be on the sixth floor of Building 213 at the Washington, DC, Navy Yard. Units of the District of Columbia Fire Department arriving on the scene found the floor filled with a heavy concentration of toxic fumes. Although all of the fire fighters carried masks, none were used, since neither the fire nor the smoke was so excessive as to prevent entry without masks. The fire, which was confined to an office copying machine constructed of plastic and Teflon parts, was quickly extinguished.

The fire companies entered the building via the elevator, placed several portable fans for ventilation, and left the building about 20 minutes later. On returning to their quarters, many of the fire fighters experienced unusual and unexplainable symptoms, including a constricting tightness localized to the anterior part of the chest. This chest discomfort was described as a searing, burning sensation accompanied by dyspnea as well as a "burning sensation appearing to close off the throat." These symptoms were in addition to the usual headache, dizziness or vertigo, and nausea, which, in our experience, is frequently seen in cases of nonchemical smoke inhalation. Some symptoms persisted over a course of several days following exposure to the fumes. The dyspnea was noted on mild exertion and was associated with moderate apprehension by all of the affected fire fighters. A number of the fire fighters exposed at this fire experienced severe conjunctivitis, lacrimation, and dyspnea persisting for 24 hours after the fire. An intense headache, localized anteriorly and persisting about 24 hours, was also common.

From the Police and Firemens Clinic, Washington, DC.

Reprint requests to Chairman of the Board of Surgeons, Suite 1445, Chevy Chase Bldg, 5530 Wisconsin Ave, NW, Washington, DC 20015 (Dr Dyer).

REPORT OF A CASE

Approximately 24 hours after the fire, a 33-year-old fire fighter fainted in the sitting room of the truck company. It was also reported that he had a muscle spasm similar to an epileptic seizure, but recovered, was fully conscious, and got up immediately. His superior officer asked how he felt, and he replied that he was "fine" and walked into the kitchen. Following lunch, the acting sergeant on duty looked for the man to check his condition for driving and found him lying on the floor next to his bed. He was cyanotic and, despite all resuscitative efforts by an ambulance crew and the rescue squad, was pronounced dead on arrival by a fire surgeon at the George Washington University Hospital at 1:10 PM. Postmortem examination by the District of Columbia Department of Public Health Medical Examiner showed severe pulmonary hemorrhage and edema due to chemical pneumonitis secondary to exposure to chemical smoke and fire. The pathologist also reported coronary atherosclerosis.

EFFECT OF FUMES

It has been suspected for several years that the smoke and fumes from electrical fires produced greater injury now than similar fires in the past.[1,2] It was strongly suspected that hydrogen chloride released by thermal degradation of PVC, a common electrical wiring insulation material, was the lethal product causing death in this instance. The medical examiner's report and the microscopic findings subsequently confirmed our original clinical impression of the cause of death.

Hydrogen chloride, inhaled either in the gaseous state or combined with water vapor, acts as an irritant to the mucous membranes of the eyes and

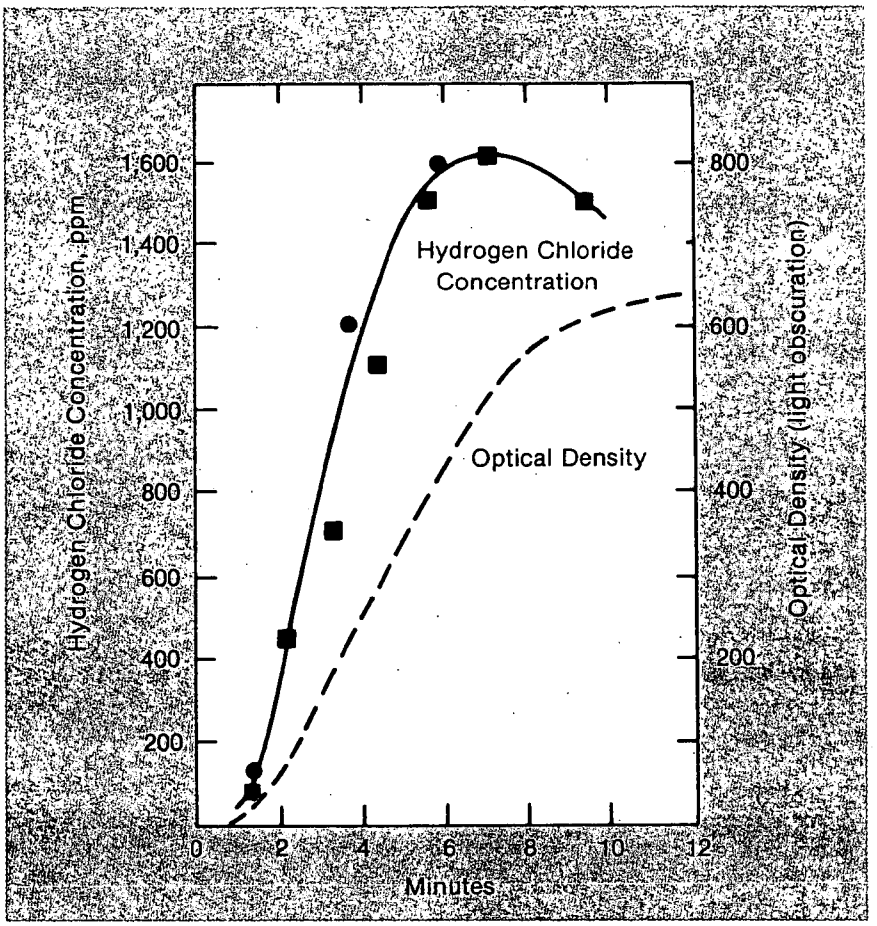

Fig 1.—Hydrogen chloride concentration and optical density of polyvinyl chloride electrical insulation decomposition products.

the respiratory tract. An HCl concentration of 15 ppm causes localized irritation to the throat after short exposure. Hydrogen chloride concentrations of 50 to 100 ppm are tolerable for one hour by humans. More severe exposures result in pulmonary edema and often in laryngeal spasm. Concentrations of 1,000 to 2,000 ppm of HCl are dangerous even with brief exposure[3] (Fig 1).

Quantitative release of HCl on thermal degradation of PVC has been well documented in the scientific and medical literature. Polyvinyl chloride, of all the synthetic plastic polymers, has been implicated as causing one of the most insidious, serious problems in fire fighting today, due to its release of HCl gas while burning. Mists of hydrochloric acid are considered less harmful than anhydrous HCl because the droplets have no hydrating action.

Animal Experiments

The toxicity of PVC has been substantiated by Kishitani[4] in his comprehensive animal experiments performed at the University of Tokyo. With respect to the toxicity of carbon monoxide, Kishitani states that the injurious nature of PVC is unique. All mice exposed to harmful gas products died, but the carboxyhemoglobin concentration in the dead animals was low (average, 21.2%). This clearly indicated that the fatalities were not due directly to CO poisoning. At autopsy, the eyes of the mice were closed, their mucous membranes were injured by chemicals, and the sclerae were discolored. The latter had become white due to the action of chlorine gas. All of the mice died in a period of 15 minutes after exposure to PVC fumes. Electrocardiographic abnormalities appeared prior to generation of large quantities of smoke. This indicated that a harmful gas produced at an early stage was causing the effect. Similar results were found on exposure to polyurethane gas. Kishitani concluded that the injurious properties of burning materials such as wood, fire retardant plywood, melamine finishing board, and acrylic resin are due to CO.

In the fatalities due to CO, the average concentration of CO was 45%. The burning of cellulose material resulted in nothing but the release of CO. In the mouse study with exposure to burning building materials, the ECG abnormalities were recorded before the smoke from the burning materials was evident.

In regard to the harmful properties of PVC to mice, as well as those from polyurethane, polysterene, and phenol, the pathologic effects of the gases, rather than those of the smoke, appeared first, as shown by atypical ECG changes. It requires less CO in combination with HCl to cause death. In conclusion, HCl and CO have a reciprocal, potentiating adverse effect.

EFFECT OF SMOKE

Smoke is a suspension of small particles in hot air and gases. It has a particulate fraction and a gaseous fraction. The particles consist of carbon and are coated with combustible products such as organic acids and aldehydes. The gaseous fraction has an extremely variable composition. Carbon monoxide and carbon dioxide are always present and constitute the bulk of this fraction.

However, a wide variety of other toxic gases are present at the scene of a fire. These may be formed by the combustion process or leak from commercial processing or storage equipment. The particulate and gaseous fractions combine to exert a large space-occupying effect and can fill an enclosed space at the expense of air. The gaseous fraction of smoke is much more dangerous to life than the particulate fraction. The nose, mouth, and throat, which filter out and trap the particulate fraction, cannot filter out the toxic gases. These gases enter the upper respiratory tract and lungs freely when inhaled. Damage to the lungs may result from exposure to a group of gases and vapors called pulmonary irritants (chlorine, phosgene, nitrogen dioxide, sulfur dioxide, and ammonia). On entering the lungs, these agents react chemically with water to produce strong acids or alkalis. A violent inflammatory response occurs, causing destruction of lung tissue.

Fire fighters and victims of fires in homes, offices, and industrial complexes are exposed to smoldering and

burning plastics and synthetics from furniture, floor and wallcoverings, textiles, and building materials. Many plastics produce large volumes of pulmonary-irritant gases when burned. Polyvinyl chloride is used extensively in furniture, both in the foamed plastic stuffing as well as the covering. Burning 450 gm of this material produces 320 gm of chlorine, phosgene, and HCl, all of which are strong pulmonary irritants. In all, there are 75 known products of PVC degradation. Practically every structure today contains plastics capable of producing lung-damaging gases when burned. Therefore, the fire fighter faces a great, new risk in almost any fire.

It became obvious that a particular pattern was emerging in which certain fire situations were productive of insidious and unpredictable fire casualties. The lethal chemical smoke was determined to be HCl resulting from the decomposition of PVC plastic used in telephone cable and electrical equipment installations.

We have found electrical and telephone cable fires to be especially hazardous to the fire fighters, due to the toxic gases produced. We have found that when a short circuit developed in a main switch, usually located in a sub-basement or penthouse of an office building or apartment house, the area was always poorly ventilated, and the plastic-covered switches quickly heat to temperatures in excess of 93.3 C. The heated conductors cause the plastic insulation to decompose and emit white, mist-like HCl fumes that resemble steam. When the temperature range of 232 to 321 C is attained, the gas may be invisible. The fire fighter may be fatally deceived if he does not know plastic-covered cable is involved in the fire he is fighting.

OVERHAUL PHASE

The period of time just after the fire is extinguished is termed the "overhaul phase." This is when the fire fighters clean up the fireground. Toxic smoke and fumes are still being emitted. This is a serious time for toxic gas inhalation to occur since many fire fighters remove their self-contained breathing apparatus during this phase. Another special hazard during this phase is the "heat sink," ie, concrete that retains a great amount of heat and releases fumes throughout the overhaul phase. Our testing has shown highly toxic concentrations of HCl in this concrete for as long as one hour after the fire has been extinguished.

FUEL LOADING

In the late 1960s, the type of "fuel loading" in office and high-rise buildings (ie, contents of the buildings) changed significantly and initiated a new awareness. The noncombustible buildings were not burning, but furniture within them, building insulation, ceiling tile, wall paneling, and decorations made partly or wholly of plastic were fueling disasters.

While a building may be constructed of fire-resistant elements, there is no control over the combustible material that an individual may elect to bring into the structure. This is the "fuel load" and may be expressed as kilograms of combustible material per square meter of floor area. Large differences exist in combustibility, smoke, and toxic gas release among different combustible materials. More than 50 sq m of red oak, all burning at its maximum rate, would be required to produce the same rate of smoke as 2.5 meters of acrylonitrile-butadiene-styrene plastic pipe. A fire of plastic materials develops extremely high temperatures because plastics possess a heat of combustion 2½ times that of other combustibles. Therefore, the fire would magnify the normal problems of radiant heat, structural damage, and exposure. The fire would exhibit a very high burning rate because the flammability of plastics is much higher than that of other combustibles.

The four most common plastics produced in the United States in the past few years are polystyrene, polyethylene, polypropylene, and PVC. A chlorethylene polymer is a plastic solid marketed under a variety of trade names, and currently being manufactured at a rate over 8.3 billion kilograms annually.

Polyvinyl chloride (Fig 2) is a plastic solid widely used as a rubber substitute and as electric and telephone wire and cable covering. It is also utilized frequently in electrical fixtures, plastic drains, as well as waste pipe

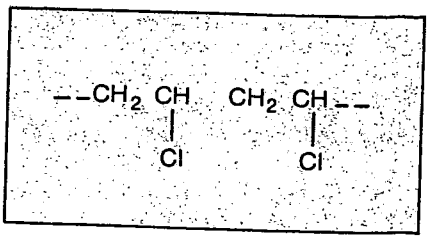

Fig 2.—Polyvinyl chloride.

for interior plumbing, pliable thin sheeting, film finishes for textiles, "noninflammable" upholstery, raincoats, tubing, belting, gaskets, shoe soles, disposable unbreakable plastic bottles, packaging materials, automobile and aircraft seatcovers, corrugated fence toppings, tarpaulins, shower curtains, phonograph records, plastic trays, baby pants, toys, curtains, and office copying-machines. It is used as an exterior finish in many vehicles, including buses and subway cars, because of its high resistance to wear and soiling.

When PVC is heated to 225 C, nothing happens. When heated above that, up to 475 C, PVC does not burn. The combustion range or flame point is 475 C. Between 225 C and 475 C, PVC loses over 60% of its weight. During this process, it thermally degrades and HCl is released. Four hundred fifty-three grams of PVC at degradation releases 320 gm of chlorine, phosgene, and HCl.

The individual toxicity factors of phosgene and the other major decomposition products of PVC, ie, benzene, toluene, total xylenes, naphthalene, and vinyl chloride, are very small, compared with the toxicity factor of HCl. Further, the total or additive toxicity factors of these minor components are also very small in comparison with HCl toxicity. Unfortunately, very little is known about the synergistic effects of toxic gases (ie, the ability of one chemical to increase or decrease the toxicity of another). The main toxic risks from the decomposition products of PVC are HCl and CO.[5]

Stone et al[6] elucidated the nature of smoke aerosol and its role in the transport of toxic gases in fire situations. They confirmed the fact that the toxic gas, HCl, is adsorbed on soot aerosol. Possible inhalation hazards of such soot are positively related to the size of the soot particles and particle agglomerates. It has been shown that

the amount and location of particle deposition in the respiratory tract depends on the particle size.[6] On inhalation, soot aerosols would enter the lower lung region and, to an extent, be retained there. Soot particle clusters, with sizes ranging from 0.1μ to 2.5μ in diameter, would be retained in the alveolar sacs to an extent of from 20% to 40% of those particles inhaled.[6] At a breathing rate of 18 liters/min for an exposure of one hour, a maximum of 0.7 gm of soot bearing 13 mg of loosely bound HCl would be retained in the lower lungs.

The effect of HCl in the gas phase is largely limited to irritability, mainly affecting the upper respiratory tract, whereas loosely bound HCl condensed on soot aerosol gains access to the lower lungs. Experiments have shown that water droplets of respirable size rapidly adsorb HCl from the gas phase and approach equilibrium concentrations in fractions of a second.[7]

SMOKE INHALATION

Respiratory distress may develop in fire fighters or fire victims immediately or within one to two days of exposure to combustion products. The best protection against these agents is the mandatory use of the self-contained breathing apparatus by every fire fighter. When anyone without a breathing apparatus is exposed to more than a few breaths of "choking smoke" characteristic of burning or smoldering plastics, he should receive prompt medical attention.

Prior to our investigation, we considered most fireground pulmonary casualties to be due to "smoke inhalation" or CO poisoning. Carbon monoxide had long been considered the leading cause of death and pulmonary morbidity in fires. Though CO is not noxious and does not actually cause serious pulmonary injury, the amount of CO in a patient is a good indicator of whether more harmful gases are present.

Before the introduction of massive fire loads of combustible and thermally decomposable plastic products, fire surgeons usually considered the CO victim to be "home safe" in four hours after exposure due to the fast half-life of CO in the blood. After exposure to plastic degradation products, a period of one to six hours elapses between exposure and onset of severe respiratory and chest symptoms. Treatment is most effective if given during this quiescent phase. Once the symptoms of difficult breathing, cyanosis, or other symptoms, as noted in the reported case, have appeared, it may be too late to prevent severe morbidity or even mortality. The "overhaul phase" after the fire is extinguished is dangerous with respect to fumes also.

A Harvard research team headed by Donald P. Dressler, MD, reported in 1973 that when burned, plastics and modern fibers produced colorless, odorless fumes that quickly displace oxygen and cause a dramatic rise in the CO_2 level of the atmosphere.[8] Therefore, a person either dies or is rendered unconscious in the early stages of a fire involving these materials. If he is unconscious, he soon dies of other lethal fume inhalations.[8] Tests performed in Cambridge, Mass, showed that fire fighters were probably affected adversely by the high level of CO_2 rather than by the initial release of toxic gases.[8]

In establishing the importance of detecting the presence of certain toxic gases, the difficulty in detecting CO has been emphasized.[9] Some human response mechanisms are more sensitive than others to CO inhalation.[9] Fairly high levels of CO affect a human's vision, but even higher levels do not affect his sense of timing. A research team headed by R. A. McFarland, MD, of Harvard University, found that when CO replaces 11% to 17% of the blood's normal oxygen, the peripheral vision is affected and the subject has difficulty viewing stimuli at a 20° angle from the line of sight.[9] The Harvard team also found that at a 17% concentration of COHb, some subjects had a momentary lapse of attention and failed to respond to all the stimuli presented. This is important in disproving the once-held concept that once an individual has detected the sharp odor of HCl he can walk away. It has been our observation that the fire fighter cannot escape the HCl fumes.

Cornish and Abar reported that CO and hydrochloric acid were the major toxic products from the combustion of PVC.[10] They pyrolized PVC polymers in a stream of air by gradually increasing the temperature from ambient to 600 C. Exposure to this air stream supplemented with oxygen produced pulmonary and interstitial edema in rats. Some of these animals also showed focal bronchial and intra-alveolar hemorrhage.

In a sealed environment (such as a centrally air-conditioned house, office, high-rise unit, or hospital), fumes from plastic degradation could kill, even if the fire is brought under control. It has been observed that a sleeping person needs an estimated 12 to 15 minutes to awaken, react to danger, and take appropriate action to save himself. With inhalation of fumes from burning plastic, he will not have that much time.

COHb LEVEL AND CIRCULATION

As noted by E.P. Radford (written communication), 43 deaths due to fire demonstrated that a blood COHb level of over 65% is nearly always lethal due to the depression of respiration and circulation. Ventricular fibrillation from acute myocardial hypoxia induced by a rapid rise of the COHb level in individuals with a restricted coronary circulation was found to be the likely explanation of a lower terminal blood COHb level. These individuals were found to have severe, preexisting coronary vascular disease.

We believe that any compromise of the coronary circulation, eg, atherosclerosis such as found in the fatal case, would be potentiated by highly irritating chemical fumes. We also believe that other pyrolysis products, especially HCl, have contributed to ventricular fibrillation since its concentration is comparable to that of CO in real fire situations involving plastics.

Kishitani has demonstrated that chlorine affects the myocardium more rapidly and more severely than CO. Carbon monoxide may cause changes in enzyme activities suggestive of myocardial damage. Hydrogen chloride has been found to be a more potent myocardial irritant whose effects may be difficult to determine by clinical observation. This is in conjunction with the development of pulmonary edema over a 24-hour period following exposure to HCl. This further complicates and compromises coronary artery oxygen saturation. This could lead to sudden death syn-

drome, similar to that in the reported case. Although in the cases of CO poisoning noted by G. Gordon, (written communication) the ECG changes did appear late if at all and the COHb varied in individuals at the same fire as well as in different fire situations, it has been our experience that all fire fighters exposed to PVC do manifest ECG signs of its toxicity. There are variable levels of its toxic effect on the lungs, mucous membranes (tracheal peeling effect), eyes, and other parts of the body.

CLINICAL STUDY

In Washington, DC, a clinical study of fire fighters suspected and later known to have been exposed to toxic products from thermal degradation of PVC was conducted by the DC Board of Police and Fire Surgeons between January 1970 and September 1975. One hundred seventy individuals were exposed from one to four different times to these products and reported two or all of the symptoms of acute toxicity, ie, pain in the anterior aspect of the chest, neck and throat pain, dyspnea, severe headache, dizziness, and irregular pulse within a few hours after exposure.

Initial physical examinations were performed by the fire surgeon on the fireground, in the hospital emergency room, or at the Police and Firemens Clinic. Laboratory studies including complete blood cell count, determinations of serum glutamic oxaloacetic transaminase, blood urea nitrogen, or creatinine, and a complete urinalysis were done. Electrocardiograms were performed initially when there was chest pain, extrasystoles, or cardiac arrhythmia. However, ECG studies were not incorporated as part of the physical evaluation until the latter part of the study when their importance was appreciated.

About one fifth of the fire fighters had extrasystoles during the first few hours after exposure. Fourteen of the last 26 firemen exposed had premature ventricular contractions. Some have had recurrence of extrasystoles within the subsequent year. Chest x-ray films were done at the initial examination and have remained normal. Serum electrolyte and arterial blood gas determinations were performed on 12 of the fire fighters who were more acutely ill, or required hospitalization. Because of the excellent clinic facilities provided by the District of Columbia government, all fire fighters were observed in a holding area after exposure and examined at the clinic or the hospital emergency room after transportation from the fireground. Twelve men were admitted to the hospital for treatment. If symptoms did not worsen over the first 24 hours in the hospital, they were released and followed up on an outpatient basis at the clinic.

Specific treatment, including oxygen given intranasally at 5 liters/min, bronchodilators, antihistamines, and decongestants in oral suspension, has been utilized in controlling most of the acute respiratory symptoms. Steroids were given intravenously to three of the fire fighters during hospitalization due to the severity of their signs and symptoms of respiratory distress.

Initial and follow-up liver function tests have remained normal in all of these patients. There has been no direct correlation between severity of symptoms and history of cigarette smoking.

None of the fire fighters has had to retire for permanent airway disorders. Serial studies and follow-up examinations will continue. Since the onset of this study among professional fire fighters, the use of the self-contained breathing apparatus has been required at all fires where toxic fumes could be present. This is necessary during the "overhaul phase" also. We urge all physicians to advocate restriction of unsupervised use of PVC products. Fire research activity should be maintained at a national level to continue study as well as preventive measures for HCl toxicity in PVC fires.

CONCLUSIONS

Hazards of Plastic Fires.—Respiratory distress may develop in fire fighters and fire victims after exposure to combustion products. The complexity of the problem is emphasized when it is recognized that the thermal degradation of PVC results in the formation of at least 75 identifiable potentially toxic compounds. Three characteristics of plastic fires are the extremely high temperatures, very high burning rates, and thick toxic smoke. The main danger to exposed fire fighting personnel at the fireground results from the massive formation of HCl gas, and in many instances, its adsorption on spherical soot particles that are carried into the victims' respiratory tracts.

Prevention.—The mandatory use of the self-contained breathing apparatus by all who will be vulnerable to toxic smoke will aid in the prevention of plastic fires. Control of hazardous building designs, including equipment and ventilation is also necessary. Protection by masks during the "overhaul phase" should be required. Sophisticated air-sampling techniques are required for definitive study, including gas chromatography. Electrocardiographic studies utilizing base line tracings directly after HCl exposure are stressed.

Areas of Future Study.—All atmospheres should be suspected by the fire fighter. There should be a search for an effective gas analyzer that can immediately assess gas concentrations released by burning or smoldering plastics. Further definitive cardiologic studies are indicated. The term "smoke inhalation" should be abandoned and replaced by "inhalation of toxic combustion products."

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ACUTE HEALTH EFFECTS AMONG FIREFIGHTERS EXPOSED TO A POLYVINYL CHLORIDE (PVC) FIRE

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Markowitz, J. S. (New York State Psychiatric Institute, New York, NY 10032), E. M. Gutterman, S. Schwartz, B. Link, and S. M. Gorman. Acute health effects among firefighters exposed to a polyvinyl chloride (PVC) fire. *Am J Epidemiol* 1989;129:1023–31.

Firefighters are frequently being called on to fight fires that are chemical in nature. In the aftermath of a chemical fire in Plainfield, New Jersey on March 20–21, 1985, the authors conducted a retrospective cohort study which surveyed 80 firefighters exposed to burning polyvinyl chloride (PVC) as well as 15 nonexposed firefighter subjects. By means of an 81-item symptom checklist, exposed firefighters reported more frequent and severe symptoms at 5–6 weeks post incident. This was true for a total symptomatology score as well as 19 individual items. Some of the items with an elevated risk were consistent with exposure to hydrogen chloride, the main pyrolysis product of polyvinyl chloride. Other items with an elevated risk appeared to be related to smoke inhalation while others seemed psychosocial in nature. Analyses conducted within the exposed firefighter group showed that fighting the fire the first day, being a truckman, and residence within 1 mile (1.6 km) of the firehouse were significant risk factors for high total symptom scores. These risk factors may have been associated with level or duration of exposure to the toxic substances produced during the fire.

environmental exposure; occupational diseases; polyvinyls

In addition to civilian loss of life and property, uncontrolled fires exact a toll on the health and well being of firefighters. A majority of the negative health sequelae that arise from fires are related to smoke and fumes as opposed to burns (1). In fact, it is now believed that most fire casualties are attributable to the effects of toxic gases (2). Despite the large numbers of fires each year as well as the large population of fire-

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Abbreviations: NS, not significant; ppm, parts per million; PVC, polyvinyl chloride; SAFTEE, Systematic Assessment For Treatment Emergent Events; SD, standard deviation.

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fighters in the United States (about one million including 800,000 volunteers), there are few systematic field data on effects among firefighters exposed to toxic combustion products. An examination of combustion products of plastics is particularly important since an increase in the casualty rate associated with toxic gases coincides with the widespread use of plastics and other industrial materials (3). This study examined the association of exposure to the combustion products of one plastic, polyvinyl chloride (PVC). As with other halogen plastics, the combustion products of polyvinyl chloride are a great deal more toxic than combustion products of naturally occurring materials (4, 5). Research on the thermal degradation products of polyvinyl chloride show that hydrogen chloride and traces of benzene and toluene are likely to evolve when polyvinyl chloride is burned (6). In fact, some 75 different combustion products may evolve when polyvinyl chloride burns (7).

There is some preliminary epidemiologic evidence that suggests the deleterious effects of polyvinyl chloride exposure. A study of polyvinyl chloride-exposed Beverly Hills Supper Club fire survivors focused on long-term impairments. Data were collected on all medically treated persons (n = 16) (8). The main target of long-term impairments was the respiratory system, paralleling reported short-term impacts. A second study of the Supper Club survivors involved 12 female litigants aged 40 years or younger (9). All subjects noted the occurrence of uterine dysfunctions, such as menstrual irregularities, and heavy bleeding, or miscarriage.

In the New York City polyvinyl chloride Telephone Company fire, 64 per cent of the firefighters reported permanent effects. The most common complaints included impaired disease resistance, coughing, hoarseness, sensitivity to smoke, asthma, and repetitive bronchitis (9).

These studies, while providing some useful clues, were weak in a number of important respects. First, the samples were small and control or comparison subjects were not always used. Second, these studies often utilized "treated" subjects or even litigants. Such samples may provide biased estimates of level and type of symptomatology. Third, data were often collected retrospectively, after significant time lags, which raises the possibility of recall problems.

In this paper, we describe a retrospective cohort study that systematically assessed health status among a sample of firefighters involved in fighting a large polyvinyl chloride fire, and which uses a control group.

Background

At about 12:15 p.m. on the afternoon of March 20, 1985, an alarm sounded at the Plainfield, New Jersey fire department for a building fire at a large warehouse leased by a plastics company. Firefighters from the department arrived at the scene within minutes but the fire was already raging out of control, producing flames 40 ft (12 m) high. Additional firefighting forces were ordered immediately, including an engine company from the North Plainfield fire department.

About an hour after the fire began, firemen battling the blaze from several locations reported skin rashes and eye irritations. An hour later, it was confirmed that the unoccupied warehouse (approximate dimensions, 200 m by 70 m) contained large quantities of polyvinyl chloride waste awaiting shipment to the company's Newark plant for remolding.

State and local health departments were notified, as was the Red Cross and the Department of Environmental Protection. Several firefighters and community residents presented at nearby Muhlenberg hospital with a range of symptoms associated with the incident.

On April 4, 1985, representatives of the Plainfield fire department delivered several debris and water specimens taken directly from the scene of the warehouse fire to Gollob Analytic Services in Berkeley Heights, New Jersey. Gollob Analytic Serv-

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ices conducted an experiment to determine what hazardous airborne combustion products were evolved when these specimens were burned in air at 2,000 F (1,093 C).

A polyvinyl chloride composite sample was prepared, consisting of approximately 50 per cent pink shredded bulk polyvinyl chloride and equal amounts of the remaining materials. The materials were incrementally inserted into a quartz combustion tube, maintained at this temperature and continuously purged with air at 2,000 cc per minute. The composite sample was combusted and the gaseous products collected and analyzed by gas chromatography/mass spectrometry. Based on its report, Gollob Analytic Services postulated that a number of hazardous substances were produced in the experiment (table 1), including significant amounts of hydrogen chloride (10). Extrapolation from laboratory data to the actual firefighting experience is uncertain, however, and we cannot rule out the possibility of other exposures, either singly or in combination.

MATERIALS AND METHODS

All 125 firefighters of the Plainfield and North Plainfield fire departments were asked to participate in the study by completing a questionnaire. Ninety-five questionnaires (76 per cent) were completed (75 per cent (78/104) in Plainfield and 81 per cent (17/21) in North Plainfield) between April 15, 1985 and May 22, 1985. All Plainfield and North Plainfield firefighters directly involved in fighting the Plainfield warehouse fire on March 20 and/or March 21 ($n = 80$) were designated exposed subjects. A group of 15 firefighters not involved in fighting the chemical fire because of vacation, illness, or home assignment from the same two fire departments constituted the comparison group.

No data were available on the nonresponders regarding their exposure status. Nevertheless, we do not believe that nonresponse in the study was a function of exposure status. This is because every attempt was made to have every firefighter in the sample participate and an equal effort was made to recruit exposed and nonexposed subjects. Furthermore, all nonresponders, regardless of their exposure status, were followed up two additional times in an attempt to convert them to responders.

Participating firefighters responded to an 81-item symptom checklist. This checklist, called SAFTEE, an acronym for Systematic Assessment For Treatment Emergent Events, was modified and adapted from an assessment schedule presently being tested at three United States research centers as a measure of drug side effects (11). The assessment time interval for both subjects and controls in the study was "since the Plainfield warehouse fire."

Each checklist item includes a severity probe which rates a symptom as mild, moderate, or severe (scored 1, 2, and 3, respectively), if it is present. Symptoms that are not present are scored zero. Since response categories for checklist items were ordinal level and the distributions skewed, Mann-Whitney U tests (12) were used to uncover significant exposed/nonexposed group differences.

In addition to individual item scores, a total checklist score was computed by summing the item scores across all 81 symptoms. (Hereafter, the sum of these 81 items will be referred to as the "total score".) Theoretically, a firefighter's total score could range from zero (no symptoms present) to 243 (all symptoms present and severe).

Data analysis

Differences between the exposed and unexposed firefighters on the 81 SAFTEE checklist items were tested statistically using an alpha level of 0.01 because of the large numbers of comparisons being made. All other tests of significance were done using an alpha level of 0.05 (two-tailed). The data analyses were conducted using the Statistical Package for the Social Sciences (SPSS-X) (13).

TABLE 1

Gollob Analytic Services report (10): summary of chemical analyses of polyvinyl chloride (PVC) combustion products involved in warehouse fire in Plainfield, NJ, March 20–21, 1985

Constituent	Combustion gases	Total emissions mg/g PVC burned
Nitrogen (%)	80+	
Oxygen (%)	14.7	
Carbon dioxide (%)	2.6	160
Hydrogen (ppm)	7,500	2.1
Carbon monoxide (ppm)	9,300	36
Methane (ppm)	1,760	4.0
Phosgene (ppm)	None detected <50	
Benzene (ppm)	146	1.6
Other organics (primarily acetylene) (ppm)	420	1.6
Hydrogen chloride (ppm)	6,800	34
Hydrogen cyanide (ppm)	0.32	0.0012
Vinyl chloride (ppm)	None detected <0.2	
Nitric oxide (ppm)	5.6	0.023
Nitrogen dioxide (ppm)	3.7	0.023
Dioctyl phthalate(mg/m)	None detected <0.5	
Polychlorinated biphenyls (mg/m)	None detected <5	
Methyl pyrrole (mg/m)	6.4	0.021
Unidentified chlorinated (mg/m)	6	0.02

RESULTS

The firefighters ranged in age from 21 to 57 years, with a mean of 37.2 years (standard deviation (SD) = 8.8). The firefighters worked as members of their respective fire departments an average of 12.3 years (SD = 8.0), with about 28 per cent having had five years or less of firefighting experience. Seventy per cent were white and about 27 per cent black. The firefighters had completed an average of 12.6 years of school and nearly all (95 per cent) had graduated high school. Over 68 per cent were currently married. Forty per cent currently smoked cigarettes. Over one-third (37 per cent) of the firefighters lived within one mile (1.6 km) of the Plainfield firehouse. All of the firefighters were male.

Table 2 shows that exposed subjects had worked significantly fewer years as firefighters (11.6 years) than nonexposed firefighters (16.2 years). A significantly smaller proportion of exposed subjects (63 per cent) than nonexposed subjects (100 per cent) were currently married. Significantly fewer exposed firefighter subjects (34 per cent) currently smoked cigarettes than nonexposed subjects (67 per cent).

Exposed subjects and nonexposed subjects differed at the alpha level of 0.01 using Mann-Whitney tests for 19 SAFTEE checklist symptoms: headaches, dizziness, eye irritation, dry mouth, chest pains, wheezing, coughing, shortness of breath, muscle, bone, or joint pain, skin irritation, rashes or itching, sore throat, blurred vision, stomach pain, increased thirst, tingling/numbness in hands and feet, tiredness, restlessness and daytime drowsiness (table 3). Relative risks for these 19 symptoms ranged from 1.8 (sore throat) to 16.3 (skin irritation). However, in most instances, the confidence intervals around the relative risks were quite large due, particularly, to the small number of nonexposed subjects.

Exposed subjects reported an average of 8.8 mild symptoms, 6.9 moderately severe symptoms, and 1.8 severe symptoms. Nonexposed subjects reported an average of 1.5 mild symptoms, 1.2 moderately severe symptoms, and 0.07 severe symptoms. On the total checklist score, exposed subjects had a mean of 28.1 (SD = 24.3) compared with 4.1 (SD = 2.9) for the nonexposed firefighters ($t = 8.5, p < 0.001$). Confirmation of these results was obtained

TABLE 2

Comparison of exposed and nonexposed Plainfield and North Plainfield firefighters involved in warehouse fire in Plainfield, NJ, March 20–21, 1985, by baseline characteristics

Baseline characteristic		Statistical test*	p value
Mean years worked as a firefighter			
Exposed (n = 79†)	11.6 ± 8.0‡	$t = 2.1$	<0.04
Nonexposed (n = 15)	16.2 ± 6.7		
Mean age (years)			
Exposed (n = 79†)	36.6 ± 8.9	$t = 1.6$	NS§
Nonexposed (n = 15)	40.6 ± 7.7		
Mean years of school completed			
Exposed (n = 80)	12.8 ± 1.4	$t = -0.8$	NS
Nonexposed (n = 15)	12.5 ± 1.1		
Ethnicity (% black)			
Exposed (n = 80)	32	$\chi^2 = 1.3$	NS
Nonexposed (n = 15)	13		
Marital status (% married)			
Exposed (n = 80)	63	$\chi^2 = 6.6$	<0.02
Nonexposed (n = 15)	100		
Current cigarette smoker (% yes)			
Exposed (n = 80)	34	$\chi^2 = 4.5$	<0.03
Nonexposed (n = 15)	67		
Lives within 1 mi (1.6 km) of firehouse (% yes)			
Exposed (n = 80)	40	$\chi^2 = 1.4$	NS
Nonexposed (n = 15)	20		
Supervisor (% yes)			
Exposed (n = 79†)	28	$\chi^2 = 0.0$	NS
Nonexposed (n = 15)	33		

* Students t test or corrected chi-square test.
† One subject had missing data.
‡ Standard deviation.
§ NS, not significant.

when the total scores of exposed and nonexposed subjects were compared using a natural logarithm scale and the pooled variance t test estimate ($t = 5.2$, $p < 0.001$).

We used multiple regression analysis to test whether the between group differences on total checklist scores would be reduced or eliminated by introducing statistical controls for the baseline variables that differentiated the two groups. The differences between exposed and nonexposed subjects on total scores remained highly significant ($p < 0.001$) after controlling for the effects of these potential confounders using both

TABLE 3

Comparison of SAFTEE† items between exposed and nonexposed Plainfield and North Plainfield firefighters involved in warehouse fire in Plainfield, NJ, March 20–21, 1985, by significant symptoms‡,§

Symptom	No. exposed with symptom (present‖/absent)	No. nonexposed with symptom (present‖/absent)	Relative risk¶	95% confidence interval (Taylor series)
Probably associated with exposure to hydrogen chloride				
Eye irritation***	55/25	2/13	5.2	1.4–18.9
Skin irritation***	42/38	0/15	16.3	1.1–251.4
Rashes or itching***	38/42	0/15	15.2	1.0–235.9
Sore throat**	51/28 (m)††	5/9 (m)	1.8	0.9–3.7
Probably psychosocial in nature				
Headaches***	62/18	3/12	3.9	1.4–10.7
Restlessness***	27/53	0/15	10.5	0.7–163.4
Dizziness***	40/40	0/15	16.0	1.0–247.0
Blurred vision**	24/55 (m)	0/15	9.8	0.6–153.0
Stomach pain**	27/52 (m)	0/14 (m)	10.3	0.7–159.9
Tingling/numbness**	27/53	0/15	10.9	0.7–169.1
Dry mouth**	30/49 (m)	1/14	5.7	0.8–38.7
Probably associated with smoke inhalation and physical aspects of fighting a fire				
Chest pains**	33/46 (m)	1/13 (m)	5.8	0.9–39.0
Wheezing**	30/47 (m)	0/14 (m)	11.7	0.8–181.0
Coughing***	50/28 (m)	3/11 (m)	3.0	1.1–8.3
Short of breath**	33/46 (m)	0/13 (m)	11.7	0.8–180.6
Increased thirst**	30/49 (m)	0/15	12.2	0.8–189.4
Muscle/joint pain**	35/45	1/14	6.6	1.0–44.3
Tiredness***	51/28 (m)	2/13	4.8	1.3–17.8
Daytime drowsiness***	38/41 (m)	0/15	15.4	1.0–237.9

** $p \leq 0.01$; *** $p \leq 0.001$ on Mann-Whitney test.

† SAFTEE, Systematic Assessment For Treatment Emergent Events symptoms checklist.

‡ *Nonsignificant symptoms:* difficult swallow, rapid heart beat, heart pounding, irregular heart beat, heartburn, nausea, vomiting, diarrhea, constipation, gas, change stool color, hemorrhoids, painful stool movement, weight gain, weight loss, increased appetite, eye swelling, double vision, light bothers you, earache, trouble hearing, ringing in ears, mouth sores, swollen tongue, too much saliva, bleeding gums, dental problems, nosebleeds, stuffy nose, laryngitis, decreased appetite, taste abnormality, painful urination, difficulty urinating, frequent urination, color change urine, decrease force of urine, arm/leg swelling, edema, unsteady on feet, trouble on starting to move, unwanted movements, rigid, tremors, acne, bruising, increased sweating, sun sensitivity, fever, chills, overarousal, difficulty falling asleep, early morning awakening, too much sleep, interrupted sleep, pain/discharge, increased sex interest, decreased sex interest, sexual dysfunction, delayed orgasm.

§ *No variance symptoms:* fainting, seizures.

‖ Symptom present: mild, moderate, and severe symptoms collapsed.

¶ Note that when cell frequency = 0, a value of 0.5 was added to each of the four cells, a method proposed by Kleinbaum et al. (17).

the untransformed and the log transformed total scores.

In subsequent analyses, we examined the predictors of high total scores using information from exposed firefighters only. We reasoned that, if the higher total scores of the exposed firefighter subjects were related to polyvinyl chloride exposure rather than baseline characteristics which differentiate the groups, the factors associated with increased duration and/or level of exposure should be risk factors within the exposed group.

Fighting the fire on March 20, 1985, the first day of the fire ($p < 0.05$), living within one mile (1.6 km) of the firehouse ($p < 0.02$), and being a truckman ($p < 0.05$) were significant risk factors. In addition, not

being a supervisor ($p < 0.07$) and being black ($p < 0.07$) were trend significant risk factors (i.e., $p > 0.05$ and < 0.1).

Since the risk factors themselves may be correlated, we sought to determine which of them were significant in predicting total scores while controlling for the other risk factors using multiple regression. Living within one mile (1.6 km) of the firehouse ($p < 0.05$) and fighting the fire on March 20 ($p < 0.02$) were significant predictors of total scores controlling for the other risk factors. In addition, being a truckman ($p < 0.08$) showed a trend for significance in the multiple regression.

Non-supervisory status was correlated with the total score in bivariate within-subjects analyses. However, this variable was not significant in the multiple regression model that predicted total scores while controlling for the other risk factor variables. The same was true for being black. In post hoc correlational analyses, being a truckman and being a nonsupervisor were significantly correlated ($r = 0.23$). Being black was positively correlated with living within a mile of the firehouse ($r = 0.35$) and inversely related to being a supervisor ($r = -0.31$). Clearly, the initial (trend) relation between being black and the total score was explained by the association of ethnicity with the other risk factors.

Discussion

It is likely, based on previous research of polyvinyl chloride emission products, plus the Gollob Analytic Services chemical analyses results (10), that hydrogen chloride was a significant chemical produced during the Plainfield warehouse fire. Sax (14) notes that hydrogen chloride can be irritating to the skin, eyes, and mucous membranes via both oral and inhalation routes. Further, "hydrochloric acid is an irritant to the mucous membranes of the eyes and respiratory tract and a concentration of 35 ppm causes irritation of the throat after short exposure .... [hydrogen chloride] will react with water or steam to produce toxic and corrosive fumes" (14, p. 728).

There were a total of 19 SAFTEE symptom checklist items on which exposed firefighter subjects differed from nonexposed firefighters ($\alpha = 0.01$). We certainly must consider the possibility that at least four of these symptoms were associated with exposure to hydrogen chloride. These include eye irritation, skin irritation, rashes or itching, and sore throat. However, given the multiple nature of the dangerous substances that may have been produced during the Plainfield warehouse fire, it is virtually impossible to make causal inferences between possible exposure and specific symptom reports. We must not rule out the possibility that some of the adverse health effects reported in this paper could be attributed to polyvinyl chloride pyrolysis products other than hydrogen chloride. Thus, a number of the other significant checklist items such as headaches, restlessness, dizziness, blurred vision, stomach pain, tingling/numbness in hands or feet, and dry mouth, may or may not have been related to chemical exposure. It is also possible that these symptoms arose from stress reactions or other psychosocial factors associated with the dramatic nature of the incident. The remainder of the significant checklist items (i.e., chest pains, wheezing, coughing, shortness of breath, increased thirst, muscle bone/joint pain, tiredness, and daytime drowsiness) could be associated with smoke inhalation and the more physical aspects of battling a prolonged fire of any kind.

Ideally, complete medical evaluations, including monitoring of arterial blood gas values, should be considered for persons exposed to polyvinyl chloride fumes even in the presence of normal findings from routine physical examinations and chest x-rays. This is because of the findings of a prior study (15) which documented the appearance of mild to moderate hypoxemia among 19 of 21 mostly asymptomatic firefighters following an office building fire where large amounts of polyvinyl chloride materials were burned. We sought to obtain medical confirmation of symptoms among

our cohort of exposed firefighters. However, this was impossible because of confidentiality issues.

As noted earlier, symptom data were collected from both exposed and nonexposed subjects during a period in 1985 which spanned about six weeks. Differences in this distribution between exposed and nonexposed subjects could conceivably affect the prevalence of symptoms since the time at risk to accrue symptoms may be unequal. To test this possibility, we controlled for time elapsed and then assessed between-exposure group differences on total scores. The exposed and nonexposed subjects were still different ($p < 0.002$). Thus, date of questionnaire completion did not appear to influence the results reported above.

The significant risk factors (i.e., fighting the fire on March 20, living within one mile (1.6 km) of the firehouse, and being a truckman) may have been related to level or duration of exposure. Fighting the fire on March 20 most likely entailed greater exposure because the fire on that first day raged out of control for many hours. Also, firefighters were unaware for some time that the fire was chemical in nature and preventive measures, such as the use of special masks, were only ordered after the chemical nature of the fire was confirmed.

Of all the firefighting roles, truckmen (i.e., members of truck companies) are likely to be stationed in locations that are more proximate to sites where the fire is more severe. Being a truckman is an example of a job-related risk factor that is most likely correlated with level or duration of exposure.

Firefighters who lived within a mile (1.6 km) of the firehouse also lived within 2¼ miles (3.6 km) of the incident site since the firehouse and the incident site are about ¾ mile (1.2 km) apart. The firefighters who lived closer to the site of the incident may have been subjected to additional chemical exposure even when not fighting the fire. In a study of male Plainfield community residents in the aftermath of the polyvinyl chloride warehouse fire that utilized the same SAFTEE symptom checklist, male residents who lived within two miles (3.2 km) of the site of the polyvinyl chloride chemical incident ($n = 19$) were significantly higher on total scores than male residents who lived further away ($n = 5$). Therefore, this factor may also be indicative of greater exposure. An alternative possibility is that firefighters who lived closer to the firehouse (and incident site) had higher work loads rather than residential exposures because they could have been able to respond quickly to calls for additional manpower.

Two alternative explanations regarding elevated symptom levels among the exposed firefighters should be mentioned. First, it was possible that unmeasured differences between exposed and nonexposed firefighters could account for differences in their symptom scores. For example, the nonexposed group could have included well-rested and relaxed firefighters just back from vacation or sick leave. No statistical controls were used to assess such effects. Second, since self-report symptom scores were used to assess physical problems dating from the time of the incident, recall bias is a potential problem. The firefighters who fought the fire, knowing that it was a chemical fire with potentially noxious fumes, may have been more vigilant in examining and remembering symptoms of ill health due to their concern that the fire had harmed them. The nonexposed firefighters had no such incentive. These potential methodological artifacts could account for inflated symptom scores for the exposed group. However, finding higher symptom checklist scores within the exposed group for those with greater exposure makes these alternative explanations less plausible. For example, the possibility that firefighters who fought the fire on March 20, truckmen, and those who lived near the firehouse would have more concern about ill effects of the fire than others who were exposed seems improbable.

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Plainfield polyvinyl chloride warehouse fire resulted in at least short-term negative health sequelae for the firefighters involved in the fire. This study provides further evidence of the invidious health consequences of polyvinyl chloride fire exposure, supporting previous findings. Furthermore, in contrast to earlier studies, it uses a larger sample size, a nontreated subject group, and a control group. The effects of exposure to the combustion products of this chemical warrant further attention.

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EMISSION OF ORGANIC COMPOUNDS BY COMBUSTION OF WASTE PLASTICS INVOLVING VINYL CHLORIDE POLYMER

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ABSTRACT

Organic compounds emitted from combustion of waste plastics involving vinyl chloride polymer were investigated in an actual waste incinerator. The amounts of volatile aliphatic hydrocarbons and volatile chlorinated organic compounds decreased when the secondary combustion temperature was controlled over 900°C. On the other hand, the amounts of some aromatic hydrocarbons increased with a rise of the secondary combustion temperature.

INTRODUCTION

The management of waste plastics is one of serious issues from a point of view of recent increase of consumer goods made of plastics. The waste plastics are treated by combustion or landfills. Carefull control is necessary in the incineration treatment of waste plastics involving chlorine-containing plastics, since they are assumed to be destroyed and converted to toxic compounds such as PCDDs and PCDFs in some cases of thermal reaction (1-4). It is urgently required to establish the optimum operational condition in combustion of these waste plastics. Several laboratory experiments on thermal decomposition of polymers have been reported(5-7). Oki et al. reported the emission of volatile chlorinated organic compounds by combustion of waste materials containing waste chlorinated plastics(8). However, there are few reports concerning with volatile or low-molecular hydrocarbons and chlorinated organic compounds emitted from actual incineration of these waste plastics.

In this study, the effect of the burning conditions on the formation

of various organic compounds by cmbustion of waste plastics involving vinyl chloride polymer was investigated in a medium-scale waste incinerator.

EXPERIMENTAL

Facility: The structure of waste incinerator is described in previous paper(9). A size of the combustion chamber is 4.6 meters in length, 2.5 meters in width and 2.6 meters high. The secondary combustion chamber is sized at 11.7 m^3 . The combustion chamber and the secondary combustion chamber are equipped with the rotary burners using heavy oil. The design capacity of combustion burner and afterburner are 35 l/h and 60 l/h respectively. The waste plastics involving vinyl chloride polymer were put into the combustion chamber to be burned. A diagram of the combustion system is shown in Fig.1.

Combustion experiments were carried out under the following conditions:

Condition A;

The combustion chamber temperature was controlled about 630°C.
The exit temperature of secondary combustion chamber was maintained about 650°C.

Condition B;

The combustion chamber temperature was controlled about 800°C.
The exit temperature of secondary combustion chamber was maintained about 920°C.

Thirty kilogram of waste plastics each was put into a combustion chamber at ten minute intervals in both conditions.

Sampling and Analytical Procedure: The sampling location is shown in Fig.1. Gas sampling was carried out at the location to investigate

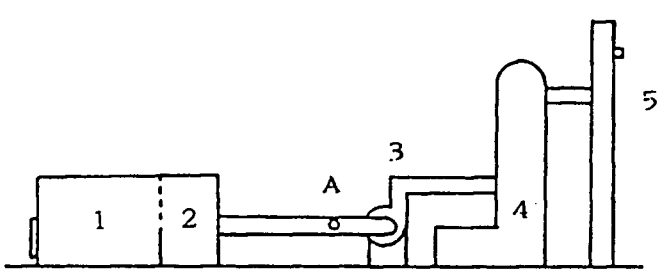

Fig. 1 Diagram of waste incinerator plant.
1;Combustion chamber, 2;secondary combustion chamber, 3;exhaust fan, 4;wet scrubber, 5;stack, A;sampling location.

the emission of hydrocarbons and chlorinate organic compounds at two different secondary combustion temperatures. The collection method using sampling bag was adopted for gas sampling of volatile hydrocarbons and volatile chlorinated organic compounds. Gas samples were drawn continuously through the probes equipped with a particle filtration system using an air pump. A part of this sample was further conditioned for the removal of moisture and was collected in 5-liter sampling bags over a 20- to 30- min period. Low molecular hydrocarbons(C_2-C_5) were analyzed with a Shimadzu 15A gas chromatograph(GC) with a flame ionization detector(FID) after pre-treatment using cold trapping with liquid oxygen. The GC conditions were as follows: column, 1% APG-L on alumina packed column(1-m x 3-mm i.d.); oven temperature, 35°C hold for 2 min to 200°C with an increasing rate of 10°C/min; injection and detection temperature, 180°C; carrier gas(N_2) flow-rate, 40 ml/min.

Hydrocarbons(C_6-C_8) were analyzed with a Hitachi 663 GC-FID after pre-treatment using cold trapping with liquid oxygen. The GC conditions were as follows: column, SPB-5 fused silica capillary column (30 m x 0.54 mm i.d. x 0.3 μm), oven temperature, 50°C hold for 4 min to 150°C with an increasing rate of 5°C/min; injection and detection temperature, 200°C; carrier gas(N_2) flow-velocity, 69.6 cm/sec; make-up gas(N_2) flow-rate, 20 ml/min.

Volatile chlorinated organic compounds were analyzed with a Hitachi 663 GC with an electron capture detector(ECD). The GC conditions were as follows: column, 20% Squalane on chromosorb W AW packed column(3-m x 3-mm i.d.); oven temperature, 90°C; injection and detector temperature, 200°C; carrier gas(N_2) flow-rate,35 ml/min.

In order to analyze other organic compounds, GC/MS analysis was used. The exhaust gas was passed through two impingers in series which contained each 10 ml of hexane. After sampling, the combined hexane solution was dried on anhydrous sodium sulfate and carefully concentrated to a small volume by nitrogen-stream blowing below 40°C. The GC conditions were as follows: instrument, a Hewlett-Packard 5890A GC connected with a System Instruments 6000B integrator; column, PTE™ 5 fused silica capillary column(30-m x 0.25-mm i.d. x 0.25-μm); oven temperature, 40°C hold for 2 min to 230°C with an increasing rate of 4°C/min; injection temperature, 250°C; detector, FID; detector temperature, 300°C; carrier gas(He) flow-velocity, 34.2 cm/sec. The operating conditions of mass spectrometry(MS) were as follows; instrument, JEOL DX-300 mass spectrometer connected with a Hewlett Packard 1510A GC and with a JEOL JMA-3500 data analysis system; mass range, m/z 10 to 500; scan speed, 1.3 sec; repetition time, 2 sec; ionization energy, 70eV; ionizing current, 300 μA; ion-source temperature, 200°C; ion-source pressure, $2x10^{-6}$ torr. The GC conditions were the same as described above.

RESULTS AND DISCUSSION

Two different operational conditions were used to compare the emission of various organic compounds by combustion of waste plastics involving vinyl chloride polymer. Actual combustion conditions are shown in Table 1. Thirty kirogram of waste plastics each was put into a combustion chamber at ten minute intervals. The temperatures of the secondary combustion chamber in condition A and B were maintained about 650°C and 920°C respectively, and the residence time was 1.8 seconds in each condition. Oxygen concentration in chamber always exceeded 18 %. The concentration of carbon monoxide was 0.008-0.014% in condition A, less than 0.001% in condition B. Therefore, a complete combustion state was almost accomplished in condition B.

Typical gas chromatograms are shown in Fig.2 to 5. Identification of these compounds was carried out by retention time on GC/FID or GC/ECD and by mass spectrum on GC/MS. Results of quantitation are shown in Table 2. The higher temperature of the combustion and second combustion chamber were, the lower the concentration of most of volatile aliphatic compounds (C_2-C_8) and volatile chlorinated organic compounds became. These results suggest that the temperature of secondary combustion over 900°C is effective to complete decomposition of these compounds.

The concentrations of trichloroethylene and tetrachloroethylene found in our experiment were as same level as those in waste organochlorine material combustion reported by Oki et al.(8). Chloroform and carbon tetrachloride were below detectable levels. The concentration of 1,1,1-

Table 1. Operational conditions for waste incinerator

	Condition A	Condition B
Amount of waste plastics burned (kg/h)	180	180
Combustion chamber temperature (°C)	624-661	774-820
Secondary combustion chamber temperature (°C)	654-682	905-940
Residence time (sec)	1.8	1.8
Amount of wet exhaust gas (Nm^3/h)	23000	23500
Exhaust gas temperature (°C)	178-196	221-233
Composition of exhaust gas		
Carbon dioxide (%)	1.4-1.7	2.4-2.6
Oxygen (%)	18.6-19.2	17.9-18.2
Carbon monoxide (%)	0.008-0.014	<0.001

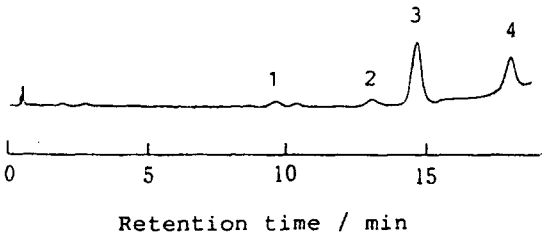

Fig.2 Typical gas chromatogram of aliphatic hydrocarbons in exhaust gas.
1;Propylene, 2;iso-Butene, 3;1-Butene, 4;n-Hexane.

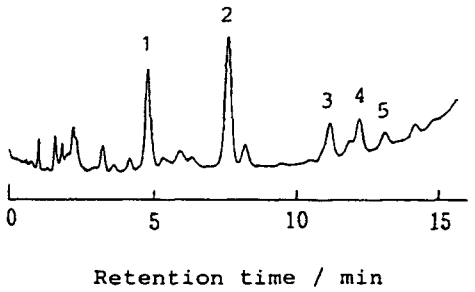

Fig.3 Typical gas chromatogram of aromatic hydrocarbons in exhaust gas.
1;Benzene, 2;Toluene, 3;Ethylbenzene, 4;p & m-Xylene, 5;o-Xylene.

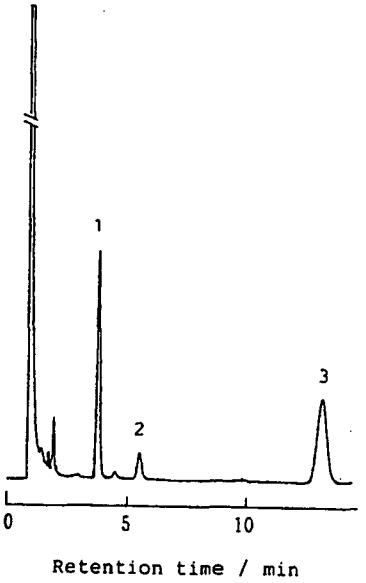

Fig.4 Typical gas chromatogram of chlorinated organic compounds in exhaust gas.
1;1,1,1-Trichloroethane, 2;Trichloroethylene
3;Tetrachloroethylene.

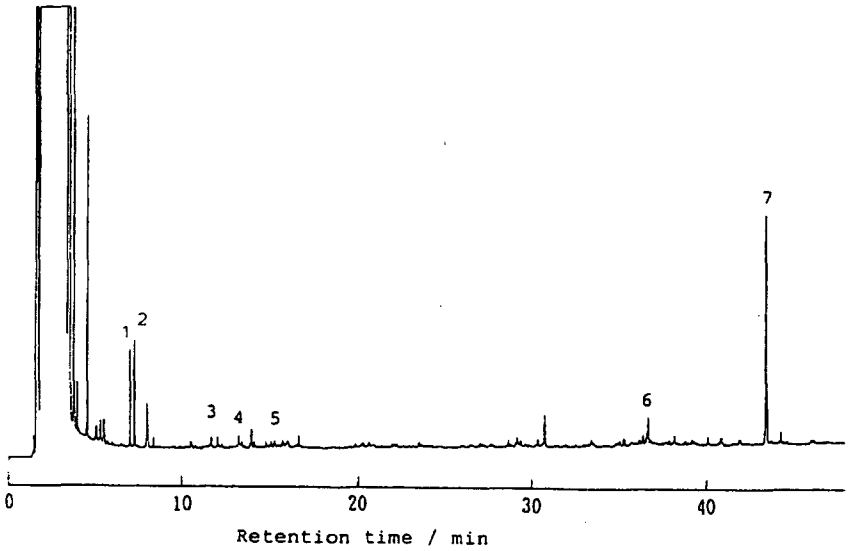

Fig.5 Typical gas chromatogram of organic compounds in exhaust gas.
1;Ethylbenzene, 2;Xylene, 3;2-Ethylhexanol, 4;Methyldodecane
5;Methylundecene, 6;Pentyl benzoate, 7;Dibutyl phthalate.

Table 2 Concentrations of organic compounds in exhaust gas.

Unit; $\mu g/m^3$

Compound	Condition A	Condition B
Aliphatic hydrocarbons		
Ethylene	20	<5
Propylene	<5	14
iso-Butane	95	<5
iso-Butene	60	28
1-Butene	360	250
n-Hexane	57	8
2-Methylheptane	15	<5
Metyldodecane	8	68
Methylundecene	<5	21
Aromatic hydrocarbons		
Benzene	83	17
Toluene	130	240
Ethylbenzene	38	85
Xylene	42	84
Chlorinated organic compounds		
Chloroform	<1	<1
Carbon tetrachloride	<0.5	<0.5
1,1,1-Trichloroethane	210	140
Trichloroethylene	82	47
Tetrachloroethylene	170	22
Others		
2-Ethylhexanol	11	43
Pentyl benzoate	28	<5
Dibutyl phthalate	260	120

trichloroethane was the most predominant among these five chlorinated organic compounds. But it does not almost contribute to air pollution because the both of the concentration and the emission amount are very low level.

On the other hand, the amounts of aromatic hydrocarbons such as toluene, ethylbenzene and xylene increased with the rise of secondary combustion temperature. This result suggests that the decomposition rate of aromatic hydrocarbons is much lower than that of the other hydrocarbons such as volatile aliphatic hydrocarbons if the formation amounts of their compounds

are almost the same level, as described in laboratory research reports(10).

It was assumed that dibutyl phthalate, detected as shown in Table 2, originated from plasticizer contained in various plastics burned and retained in emission gas without decomposition even in the combustion conditions mentioned above. Formation mechanism of 2-ethylhexanol is not clear and benzoate formation in the conditions is reasonable because benzene ring is formed in high temperature state.

The concentration of hydrogen chloride, being 6-10 mg/Nm^3 before wet scrubber in both conditions, decreased to 3-4 mg/Nm^3 by washing with sodium hydroxide solution in the scrubber. Phosgene levels were below the detection limit (0.01 ppm) in these conditions.

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Pollutants in incineration flue gas

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Abstract

Previous studies have shown that pollutants from incineration include heavy metals, organic compounds, particulate and acid gas. However, most studies on a single pollutant, it is rare for a study to concentrate on all possible pollutants and the relations between these pollutants under various incineration conditions. The objective of this work was to experimentally study the effect of different operating conditions on the pollutants emitted during incineration and the relations between these pollutants. The operating conditions of the experiments included the temperature of the combustion chamber and the species of organics. The findings indicated that the concentration of hydrogen chloride (HCl) in the presence of polyvinyl chloride (PVC) was higher than that of sodium chloride (NaCl). Regardless of what Cl-containing feedstock was added, the concentration of chromium (Cr) was constant. When organic chloride was added, Cr was the main metallic element which influenced the formation of polycyclic aromatic hydrocarbons (PAHs). On the other hand, when inorganic chloride (NaCl) was added, lead (Pb) was the major element. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Incineration; Heavy metal; Acid gas; PAHs; PVC; NaCl

1. Introduction

Incineration is one of the best disposal technologies for municipal solid waste, since it has the advantages of volume reduction and high toxicity reduction. In addition, the heat energy produced during incineration can be recovered for electric power generation. However, inadequate design or operation can result in the emission of pollutants. The pollutants contain heavy metals, acid gases and toxic organic compounds, which pose serious threats to human health. During incineration most heavy metals react with oxygen or chlorine to form metallic oxides or metallic chlorides. Some of the species with low volatility remain

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in the sand bed. Conversely, metallic vapors of high volatility, which are carried out with the flue gas, generate condensates during cooling. This process of vapor condensation includes homogeneous nucleation and heterogeneous condensation. The reactive characteristic of heavy metals results from heating during incineration, giving rise to chemical interaction, vaporization, condensation, coagulation and deposition. The chlorides, sulfides and nitrides in municipal solid waste (MSW) react with hydrogen and oxygen to generate hydrogen chloride, sulfuric acid and nitric acid. The generation and control of acid gases is related to the operating temperature, the waste composition and the air pollution control device (APCD) [1–10]. In addition, Wey and Fang [11] indicated that the quantity of heavy metals and the species containing chlorides in MSW could affect the generation of hydrogen chloride. On the other hand, kinetic restrictions result both in incomplete combustion, and also in the formation of trace organics, such as PAHs, dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). In addition, heavy metals affect the formation of PAHs. Wey et al. [12] found that Cd and Cr in fly-ash provide the activity required for the reaction between PAH precursors and the low-ring PAHs of fly-ash. Cr promoted the formation of five- and six-ring PAHs. Pb provided many more adsorption sites than Cr, but the catalyzing ability of Pb is far lower than that of Cr. The presence of excess O_2, Fe, Sn and chlorides could catalyze the formation of PCDDs/PCDFs [13,14]. The above studies just focus on single pollutants. The generation of all possible pollutants and the relations between these pollutants under various incineration conditions were rarely studied.

The research presented here, a pilot scale incinerator was used to evaluate the potential pollutants from the incineration of MSW and to understand the relations between these pollutants before the air pollution control device (APCD).

2. Experimental

2.1. Preparation of simulated feed wastes

According to the chemical analytic composition of MSW in Taiwan in 1996 (Table 1), the simulated feed wastes used in the experiments were composed of sawdust, low-density polyethylene (LDPE), PVC (or NaCl), sulfur (S) and a heavy metal solution. Three investigated metals Cd, Pb, Cr (with nitrate) of 0.01, 0.1 and 0.1 wt.%, respectively, were dissolved in the distilled water. Each sample of mixed feedstock described above was enclosed in a polyethylene (PE) bag of 0.25 g. Table 2 lists the detailed composition of various simulated feedstock.

2.2. Apparatus

The reactor for the present study is a bubble fluidized bed incinerator, consisting of a feedstock feeder, a preheated chamber, a primary combustion chamber, and a secondary combustion chamber (Fig. 1). The preheated chamber was 50 cm long. The primary combustion chamber was 110 cm high and 10 cm in diameter. The secondary combustion chamber was 100 cm high and 25 cm in diameter. The incinerator was fitted with a perforated stainless steel gas distributor. Seven thermocouples were used to determine the temperature profile in the preheated chamber, sand bed, freeboard chamber and outlet of freeboard chamber.

Table 1
The chemical analytic composition of MSW in Taiwan in 1996 [17]

Moisture (%)	50.6
Ash (%)	13.79
Combustibles (%)	
C	18.99
H	2.82
O	13.06
N	0.45
S	0.12
Cl	0.16
Heavy metal (%)	
Cd	0.012
Hg	0.00025
Pb	0.1
Cr	0.1
HHV (kcal/kg)	2106.72
LHV (kcal/kg)	1650.69
C/N	41.74

The flue gas was treated by a cooling tower, two consecutive cyclones and a wet scrubber, and then induced into atmosphere.

2.3. Experimental procedure

By calculating the required amount of theoretical air and an excess factor of 60%, 53 l/min input air at room temperature was determined. The effects of sand bed temperature on

Table 2
The composition of feedstock

Run no.	Feedstock (g per bag)									
	PE[a] bag	LDPE[b]	Sawdust	S	$Cd(NO_3)_2$	$Pb(NO_3)_2$	$Cr(NO_3)_3$	Water	PVC[c]	NaCl
1	0.25	0.12	1.322	0.003	0.00055	0.0042	0.0089	1	0.006	–
2	0.25	0.12	1.322	0.003	0.00055	0.0042	0.0089	1	0.006	–
3	0.25	0.12	1.322	0.003	0.00055	0.0042	0.0089	1	0.006	–
4	0.25	0.12	1.322	0.003	0.00055	0.0042	0.0089	1	–	0.0056
5	0.25	0.12	1.322	0.003	0.00055	0.0042	0.0089	1	–	0.0056
6	0.25	0.12	1.322	0.003	0.00055	0.0042	0.0089	1	–	0.0056
7	0.25	0.12	1.322	0.003	0.00055	0.0042	0.0089	1	0.006	–
8	0.25	0.12	1.322	0.003	0.00055	0.0042	0.0089	1	0.006	–
9	0.25	0.12	1.322	0.003	0.00055	0.0042	0.0089	1	0.006	–
10	0.25	0.12	1.322	0.003	0.00055	0.0042	0.0089	1	–	0.0056
11	0.25	0.12	1.322	0.003	0.00055	0.0042	0.0089	1	–	0.0056
12	0.25	0.12	1.322	0.003	0.00055	0.0042	0.0089	1	–	0.0056

[a] PE: polyethylene.
[b] LDPE: low-density polyethylene.
[c] PVC: polyvinyl chloride.

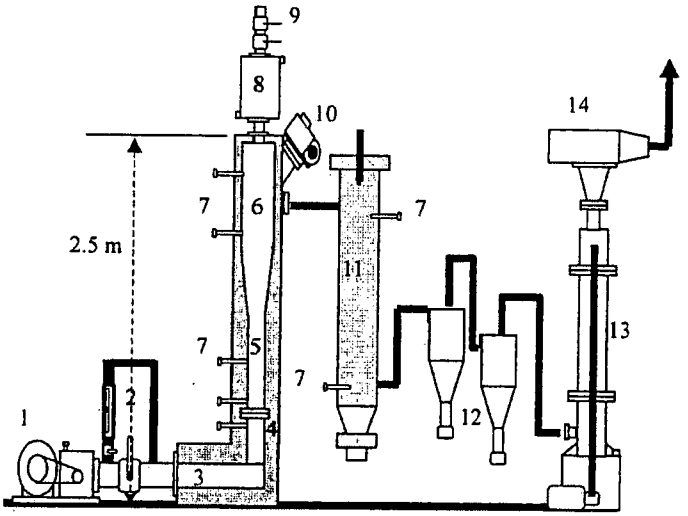

Fig. 1. The bubble fluidized bed incinerator. (1) blower, (2) flow meter, (3) air preheated chamber, (4) air distributor, (5) primary combustion chamber, (6) secondary combustion chamber, (7) thermo-couples, (8) cooling system for feeding, (9) feeder, (10) burner, (11) cooling tower or spray dryer reactor, (12) cyclones, (13) scrubber, (14) I. D. fan.

formation of various concentration of pollutants were examined by setting the sand bed temperature at 700–900°C. When investigating the effects of freeboard zone temperature on pollutants formation, the sand bed temperature was set at 700°C and the freeboard zone temperature controlled by gas burner (when on or off) was set at 700–900°C. The actual measured temperature and the operating condition of each run were listed in Table 3.

Table 3
The operating conditions of each run

Run no.	Temperature (°C)				Cl-containing species
	Primary combustion chamber		Average[a]	Secondary combustion chamber	
	Above sand bed	In sand bed			
1	722.2	755	738.6	–	PVC
2	819.1	853	836	–	PVC
3	852.4	883.6	868	–	PVC
4	768	894	831	–	NaCl
5	837	978	908	–	NaCl
6	939	1000	970	–	NaCl
7	725.8	681	703	711	PVC
8	725	698	712	802	PVC
9	728	706	717	936	PVC
10	727	698	713	703	NaCl
11	729	679	704	807	NaCl
12	728	664	696	925	NaCl

[a] Average temperature = (above sand bed temperature + in sand bed temperature)/2.

The static sand bed height was 15 cm high and the size of silica sand employed here was about 840 μm. The corresponding minimum fluidization velocity was 20.92–23.86 cm/s. The chamber was heated by electrical heaters, and when the set temperature reached a steady state, every synthetic feed waste was fed into the incinerator at regular interval of 20 s.

2.4. Methods of sampling and analysis

2.4.1. Metals

The flue gas containing heavy metal pollutants was sampled by a stainless sampling probe and passed through the filter holder contained a glass fiber filter, which collected particles, then passed through impingers to absorb the remaining metals. Isokinetic sampling was performed. The sampling position was located after secondary combustion chamber and the sampling apparatus is shown in Fig. 2, which refers to the standard USEPA method 5 (M5). The impingers were submerged in an ice bath to enhance condensation, and the mixed absorption solution of impingers were 200 ml 5% HNO_3 and 10% H_2O_2. After the sampling train was completed, the metal samples contained glass fiber filter and absorption solution were pretreated by microwave digestion, and the recovery efficiency was measured. The concentration of metals was then analyzed by atomic adsorption spectroscopy (Hitachi Model Z-8000 Polarized Zeeman AAS) according to USEPA method 3050.

2.4.2. HCl, SO_2 and NO_x

The same sampling method for metals was employed to sample HCl as well (Fig. 2). The impingers with 100 ml 0.1N NaOH absorption solution were used to adsorb the remaining

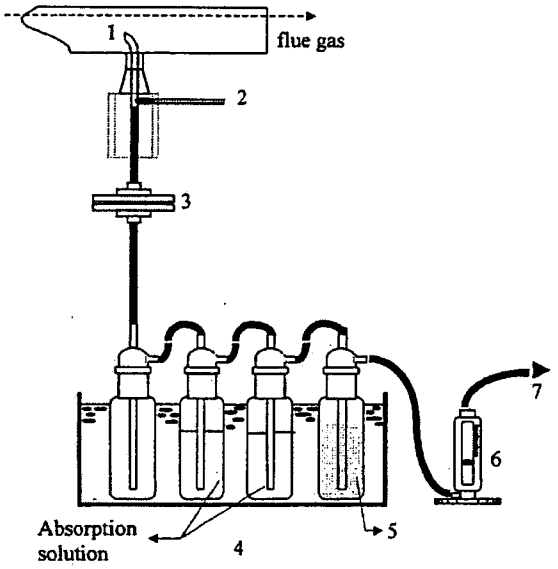

Fig. 2. The sampling train for HCl or heavy metal. (1) sampling probe, (2) thermometer, (3) filter holder, (4) impingers, (5) silica gel, (6) flow meter, (7) connect of vacuum pump.

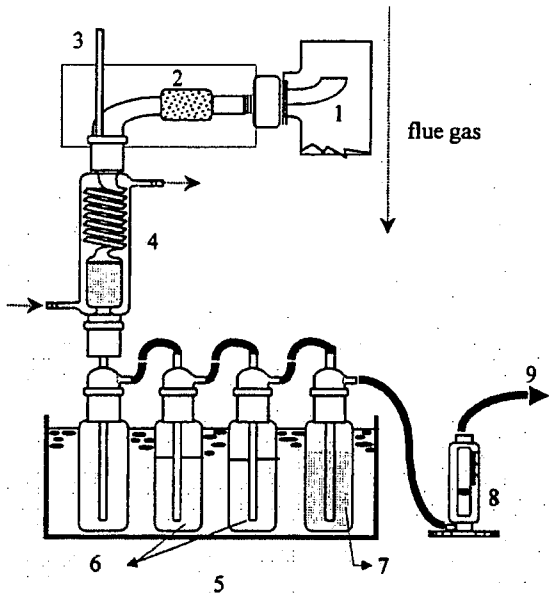

Fig. 3. The sampling train for PAHs. (1) sampling probe, (2) heated filter and heating hose, (3) thermometer, (4) cooling tube and XAD-4 adsorption tube, (5) impingers, (6) 200 ml. distilled water, (7) silica gel, (8) flow meter, (9) connect of vacuum pump.

HCl. The analysis of HCl was performed by the method of colorimetry using mercuric thiocyanate (ROC EPA NIEA method A412.70A). The concentration of SO_2 and NO_x were detected using a flue gas analyzer (BACHARACH model 300). The analyzer was corrected using the standard gas with determinate concentration before the experiment process. The range of concentration for SO_2 and NO_x monitoring was 0–1999 ppm, and their accuracy was ±5% or ±10 ppm.

2.4.3. Organic compounds

The same sampling location used for metals was used to sample organic compounds as well. Isokinetic sampling was also performed. The USEPA modified method 5 (MM5) was used for sampling (Fig. 3). The flue gas containing organics was sampled using a stainless sampling probe and passed through the heated filter packed with glass fiber, which removed particles. Then it was passed through a cooling tube and the remaining organics was captured using an adsorption tube packed with 6 g XAD-4 resin. Furthermore, the organic samples were initially extracted for 20 h using a Soxhlet extraction process and the solution was concentrated to 1 ml using a KD evaporative concentrator. Finally, the samples were put into 1.8 ml brown vials and stored at 4°C. These samples were later (in 14 days) analyzed with a GC/FID detector (Perkin-Elmer Autosystem GC). The recovery efficiency and multiple analyses were carried out to identify the precision and accuracy of above analytical procedure. The recovery efficiency of PAHs is about 60.6–99.7%, and the standard deviation of the PAHs analysis is about 1.1–15.3.

3. Results and discussion

3.1. Solid-phase pollutants

Most of the light and small particles emitted with the flue gas during incineration are carbon-based. The concentration and properties of these particles not only are relative to the phenomenon of homogeneous nucleation and heterogeneous condensation but also affect the efficiency of the air pollution control device (APCD). Fig. 4 shows the comparison of particulate concentration under various operating conditions during the incineration, indicating that the operating conditions of the secondary combustion chamber reduce the particulate concentration. Additionally, when the burner was off (only with sand bed combustion, Fig. 4(a)), the particulate concentration increased if inorganic chloride (NaCl) was added. This could be because the sodium is conversed to sodium ion at high temperature and then combines with other atom forming novel species. Therefore, the particulate concentration is higher than the presence of organic chloride (PVC). When the burner was on (with sand bed combustion and freeboard combustion), however, the influence of combustion efficiency was more than the chloride additives (Fig. 4(b)). On the other hand, when the burner

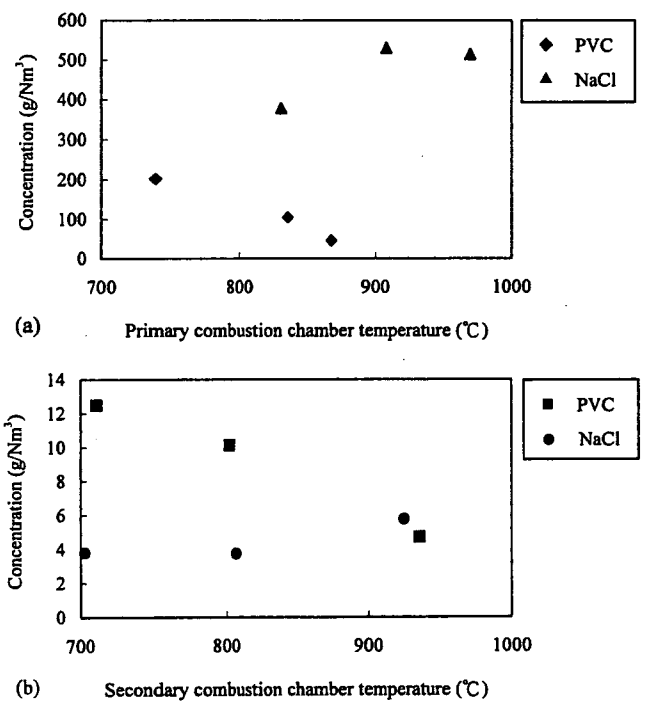

Fig. 4. The concentration of particles under various operating conditions: (a) burner off; (b) burner on (the sand bed temperature was set at 700°C).

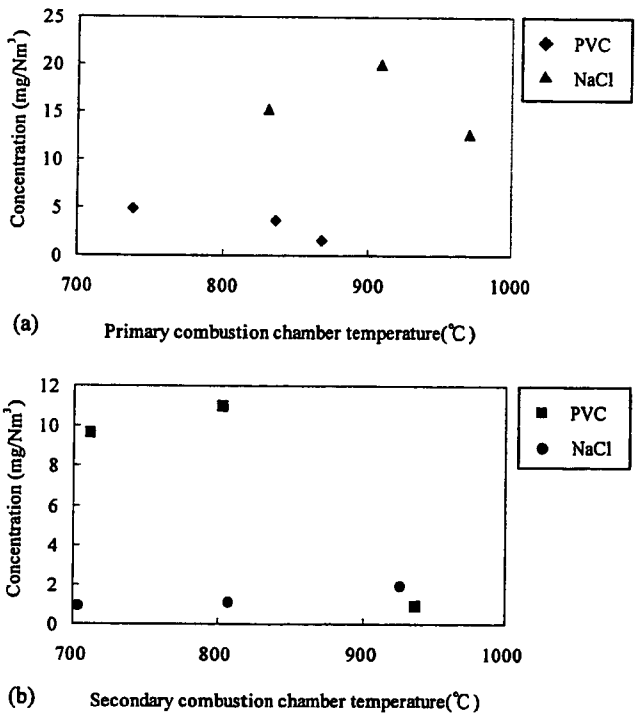

Fig. 5. The generation of Pb under various chloride additives: (a) burner off; (b) burner on (the sand bed temperature was set at 700°C).

was off, the solid wastes would not have sufficient residence time for high temperature combustion and, as a result, would produce lots of unburned carbons.

3.2. Heavy metal pollutants

The main objective of operating the burner is to make the products of incomplete combustion (PICs) reach complete combustion. The species, which enter the secondary combustion chamber with the flue gas, are the vapors of heavy metal, metallic compounds of high volatility and traces of bottom ash. These heavy metals and their compounds may convert to other types of metallic compounds by recombining in the secondary combustion chamber. Figs. 5 and 6 present the effects of various chloride additives on Pb and Cd formation. Fig. 5(a) indicates that the concentration of Pb increases when inorganic chloride (NaCl) was added and the burner was off. When the burner was on (Fig. 5(b)), however, the presence of PVC increases the concentration of Pb as well. The results of Fig. 6 are the same as Fig. 5. Wey et al. [2] and Chen et al. [3,4] indicate that when organic chloride (PVC) was added, the potential for metallic chloride formation is higher than that of metallic oxide during incineration process and the distribution of metal in the sand bed would be reduced due to the high volatility of metallic chlorides. Moreover, the possibility

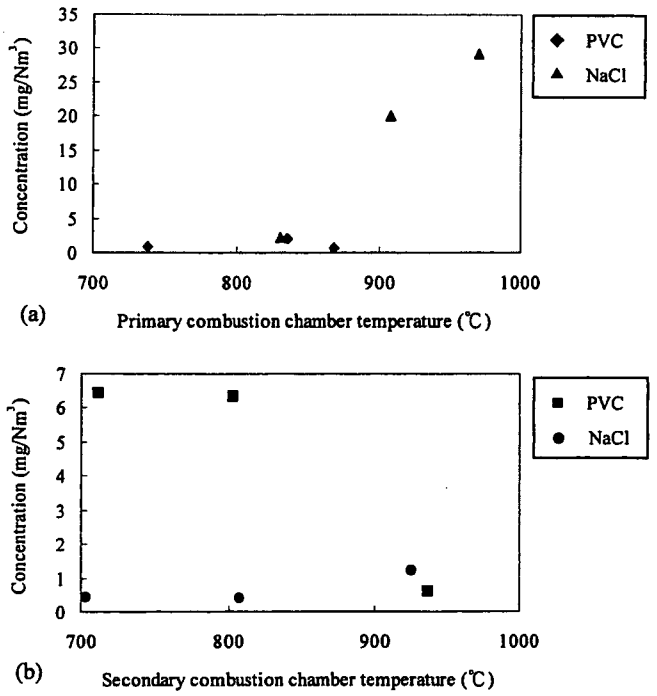

Fig. 6. The generation of Cd under various chloride additives: (a) burner off; (b) burner on (the sand bed temperature was set at 700°C).

of chlorine that reacts with the metal during incineration is small because the affinity of chlorine and sodium is stronger than that of metal. Most metals react with oxygen to form metallic oxides, which have a high boiling point and remain in the sand bed. The concentration of most metals tends to be reduced when inorganic chloride (NaCl) was added. Fig. 7 presents the effect of various chloride additives on Cr emission. It can be observed that the effect of temperature on the emission concentration of Cr is small, regardless of the presence of organic or inorganic chloride. Some researchers [2,15] indicate that the main chromium specie is $Cr_2O_3(s)$ accounting for its stability at the temperature of 600–1200 K during incineration, and a trace of $CrO_2Cl_2(g)$ is generated as the amount of chlorine increases.

3.3. Acid gas pollutants

Fig. 8 presents the effect of various chloride additives on HCl formation, indicating that the concentration of HCl in the presence of organic chloride (PVC) is slight higher than that in the presence of inorganic chloride (NaCl). This is because that PVC can provide HCl with the source of hydrogen, so the chlorine ions can connect with hydrogen ions to form HCl at high temperature rapidly. Nevertheless, NaCl do not provide the source of

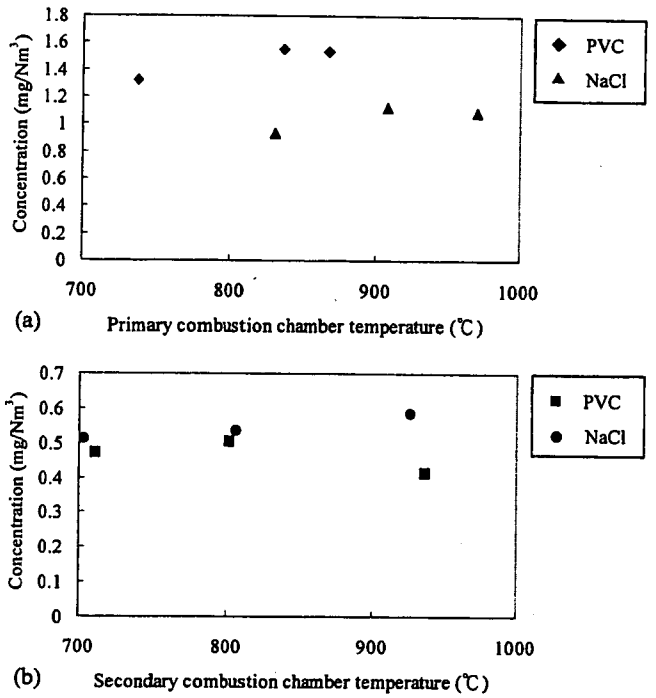

Fig. 7. The generation of Cr under various chloride additives: (a) burner off; (b) burner on (the sand bed temperature was set at 700°C).

hydrogen inversely, the formation of HCl must depend on water in the waste. Moreover, the affinity between sodium and hydrogen is larger than chlorine and hydrogen. Therefore, the concentration of HCl in the presence of inorganic chloride (NaCl) is slight lower than that in the presence of organic chloride.

Fig. 9 presents the effect of various chloride additives on SO_2 formation, indicating that the concentration of SO_2 decreases with the temperature increases in the presence of inorganic chloride. However, when organic chloride was added, the concentration of SO_2 has no significant changes.

Fig. 10 presents the effect of various chloride additives on NO_x formation during the incineration process. The results indicate that the chloride additives do not influence the concentration of NO_x regularly. Comparing Fig. 10(a) and (b), when the burner was on, the concentration of NO_x was higher than when the burner was off. The main reason for this phenomenon is that thermo-NO_x or fuel-NO_x are produced at higher temperature. Although the average temperature of primary combustion chamber (burner off) was similar to the temperature of secondary combustion chamber (burner on), the local high temperature generated by burner would result in the formation of thermo-NO_x. In addition, the fuel of burner employed in the present study is the liquefied natural gas that contains nitride. Therefore, the fuel-NO_x is possibly produced during incineration as well.

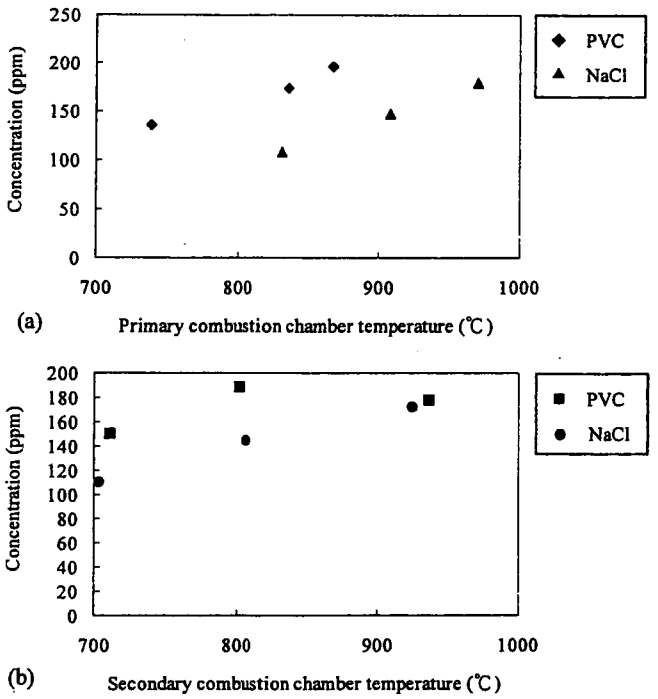

Fig. 8. The generation of HCl under various chloride additives: (a) burner off; (b) burner on (the sand bed temperature was set at 700°C).

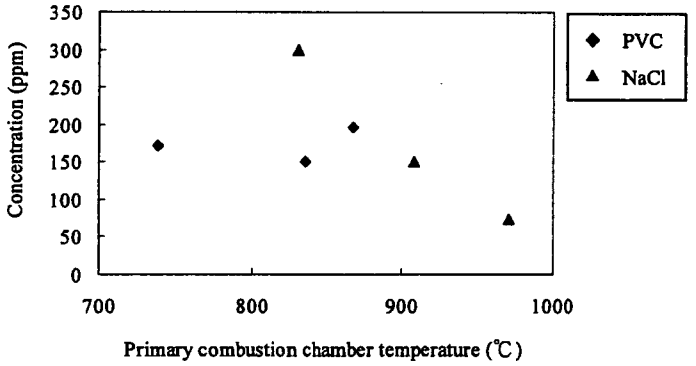

Fig. 9. The generation of SO_2 under various chloride additives.

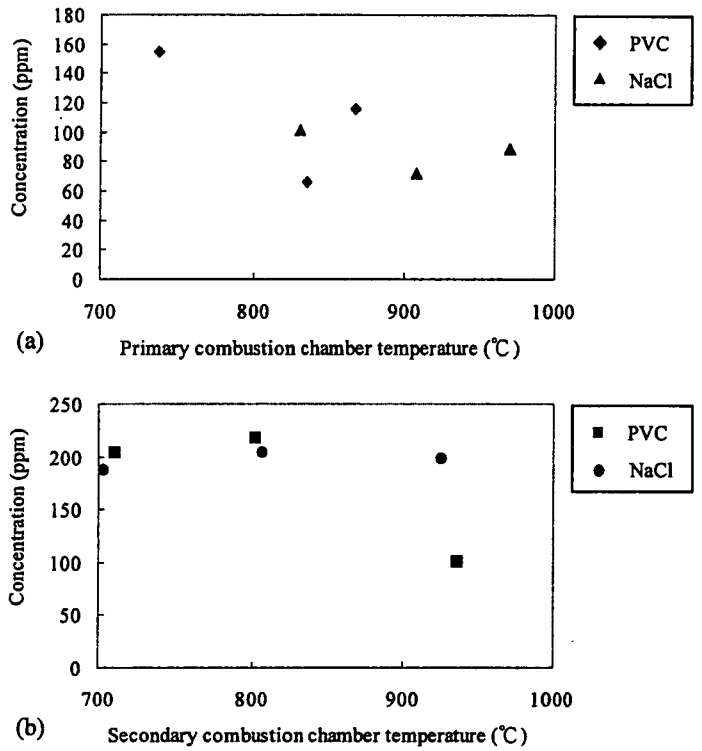

Fig. 10. The generation of NO_x under various chloride additives: (a) burner off; (b) burner on (the sand bed temperature was set at 700°C).

3.4. Organic pollutants

Table 4 lists the classifications and abbreviation of organic compounds studied at present study. Fig. 11 presents the effect of temperature on the PAHs formation in the presence of PVC when the burner was off, indicating that the main species of PAHs are naphthalene (NaP) and acenaphthylene (AcPy) when the temperature of the primary combustion chamber reaches 738°C. But these compounds are gradually converted to fluorine (Flu), phenanthrene (Pha) and anthracene (Ant) as the temperature increases. The main result is that the electronegative charge of chlorine is strong, and it may connect to the alkene or alkyne, and the organic would recombine to form stable ring-species.

Fig. 12 presents the effect of temperature on the PAHs formation in the presence of inorganic chloride (NaCl) when the burner was off, indicating a wide range of organic species is generated. However, most organic compounds are destroyed at higher temperature (970°C) to form CO_2 and H_2O. It indicates that the concentrations of organic compounds decrease with increase in temperature.

Table 4
Classifications and abbreviation of organics studied at present study

Multi-ring compounds (PAHs)	Abbreviation
Two-ring compounds	
Naphthalene	Nap
Three-ring compounds	
Acenaphthylene	AcPy
Acenaphthene	AcP
Fluorene	Flu
Phenanthrene	Pha
Anthracene	Ant
Four-ring compounds	
Fluoranthene	FluA
Pyrene	Pyr
Benzo(a)anthracene	B(a)A
Chrysene	Chr
Five-ring compounds	
Benzo(b)fluoranthene	B(b)F
Benzo(k)fluoranthene	B(k)F
Six-ring compounds	
Benzo(a)pyrene	B(a)P
Dibenzo(a,h)anthracene	DbA
Benzo(ghi)perylene	B(ghi)P
Indeno(1,2,3-cd)pyrene	InP

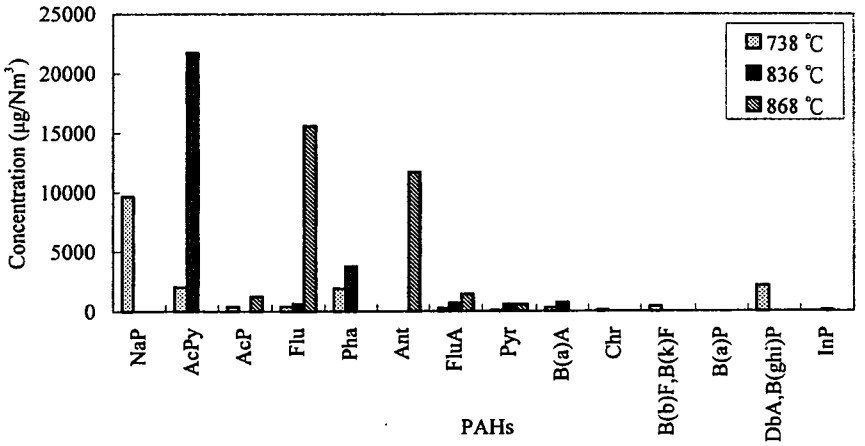

Fig. 11. The effect of temperature on PAHs formation (PVC feed; burner off).

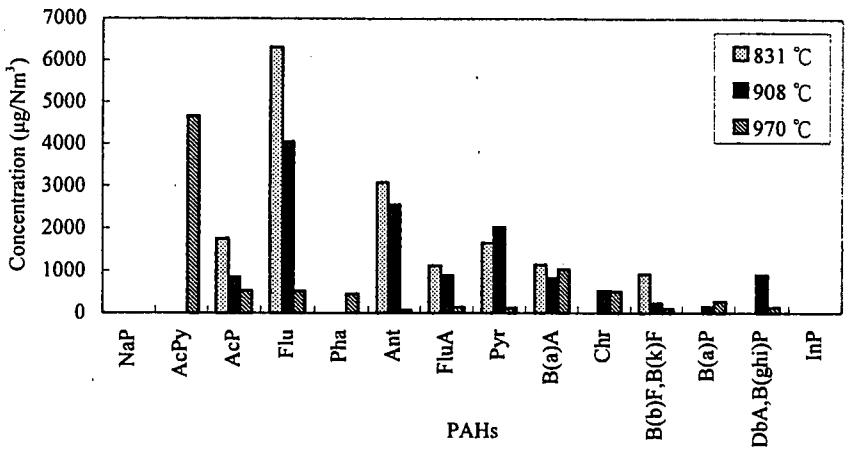

Fig. 12. The effect of temperature on PAHs formation (NaCl feed; burner off).

Fig. 13 presents a comparison of the concentration of PAHs in the presence of organic chloride when the burner was on or off. The results show that most PAHs were destroyed at higher temperature (burner on). Only a few PAHs were converted to other high-ring PAHs after the bonds were broken. The organic compounds gradually convert to three-, four- and even five-ringed as the temperature increases. When the temperature of secondary combustion chamber is 711°C, the main organic pollutants was two- or three-ring PAHs.

Fig. 14 presents a comparison of the concentration of the PAHs in the presence of inorganic chloride (NaCl) whether the burner was on or off. The results reveal that when

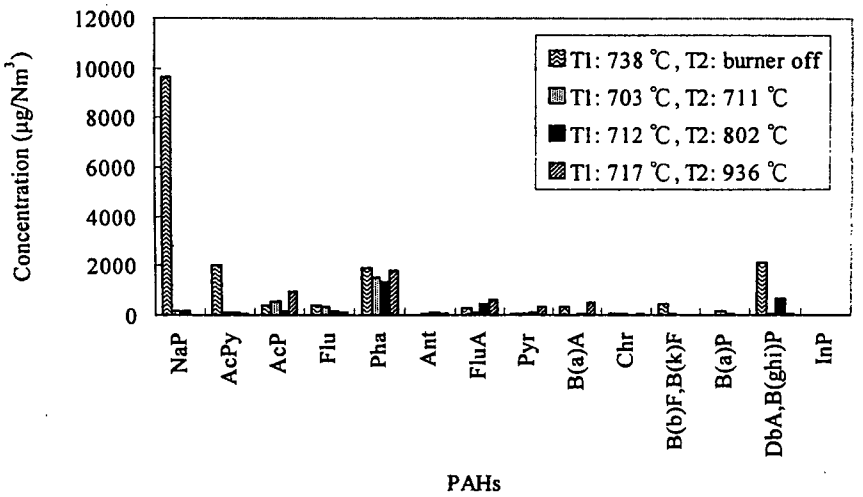

Fig. 13. The comparison of the concentration of PAHs in the presence of PVC whether the burner was on or off.

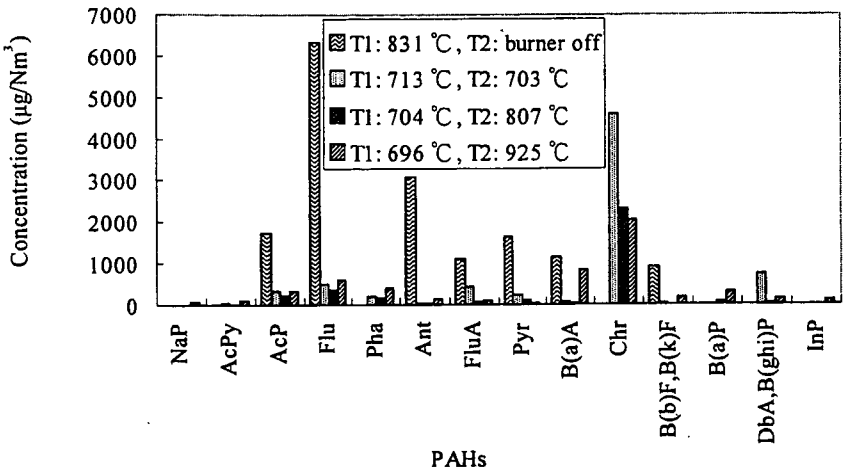

Fig. 14. The comparison of the concentration of PAHs in the presence of NaCl whether the burner was on or off.

the burner was off, most PAHs species had a three- and four-ring structure. Nevertheless, when the burner was on, the higher temperature could effectively decompose three- and four-ring PAHs and then a portion of them would recombine forming PAHs of more rings at higher temperature. Therefore, the concentrations of high-ring structure of PAHs increase slightly.

Wey et al. [16] indicated that the presence of Pb can reduce the activation energy required for the reaction between precursors and low-ring PAHs in the gas phase, so the concentration of fluoranthene (FluA), pyrene (Pyr), benzo(a)anthracene (B(a)A), chrysene (Chr) and benzo(a)pyrene (B(a)P) are higher than that of other species at high temperature. Cd and Cr in the fly-ash provided the activity required by the reaction between PAHs precursors and the low-ring PAHs of fly-ash. Cr prompted the formation of five- and six-ring PAHs, for example, the concentration of PhA, FluA, Pyr, indeno(1,2,3-cd)pyrene (InP) and benzo(ghi)perylene (B(ghi)P) are higher than that of other species. In addition, Pb provides many more adsorption sites than Cr, although the catalyzing ability of Pb is far lower than that of Cr.

The concentrations of PhA, FluA, Pyr and B(a)A in Fig. 13 are higher than those of other species. The concentrations of B(a)A, Chr and B(a)P in Fig. 13 are clearly higher than the others. It could be concluded that the situation in Fig. 13 is due to the influence of Cr, and the presence of Pb influences the results of Fig. 14. Compared to Figs. 5 and 7, the concentration of Pb in the presence of PVC is lower than that in the presence of NaCl, although the concentration of Cr is opposite. So the main result for this phenomenon in Fig. 14 is the catalyzing ability of Cr in the presence of PVC is far higher than that of Pb. When inorganic chloride was added, although the catalyzing ability of Cr is higher than that of Pb, the concentration of Pb is far higher than that of Cr. The effect of catalysis of Pb on PAHs is more significant.

4. Conclusions

The main objective of the present study was to study the pollutants emitted from the incineration of MSW and the relations between these pollutants under various operating conditions. The results show that the concentration of Cd increased as the temperature increased. The concentration of Pb in the presence of inorganic chloride (NaCl) increased as the temperature increased. Regardless of what Cl-containing feedstock was added, the concentration of Cr was constant. In addition, the concentration of HCl in the presence of PVC was higher than that of NaCl. When organic chloride was added, the PAH species, which were not destroyed at high temperature would convert from a two- to a three-ring structure PAHs as the temperature increased. When organic chloride was added, Cr was the main metallic element which influenced the formation of PAHs. On the other hand, when inorganic chloride (NaCl) was added, Pb was the major element.

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Short-Term Adverse Health Effects in a Community Exposed to a Large Polyvinylchloride Plastics Fire

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ABSTRACT. The purpose of this study was the documentation of the short-term morbidity and mortality experiences of an urban community exposed to the airborne byproducts of a large polyvinylchloride plastics fire. The authors administered a survey to representatives of each household who had lived in an area evacuated during the fire. A time-series analysis was performed on emergency room visits and admissions for all hospitals in the city. Chloracne surveillance was instituted. Sixty-two percent of the individuals surveyed from the evacuation area reported no health concerns or symptoms related to the fire. Thirty-eight percent of the residents reported symptoms, and less than 2% of those surveyed reported that they sought medical attention for their health concerns. There was no evidence of increased hospital admissions or emergency room use during and immediately following the fire. No cases of chloracne were reported, and no deaths or serious injuries occurred during the fire. Polyvinylchloride plastics recycling plants pose potential health hazards to civilian populations. Public health authorities should be prepared to assess population health status rapidly and to disseminate relevant health information in a timely way during a crisis.
<Key words: chloracne, hospital admissions, plastics, polyvinylchloride>

POLYVINYLCHLORIDE (PVC) plastic is ubiquitous in the modern world. PVC plastic is inexpensive to manufacture and has numerous industrial and domestic applications. In its stable form, PVC is relatively nontoxic; however, during combustion it can release several toxic compounds.[1] PVC plastics fires have reportedly caused morbidity and mortality in firefighters, electricians, and persons trapped indoors.[2–6]

Recycling of plastic products is a prominent strategy for sustainable economies; therefore, plastics recycling plants are often in possession of large amounts of PVC-containing products. Many of these plants are located

near residential areas. Fires in PVC recycling plants that abut residential areas pose potential health risks to surrounding communities.

Large PVC plastics fires have been reported.[7,8] The health effects of PVC plastics fires have been well documented among firefighters.[2–5,9–12] However, there have been few reports of measured morbidity and mortality in the communities affected by PVC plastics fires. In this article, we report the measured short-term morbidity and mortality from a large PVC plastics fire in an urban area of Canada.

Background

On July 9, 1997, a fire broke out at a large plastics recycling plant in the industrial section of Hamilton, Ontario. Hamilton is a city with a population of 410,000, and it is located at the Western end of Lake Ontario. The 7,400-m^2 building contained several thousand tons of off-quality auto parts composed mainly of PVC plastics and polyurethane. The plant was located immediately adjacent to a densely populated residential area. In addition, in the immediate vicinity were a tertiary-care hospital, a correctional institute, and several factories and businesses.

The fire was large and difficult to control. It burned for approximately 80 hr before it was extinguished. During the first 2 d of the fire, the plume ascended vertically and dispersed into the atmosphere. On July 11, a thermal inversion occurred. At the same time, the fire lost energy because fire-fighting efforts were successful. As a result of these two events, levels of potentially hazardous chemicals increased in the immediate vicinity of the fire. Evacuation was ordered for the civilian population in an area that immediately surrounded the fire zone. The evacuation was rescinded within 12 hr.

Detailed measurements of exposures were conducted by the Ontario Ministry of Energy and Environment. Two Trace Atmospheric Gas Analyzer (TAGA) mobile vans arrived at the scene. The TAGA van permits measurements of hydrogen chloride, volatile organic compounds, and carbon monoxide. Many of these readings are instantaneous. Investigators established fixed-site monitors to measure polychlorinated biphenyls (PCBs), dioxins, furans, and particulate matter. Colorimetric tubes, which were exposed downwind, measured cyanide, vinyl acetate, and acid gases. Carbon monoxide and nitrogen oxides were measured. Runoff water from the fire was sequestered and measured for metals. Soil and vegetation were also sampled for dioxin levels. Of all the exposures related specifically to PVC plastics, hydrogen chloride predominated in terms of abundance, and dioxin predominated in terms of media attention and community concern.

Method

Two studies and a surveillance program were established in the aftermath of the fire: (1) a health survey of the residents in the evacuation area, (2) a time-series analysis of emergency room use and admissions through the emergency room, and (3) a surveillance program for chloracne.

Health survey. A health survey was conducted by staff of the Hamilton-Wentworth Public Health Department. The preliminary survey questionnaire was drafted on July 13, 1997. Following a brief orientation session by a Health Department supervisor, 8 public health nurses administered the survey to all households in the evacuation area. The interviews were conducted from July 13 to July 15, 1997.

Information was collected from a household representative, and data were provided for each member of the household. Respondents were asked open-ended questions about whether they or any other household members had either general concerns or health concerns. Data were collected about the onset, nature, and duration of health symptoms, and whether medical attention had been sought. Investigators used specific probes to elicit symptoms of breathing difficulties, throat irritation, dizziness, lightheadedness, or nausea/abdominal pain on any of the 6 d following the fire.

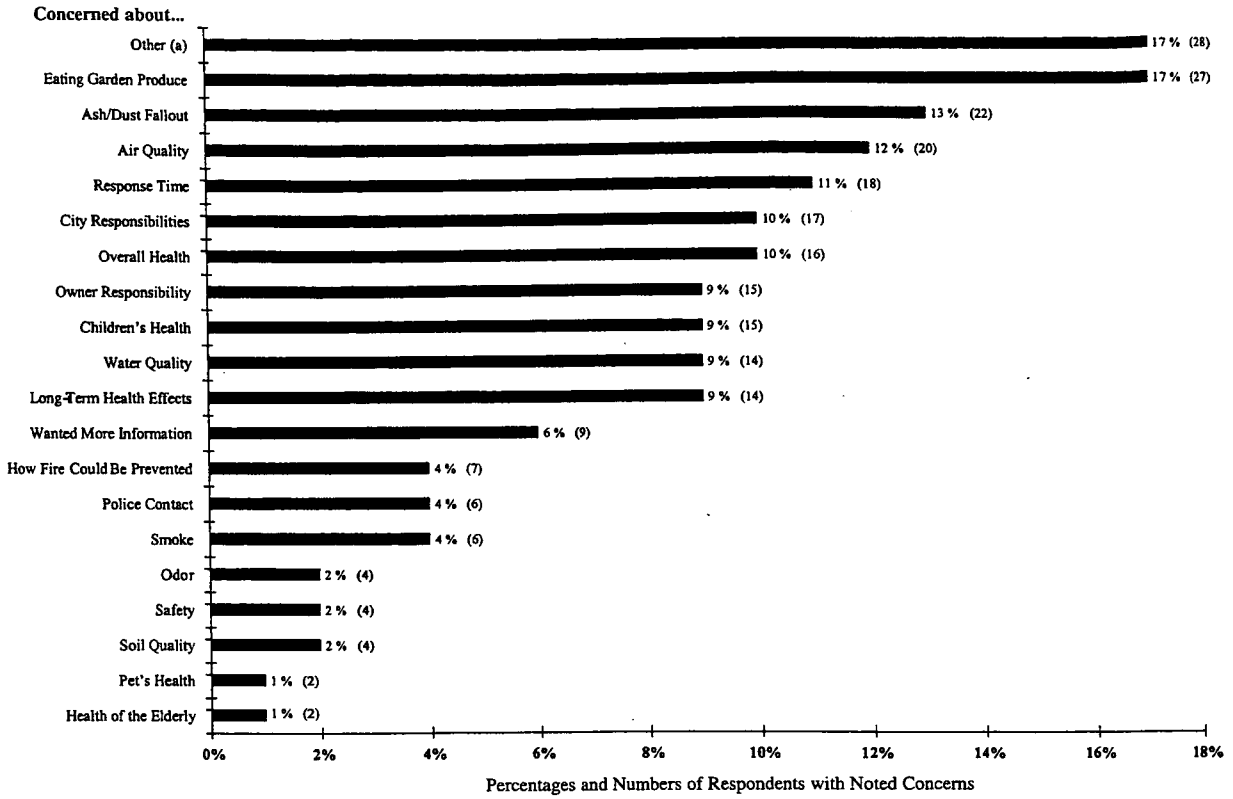
Emergency room visits and hospital admissions. Emergency room logs were obtained from the following 5 major hospitals that served the Hamilton-Wentworth region affected by the fire: Hamilton General, Henderson General, McMaster University Medical Centre, Chedoke Hospital, and St. Joseph's Hospital. Data were requested on the basis of an epidemiological month (i.e., 14 d preceding and 12 d following the fire for the years 1996 and 1997). A time series of at least 30 points is recommended if regression models are to be fit. Framing the period in terms of days before and after the fire permits the fire days to be central in any time-plot graphs and aids in the perceptual interpretation of the graph. This approach also permits an appreciation of day-to-day variability and any trends evident in the data. The data from the previous year serves as a "control" in that it is an identical time period in the same location without the disturbing influence of the fire.

Chloracne surveillance. Chloracne is a sign of severe dioxin exposure.[13,14] An information package that described the morphological features of chloracne was distributed to family physicians in the fire area. A dermatologist from an academic tertiary care medical center agreed to serve as an expert consultant. The Public Health Department agreed to keep a register of recorded cases.

Analysis. Descriptive statistics were tabulated for survey responses. Open-ended answers were coded and aggregated. Independent time series were created for overall emergency room visits and admissions to the hospital through the emergency room for both 1996 and 1997. Time plots of daily visits and admissions were created for each hospital for both years. Simple descriptive statistics were calculated for each time series for each year.

Results

Health survey. Questionnaires were completed in 86% (163/190) of the households. The average age of



(a) - Other Concerns mentioned (number of respondents reporting a concern in brackets):

Nervous re: fire proximity (1)	Hoping for workplace safety measures (1)	Want community forum (1)	Wants site cleaned up (1)	Empathy for owner (1)
Compensation (2)	Frightened, nervous (1)	Handled well (1)	Lost wages/upkeep (1)	Decreased property value (1)
Against rebuilding (1)	Class action suit/legal rights (2)	Police/fire handled well (1)	No police traffic control (1)	Looting (1)
Unaffected (1)	Unable to get information (1)	Why community activities continued (1)	Not paying property tax (1)	
Police didn't come to house (2)	No bus service (1)	Evacuation unnecessary (1)	Safety of swimming in Bay (1)	

Fig. 1. General concerns of residents interviewed (*N* = 163): July 1997 survey of residents in the Plastimet fire evacuation area. (*Source:* Hamilton-Wentworth Regional Public Health Department: a teaching health unit affiliated with McMaster University and the University of Guelph, August 1997.)

the respondents was 44 y, and 44% (71/163) of the respondents were males.

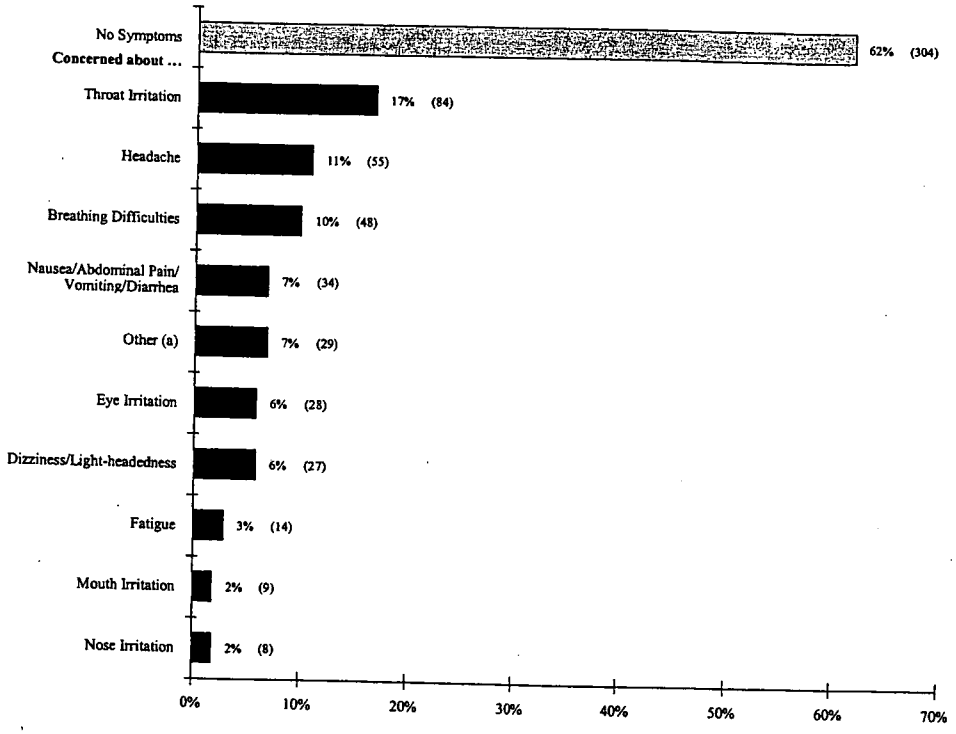
The numbers of persons (residents or visitors) in each of the 163 households were as follows: 28 single-person households, 45 2-person households, 31 3-person households, and 59 households with 4 or more persons. Therefore, information was gathered from 163 respondents who reported on an additional 325 persons. Health information was obtained for a total of 488 residents, 51% of whom were female and 49% of whom were male.

The reported general concerns are shown in Figure 1. A total of 222 general concerns were reported by 61% (99/163) of the respondents. The 10 most frequently reported concerns were eating garden produce, ash/dust fallout, air quality, response time of public officials, city responsibilities, possible effects on overall health, responsibilities of the plant owner, potential effects on children, long-term health consequences, and water contamination.

The symptoms reported most frequently by respondents over a 6-d period are shown in Figure 2; 62% of the 488 residents in 163 households reported no symptoms during the days of the fire, and 17% (84/488) of the residents reportedly had throat irritation. Other symptoms reported, in order of descending frequency, were as follows: headache, breathing difficulty, nausea, abdominal pain, vomiting, diarrhea, eye irritation, dizziness/lightheadedness, mouth irritation, and nose irritation.

Symptoms, by day, are shown in Figure 3. Symptoms were most prevalent on July 11—the day of the evacuation. The prevalence of symptomatology declined daily subsequent to the fire. Of the residents who reported symptoms, 2% (11/488) reported that they sought medical attention, 8 contacted their family physician, and 2 reported visiting the emergency room (1 of whom reported a 3-d hospital stay). One person reported seeking health-care information from the public-health nurse at the fire evacuation field office. It is interesting to note that when asked about their whereabouts during the evacuation period, 70% (112/163) of respondents reported that they left the neighborhood for some or all of the evacuation period.

Emergency room visits and hospital admissions. Figures 4 and 5 demonstrate the time plots for emergency room visits and hospital admissions, aggregated for all 5 hospitals. The time plots were comparable for both



(a) - Other Health Concerns/Symptoms (number of residents reporting a health concern/symptom in brackets):

Nervous
Asthma (2)
Angina requiring medication (3)
Nosebleed (1)
Heart Condition unaffected (1)
Weak, lethargic (2)
Irritable (2)
Allergies (2)
Pressure in head (1)
Less appetite (1)
Plugged ears (1)
Brunt, blistered (1)
Risk due to previous infection (1)
Fever (1)
Insomnia (3)
Congestion (1)
Malaise (2)
Dehydrated (1)
Sore back and neck (2)

(b) - Note: The survey questionnaire was administered to 163 respondents who reported on themselves and the other 325 residents in the households, giving a total of 488 residents

Fig. 2. Health concerns/symptoms reported, by survey, by residents during the 6-d period that followed the fire: July 1997 residents in the Plastimet fire evacuation area. *Note*: The survey questionnaire was administered to 163 respondents who reported on themselves and the other 325 residents in the households, thus giving a total of 488 residents. (*Source:* Hamilton-Wentworth Regional Public Health Department: a teaching health unit affiliated with McMaster University and the University of Guelph, August 1997.)

years; the overall average numbers of admissions were slightly higher in 1996 than in 1997. There was no conspicuous increase in either visits or admissions in the time during or immediately following the fire. The depressions in the graph around June 30 are the result of missing data from two hospitals for both years. The missing data did not include the days of the fire; therefore, they did not affect the interpretation adversely. The mean daily emergency visit and admission counts for 1996 and 1997 are summarized in Table 1.

Chloracne surveillance and additional measures. No cases of chloracne were reported. No fatalities resulted from the fire in the firefighters, emergency service providers, or the community.

Discussion

The literature on the immediate health effects of PVC plastics fires on communities is sparse. A comprehensive search of the MEDLINE database revealed only one report that contained reference to health impacts in communities affected by PVC plastics fires.[7] The report is largely a narrative account of what transpired. The table of data relates to a descriptive summary of complaints reported by emergency personnel who attended the fire and who sought medical attention in the casualty department. Large plastics fires can emit a wide range of toxins into the atmosphere. More than 70 toxic substances have been measured in PVC plastics fires.[1,2] Exposures from this fire were predominantly airborne, although dermal exposure to mists of hydrogen chloride also occurred. Elevations of toxins above acceptable levels occurred briefly and likely did not pose significant long-term risks.

The survey and hospital data analysis indicated that morbidity related to the fire studied herein was moderate and was likely short in duration. The survey data indicated that mucous membrane irritation (e.g., eyes, ears, throat) and breathing difficulties were prominent in those who reported symptoms. There were no concurrent control data with which to compare the frequencies of reported symptomatology. However, comparable data originate from a randomly conducted

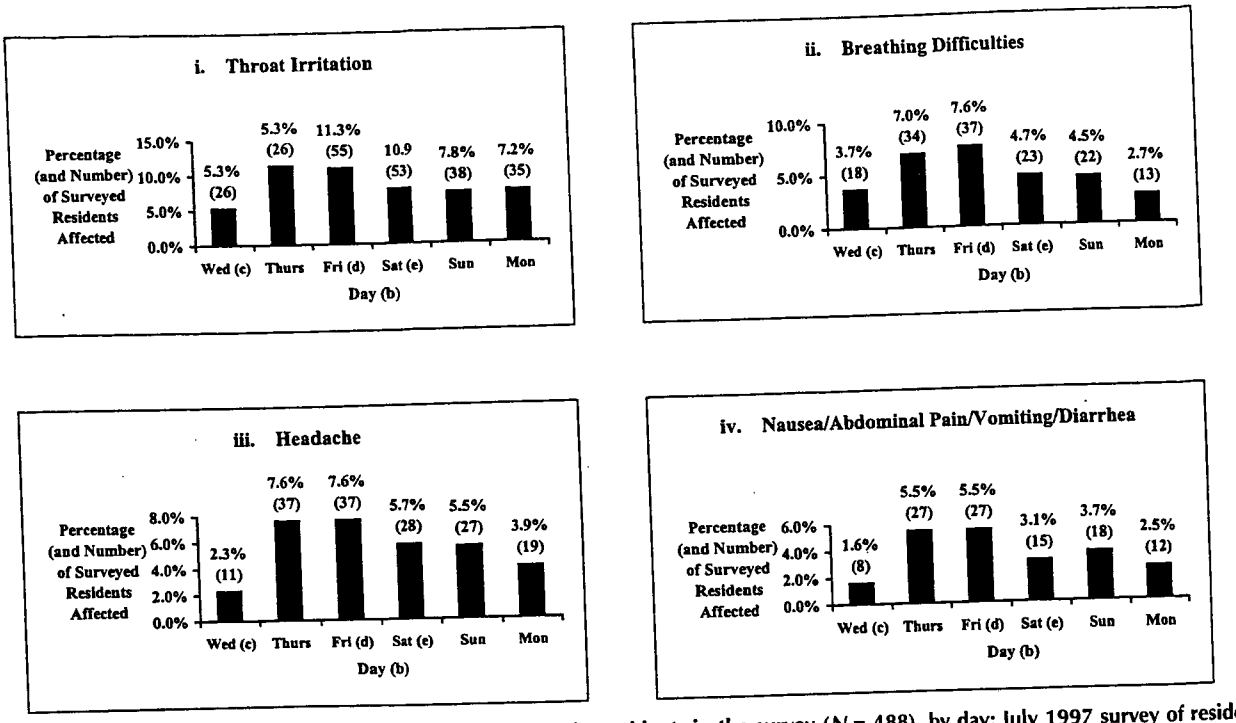


Fig. 3. The most frequent health concerns/symptoms reported by the residents in the survey (N = 488), by day: July 1997 survey of residents in Plastimet fire evacuation area. *Note:* The survey questionnaire was administered to 163 respondents who reported on themselves and the other 325 residents in the households, giving a total of 488 residents. (*Source:* Hamilton-Wentworth Regional Public Health Department: a teaching health unit affiliated with McMaster University and the University of Guelph, August 1997.)

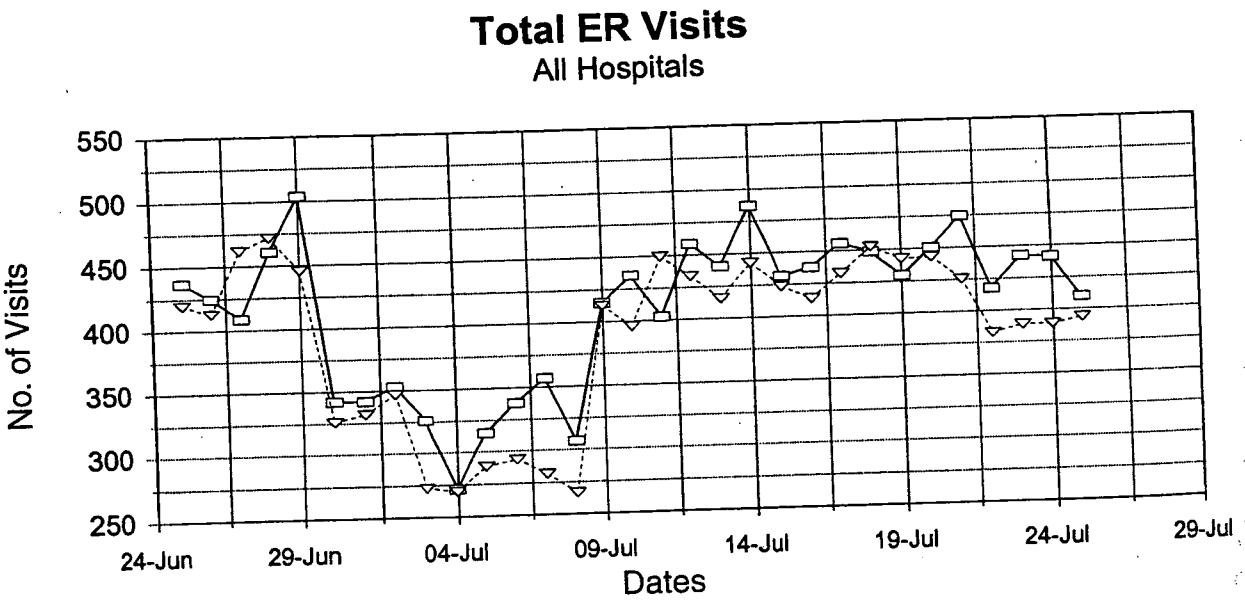


Fig. 4. Graph representing the overall series for total emergency room visits for all the hospitals. The rectangular markers represent 1996 and the inverted pyramids represent 1997. The missing values from McMaster University Medical Center and Chedoke Hospital for the days between June 30 and July 8 in both years markedly influenced the perception of the graph.

health survey of the 500 residents in 1995. In this study, investigators determined the prevalence of cough/shortness of breath (12.4% [n = 62]). This percentage is comparable with the 10% who reported breathing difficulties immediately following the fire. There are no area-specific data for the usual incidence of headache and abdominal symptoms. The throat and eye irritation is plausibly related to exposure to hydrochloric acid, which is formed when water comes into contact with hydrogen chloride.[1–5] Therefore, the process of extinguishing the fire creates its own hazard.

The survey provided residents an opportunity to report health and general concerns in the immediate aftermath of the fire. In the subsequent months, con

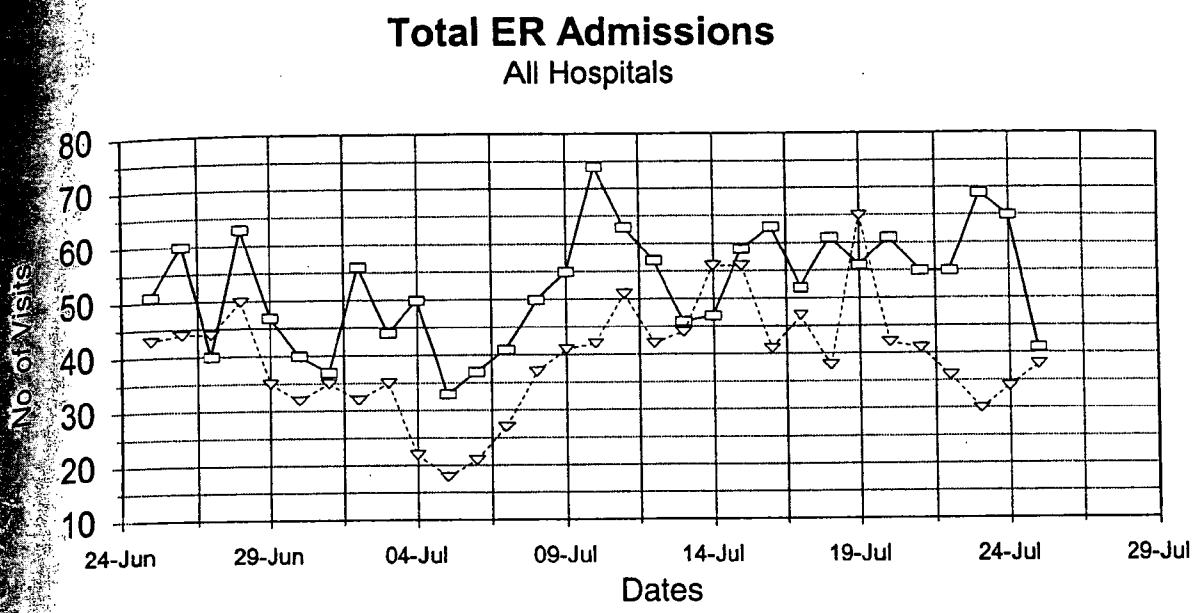


Fig. 5. Graph representing the overall series of hospital admissions from the emergency room from four hospitals that had admissions. The square markers represent 1996 and the inverted pyramids represent 1997. There were no hospital admissions from the emergency room for Chedoke Hospital. Note that the McMaster University Medical Centre series had 0 values from June 30 to July 8 in both 1996 and 1997.

Table 1.—Mean Admissions and Emergency Room Visits for the Time Period between July 2, 1996, and July 25, 1997

	Year			
	1996		1997	
Admissions/visits	$\bar{x}$	*SD*	$\bar{x}$	*SD*
Admissions	52.5	10.3	39.3	10.3
Emergency room visits	409.0	58.3	388.0	64.3

Notes: $\bar{x}$ = mean, and *SD* = standard deviation.

cerns over long-term health effects from the fire predominated in the community and media. This was particularly the case after an activist group announced that the immediate area was very contaminated with dioxins. Subsequent testing from the Ontario Ministry of the Environment and Energy (OMOEE), and independent laboratories confirmed that soil and vegetation dioxin levels were similar to levels found in other Canadian urban areas. Two independent models estimated that airborne exposure to dioxin may have exceeded Canadian lifetime acceptable daily intake standards by a magnitude of 2 on the day of evacuation. The weekly averaged intake, however, was below the established levels. (Note: A complete report of the environmental measurements and risk assessment associated with the exposures can be found in the OMOEE technical report. The report includes a detailed discussion of the dioxin levels found during the fire. It is available for downloading at the following Uniform Resource Locator: http://www.ene.gov.on.ca/envision/techdocs/index.htm #fire.)

The time-series plots indicate that, in general, the daily counts were lower in 1997 than in 1996. There appeared to be a small, but visible peak of admissions and visits around the 14th of July for Hamilton General, St Josephs, and Henderson General hospitals (data not shown). The peaking of visits and admissions was very modest and did not rise above the highest daily levels recorded in the previous year or previous to the fire in the same year. The aggregated overall series indicates comparability between years and no dramatic increase in the time period immediately around the fire. Published studies on hydrogen chloride exposure indicate that severe symptoms develop within 24–48 hr of exposure.[2] The failure of admissions and visits to rise substantially in the period immediately after the fire indicates that exposure levels were not sufficiently high to cause respiratory distress in a large proportion of the exposed community. Sensitive individuals may have been adversely affected, but this study design did not specifically identify and sample these individuals.

One of the limitations of our investigation was that no standardized questionnaire existed for conducting surveys in the aftermath of PVC plastics fires. Given that the survey was developed rapidly for the purposes of documenting symptoms and concerns as expeditiously as possible, face validity was assumed. Pretesting of the survey instrument, detailed training of the nurses administering the survey, and verification of standard administration by staff could not be guaranteed; therefore, one must exercise some caution in interpreting the survey results. Extensive media coverage, which addressed potential health effects of the fire, may have exerted a framing bias. No baseline data on overall health status and concerns exist.

Inasmuch as the hospital records analysis relates to hospital utilization, by definition it will miss morbidity

cases that do not come to the hospital. Bates described a hierarchy of adverse health effects associated with short-term exposures to ambient air pollution.[15] At the top of the hierarchy is increased mortality, which is followed by increased hospital admissions and increased emergency room visits. The survey indicated that only 2% of respondents sought health care during the time of or immediately after the fire. However, these results accounted only for those in the evacuation area. Given that the plume was protean in movement, others in the community may have been exposed. Our hospital study covered all the hospitals in the region; therefore, the study results should be reliable indicators of morbidity in the community at large. However, our study could not capture morbidity associated with visits to physicians' offices.

In addition, the survey and hospital records study did not capture intermediate term morbidity. Health concerns in the community increased after the survey was administered. Exposure to hydrogen chloride from PVC plastics fires can also cause prolonged respiratory problems. Whereas this result has been documented for firefighters, it is not implausible for a similar phenomenon to occur in civilian populations.[5]

In our study, we focused on visits and admissions without regard to diagnosis. This decision was made at the outset for the following reasons. The time-plotting exercise was seen as a screening process. If there was an evident peak in the time plots around the time of the fire, then quite plausibly it would be related to the fire, and further examination would be required to determine the nature of the morbidity. Further characterization of morbidity would require creation of a standard data extraction and recording sheet, inasmuch as the reliability and validity of emergency room diagnosis codes are questionable.

The results of this report must be interpreted in light of the nature of the exposure. The population was exposed to a substantial, preventable, and involuntary risk. They were, therefore, harmed without consent. The owner of the recycling plant was in violation of the municipal fire code when the fire occurred. The land on which the recycling plant was located was also the site of a previous environmental emergency in Hamilton.[16]

Conclusions

Combusted PVC plastic can pose a potential health threat to civilian populations. Policymakers, public-health officials, and environmental officials should be cognizant of the threats posed to civilian populations by plastics recycling plants located close to residential areas. Information about the potential adverse health effects of combusted PVC plastics should be available to public health officials for rapid dissemination to health-care providers, community members, and emergency service personnel. The existence of a standardized symptom record would aid in the rapid assessment of community health status in the aftermath of similar disasters.[17]

* * * * * * * * * *

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Evaluation of Toxic Potency Values for Smoke from Products and Materials

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Abstract. Many devices have been used to generate data on the toxic potency of smoke from burning products and materials. This paper critically reviews those apparatus and sorts them by the combustion conditions (related to a type of fire) producing the smoke, the specimens tested, and the animal effect measured. All the usable data were derived using rats, and the toxicological effects encountered were lethality, represented by an LC_{50} value, and incapacitation, expressed as an IC_{50} value. The data showed a wide range of toxic potency values for the products and materials tested. For those engineering applications where the mix of combustibles is unknown, generic values of smoke toxic potency were derived. Statistical analysis of the wealth of published data yielded a generic LC_{50} value of 30 g/m^3 ± 20 g/m^3 (one standard deviation) for 30 minute exposure of rats for smoke from well-ventilated combustion. There are limited data for underventilated combustion, and a value of 15 g/m^3 ± 5 g/m^3 is suggested. The mean value of the ratios of IC_{50} values to LC_{50} values is 0.50 ± 0.21, consistent with a prior review. Thus, for well-ventilated fires, a generic 30 minute IC_{50} value (for rats) would be 15 g/m^3 ± 10 g/m^3; for underventilated fires, the corresponding number would be 7 g/m^3 ± 2 g/m^3. There are some materials with appreciably lower potency values, indicating higher smoke toxicity. If materials like these are expected to comprise a large fraction of the fuel load, a lower generic value should be used.

Key words: fire, smoke, smoke toxicity, incapacitation, lethality

1. Introduction

To be able to perform the toxicity component of a fire hazard or risk analysis, the practitioner needs to know how much smoke it takes to produce undesirable effects on people. Over the past 30 years, scientists have developed numerous methods and extensive data for a variety of single component materials and commercial products. Nearly all of the studies involved combusting a small sample in a laboratory apparatus intended to simulate some type of fire; exposing laboratory animals, generally rodents, to the smoke; and characterizing the result. The typical measurement is an EC_{50}, the concentration of smoke (e.g., in g/m^3) needed to produce an effect in half (50%) of the animals in a given exposure time. Nearly all of the material and product data are for lethality (LC_{50}) or incapacitation (IC_{50}).

This paper examines that wealth of data, sorts it by the combustion conditions (related to a type of fire) producing the smoke, the specimens tested, and the animal effect measured. We then update the generic values to use in fire hazard analysis when the composition of the mix of combustibles is unknown. This is valuable in both building design and fire

reconstruction. A key component of this evaluation is the assignment of a confidence limits to the derived toxic potency values.

2. Compilation of Toxicological Data

The search for lethal and sublethal toxic potency data for materials and products involved on-line library searches for pertinent books, journal articles, proceedings, and technical reports. The primary on-line database used for this literature search was the Fire Research Information Services (FRIS) maintained by the Building and Fire Research Laboratory at NIST. Other on-line library searches were performed using TOXLINE and MEDLINE (maintained by the National Institutes of Health) and the Office of Pollution Prevention and Toxic Substance Library (maintained by the Environmental Protection Agency). In addition, technical experts involved in the project were asked for unpublished data and other published data that were not readily available otherwise. Table 1 presents a summary of the literature search, including the number of citations found. A complete list of references obtained is presented as a separate list in the Appendix to this paper.

TABLE 1
Sources of Toxic Potency Data

Source	Number of Citations
Annual Review of Pharmacology and Toxicology	1
ASTM/ISO Publications	4
Environmental Health Perspectives	2
Journal of American Industrial Hygiene Association	2
Journal of Archives of Environmental Health	3
Journal of Combustion Science and Technology	1
Journal of Combustion Toxicology	39
Journal of Consumer Product Flammability	1
Journal of Fire and Flammability	1
Journal of Fire and Materials	18
Journal of Fire Safety	2
Journal of Fire Sciences	23
Journal of Fire Technology	4
Journal of Forensic Materials and Pathology	1
Journal of Fundamental and Applied Toxicology	3
Journal of Industrial Hygiene and Occupational Medicine	1
Journal of Macromolecular Science-Chemistry	1
Journal of Medical Science and Law	1
Journal of Science	2
Journal of Testing and Evaluation	1
Journal of the American College of Toxicology	2
Journal of Toxicology	1
Journal of Toxicology and Applied Pharmacology	3
Journal Zeitschrift Fur Rechtsmedizin	1
NIST Publication, Technical Notes, and Reports	23
Proceedings	38
Other Reports	25
Toxicology Letters	1

3. Data Organization

The literature review identified different types of toxicity test methods ranging from laboratory small-scale tests to full-scale tests. To enable analysis of the full set of toxic potency data, the results from the various test methods were categorized by:

- Combustion/pyrolysis condition
- Material/product examined
- Type of test animal
- Toxicological endpoint

3.1. Combustion/pyrolysis Conditions

There is a small number of types of thermal decomposition in fires:

- oxidative pyrolysis (non-flaming), typical of products being heated without bursting into flames themselves;
- well-ventilated flaming combustion, typical of pre-flashover fires;
- ventilation-limited combustion, typical of post-flashover fires or fires in nominally airtight spaces; and
- smoldering, or self-sustaining, non-flaming combustion.

The purpose of a small-scale toxic potency measurement is to obtain data from a small material or product sample that is germane to some particular set of realistic fires. In this section, we assess the combustion conditions in the 12 small-scale apparatus for which data are available. Each apparatus will then be aligned with one or more of these realistic fire conditions.

As shown in Table 2, the combustors in the small-scale apparatus fall into three types: cup furnace, radiant heater, and tube furnace. While measurements of combustion gases have been made in a number of other small-scale devices, these 12 are the only ones for which animal exposure data have been reported.

TABLE 2
Small-Scale Toxicity Test Methods

Method Group	Individual Test
Cup Furnace Methods	NBS Cup Furnace
	Dow Chemical Company Method
	University of Utah Method
Radiant Heat Methods	Weyerhaeuser Method
	NIST/SwRI Method
Tube Furnace Methods	UPITT Method
	DIN 53 436 Method
	Federal Aviation Administration Method
	University of San Francisco Method
	University of Michigan Method
	University of Tennessee Method
	NASA/JSC Method

In the cup furnace methods, the sample is placed in an open-top quartz beaker that is set in a furnace. The bottom and lower portions of the beaker are heated to a pre-set *temperature*, which is generally picked to be above or below the autoignition temperature (AIT) of the pyrolysis vapors. The oxidative pyrolysis or combustion vapors rise and flow out the top of the beaker into the box in which the animals are exposed. The box is closed, so the test animals experience the accumulated combustion products, some of which diminish in concentration due to adsorption on the chamber walls. Combustion tests have shown that the lethal toxic potency of pyrolysis smoke is at a maximum at furnace temperatures near the AIT. Thus, in most non-flaming cup furnace tests, the furnace temperatures are kept at approximately 25°C below the predetermined AIT to ensure conservative toxic potency values. For flaming tests, the oxygen concentration remains high enough that the vitiation does not obscure the toxicity of the smoke. Natural buoyancy tends to draw sufficient "fresh" air to the sample so that the combustion product profile for flaming samples is indicative of fuel-limited combustion. Thus, cup furnace data are typically used to represent well-ventilated flaming combustion and oxidative pyrolysis.

In the radiant heat devices, the sample is exposed to a defined *heat flux*. The irradiance is generally sufficiently high (e.g., 50 kW/m^2) and abetted by an ignition device to ensure flaming for all but the most resistive products or low enough (e.g., 25 kW/m^2) to preclude flaming of all but the most readily ignitable smoke. The combustion products remain in a closed compartment, and the animals are exposed to the time-integrated accumulation of smoke. The smoke is indicative of well-ventilated burning. [It has also been shown that the data can be used to calculate the toxic potency of smoke from post-flashover burning by enhancing the carbon monoxide yield to that level observed in post-flashover fires [1]. No corrections were made for changes in the yields of other toxicants.]

Like the cup furnaces, the combustion environment in tube furnaces is defined by *temperature*. This can be uniform, a fixed value, or a time-variant (ramped) range. The sample lies within a long horizontal tube, much of which lies inside the furnace. In some devices the sample is stationary, in others it is moved through the heated zone of the tube, replenishing the supply of fresh fuel. In the tube furnace experiments reviewed there is no mention of the ignition of smoke in the combustion device. Tube furnaces are open systems (except for the University of San Francisco Method), with the air flowing to the sample and through the combustion zone. The animals are thus exposed to a time-varying smoke composition. The exception was the DIN test, in which both the sample and air were introduced at constant rates.

None of these devices can accurately replicate a true smoldering combustion. Achievement of the low heat losses needed for this self-sustained process requires a physically larger sample than that which can be accommodated by bench-scale devices.

With the exception of the radiant heat methods, these furnaces are limited in their ability to evaluate test specimens representative of configured products (e.g., mattresses or chairs). Depending on the end product design, this may have a significant effect on the combustion of the specimen in the apparatus and on the measured toxic potency.

In most of the cited literature, the combustion conditions represented in a test were either vague or completely undefined. Thus, in order to make use of as large a fraction of the accumulated data as possible, we attempted our own assignments. This was achieved as

follows:

- For those tests in which the sample flamed, the ratio of the concentrations or yields of carbon dioxide (CO_2) and carbon monoxide (CO) was reported, and the $[CO_2]/[CO]$ ratio was eight or greater, the combustion mode was considered well-ventilated. For tests in which the $[CO_2]/[CO]$ ratio was less than 8, the combustion mode was considered ventilation-limited. In cases of flaming combustion where the concentrations or yields were not reported, the toxicity data were most often set aside. [It was recognized that a flame-resistant material could yield a low $[CO_2]/[CO]$ ratio even under well-ventilated conditions.]
- In some flaming experiments, the nature of the sample being burned had a strong influence on the ventilation. For example, in cup furnace experiments with low-density samples (with a corresponding large size relative to the beaker), oxygen access to the burning site is expected to be impeded, and the combustion would tend toward ventilation-limited. In experiments with high-density samples (with a corresponding small size relative to the beaker), oxygen levels are expected to be higher.
- In many of the tube furnace tests, it was not reported whether the sample flamed and, if so, for what portion of the test. To determine retroactively whether flaming was likely, we compared the reported furnace temperature with an AIT for the material being tested. [The source of these temperatures was the cup furnace literature, in which the AIT of the test material was measured in order to assure flaming or non-flaming combustion. Knowing that, e.g., all polystyrenes do not have the same AIT, we nonetheless used the cup furnace AIT value as indicative, for lack of better information.] If the furnace temperature was at least 25°C above the AIT, we considered the combustion to be flaming. Where the furnace temperature was at least 25°C below the AIT, the combustion was labeled non-flaming (oxidative pyrolysis). When the furnace temperature was within 10°C or so of the AIT, the data were set aside. In some cases, CO and CO_2 concentration or yield data were reported. This information was also used to make the determination of combustion conditions.

Reports on many of the tube furnace articles (specifically, the descriptions for the combustion oven experiments at the University of Pittsburgh, University of Michigan, University of Tennessee, and NASA/Johnson Space Center) did not provide sufficient information to establish the fire conditions being represented. Furthermore, in some of the tests, spontaneous flaming occurred in otherwise non-flaming experiments. In either of these cases, the data generated from these experiments were set aside since they could not be directly related to one of the three combustion conditions. Table 3 summarizes the relationships we found between toxicity methods and fire conditions.

TABLE 3
Fire Conditions Replicated by Principal Toxicity Test Methods

	Fire Conditions			
Method Type	Well-Ventilated Flaming	Ventilation-Limited Flaming	Oxidative Pyrolysis	Mixed or Unknown
Cup Furnace	X	X	X	
Radiant Furnace	X	X		
Tube Furnace		X		X

TABLE 4
Material and Product Groupings

Acrylic Fibers	Polyesters
Acrylonitrile butadiene styrenes	Polyester fabric/polyurethane foam
Bismaleimide	Polyethylenes
Carpet (modacrylic/acrylic)	Polyphenylene oxides
Carpet foam (with nylon)	Polyphenylene sulfides
Carpet jute backing (with nylon)	Polyphenylsulfones
Chlorofluoropolymers	Polystyrene foams
Epoxy	Polyurethanes, Flexible
Fabric, vinyl	Polyurethanes, Rigid
Fluoropolymers (data set A)	Polyvinyl chlorides, Plasticized
Fluoropolymers (data set B)	Polyvinyl chlorides
Modacrylics	Urea formaldehydes
Phenolic resins	Wire insulation, NFR cross-linked EVA
Polyacrylonitriles	Wire, PTFE coaxial
Polyamides	Wire, THHN with nylon-PVC jacket
Polycarbonates	Woods

3.2. Materials and Products Examined

The citations included toxic potency data for a wide range of single component materials and for a limited number of products. Very few references provided the detailed composition of the test specimens. Typically, the sources provided the generic polymer and whether or not the material or product was fire retarded. The type or formulation of the retardant(s) was often lacking. Given the vagueness of such details, we grouped the tested items into generic classes of materials and products, which are presented in Table 4.

The fluoropolymers were separated into two distinct sets (A and B) because, as will be seen below, the lethality values fell into two groups that were two orders of magnitude apart. Fluoropolymer data set B is shown only for completeness. Real-scale experiments have shown that these very high toxic potencies are not realized when hydrogen-containing combustibles are also involved in the fire [2]. Thus, this set of values has not been used in the analyses that follow. The fluoropolymers were the only product group for which the data warranted this separation.

3.3. Test Animals

The test subjects used in all the listed toxicity test reports were rats and mice. As noted above, the data from the two methods that used mice (University of Pittsburgh and University of San Francisco devices) were not used in this analysis because of the indeterminate flame conditions in those apparatus. Thus, the data evaluated below are based solely on rats as the test subject. We do not differentiate among strains of rats used in the experiments.

The number of test subjects and their exposure to the smoke also varied among the tests. In the cup furnace and radiant heat methods, individual rats were positioned such that only their heads were exposed to the smoke. In the tube furnace methods, the animals were exposed as either individuals in a head-only position or as groups in whole-body positions. In this study, the toxicity data are evaluated only in terms of the species used, not the number or position of the subject.

TABLE 5
Toxicological Effects Measured Using Types of Test Methods

	Toxicological Effect			
Method Type	LC_{50}	LL_{50}	IC_{50}	Other
Cup Furnace	X		X	
Radiant Heat	X			
Tube Furnace	X	X		

3.4. Toxicological Endpoint

The toxicological effects encountered during the literature review were lethality and incapacitation. There were no data found on other sublethal effects. Table 5 presents a matrix of the reported lethality endpoints, grouped by the toxicity methods.

Smoke lethality was expressed as either a lethal concentration or lethal loading. The lethal concentration, which is expressed as an LC_{50}value, is the mass loading or mass combusted of a specimen per unit chamber volume (smoke concentration, in g/m^3 or mg/l) that kills 50% of the test animals during a fixed exposure time and perhaps a post-exposure observation period. The lethal loading, which is expressed as an LL_{50}value, is defined as the mass loading (g) in the furnace that kills 50% of the test animals as a result of a fixed exposure time. Unless the latter could be converted to a concentration, the data from the tests could not be used in hazard analyses and were not included in analyses here.

Sublethal endpoints are typically expressed as either an effect concentration or a time-to-effect. Time-to-effect measurements provide information on the rapidity of toxic action rather than on toxic potency. Since the purpose of this study is to generate dose-response information, the time-to-effect endpoints are not included in this evaluation. Thus, the sublethal effect data compiled here are incapacitating concentrations (expressed as an IC_{50} value), which are defined as the mass loading or mass combusted per unit chamber volume (smoke concentration, in g/m^3 or mg/l) that causes incapacitation of 50% of the test animals during a fixed exposure time and perhaps a post-exposure observation period. While a variety of pure gas exposure studies have used various techniques for measuring incapacitation, all the articles collected for this project used the hind-leg flexion conditioned avoidance response test [3].

Among the large number of methods and laboratories, there was variation in the length of time the animals were exposed to the smoke. Table 6 presents a summary of the different exposure times reported for the toxicity test methods reviewed. Most of the data are for an exposure time of 30 min with a post-exposure observation period ranging from 10 min to 14 days. In some experiments, there were no post-exposure observation periods. For the tube furnace methods (specifically the combustion oven devices including the University of Pittsburgh, University of Michigan, University of Tennessee, and NASA/JSC methods), the exposure times were (10, 30, 60, 140, or 240) min, with post-exposure observation periods of 5 min or 10 min, or 7 days or 14 days. However, since as noted above, the data from these devices did not meet other criteria, all the LC_{50} and IC_{50} values in the following discussions and analyses are for 30 min exposures.

TABLE 6
Exposure Times for Principle Test Methods Reviewed

	Exposure Time (min)				
Method Type	10	30	60	140	240
Cup Furnace		X			
Radiant Heat		X			
Tube Furnace	X	X	X	X	X

For the evaluation in this paper, we used only toxic potency data developed from tests that included a post-exposure period. In the reported tests, incapacitation (from a combination of narcotic and irritant effects) typically occurred during an animal's exposure to the smoke. Lethality, on the other hand, occurred either during the exposure to smoke or during the post-exposure period. The relationship between these post-exposure effects in rats and the effects on people during a fire remains to be assessed. However, we felt it more appropriate to use the more conservative toxic potency values (i.e., those that include a post-exposure period) for the current purpose. Alternative analyses can be performed as desired using the information assembled in the Appendix.

4. Evaluation of Toxicological Data

The usable sets of LC_{50} and IC_{50} data are shown in Tables 7 and 8, respectively. As noted above, all data are for rats exposed to the smoke for 30 min and then observed for some post-exposure period. Each cell contains a median value for the experimental determinations and 95% confidence limits; the number of determinations is also shown.

4.1. Estimation of Confidence Intervals

The original toxic potency data, compiled in the Appendix, is of varying quality. Some LC_{50} and IC_{50} values have corresponding 95% confidence intervals and some do not. In addition, the numbers of individual experiments (sample sizes) used to calculate these confidence intervals are not always available. This varying quality of the individual data presents some challenge to appraising the aggregated set of toxicological values.

To estimate the 95% confidence intervals for each combination of material, combustion condition, and toxicological endpoint, the available information was grouped into three cases:

1. For some combinations, each of the (one or more) reported toxic potency values includes a 95 % confidence interval. The standard uncertainties were derived from the confidence intervals. A hierarchical Bayesian model [4], implemented with the BUGS software [5], was then used to obtain a consensus LC_{50} or IC_{50} value and its 95% confidence interval. These results are indicated in the cells of Tables 7 and 8.
2. For other such combinations, some of the reported toxic potency values include 95% confidence intervals and some do not. To estimate 95% confidence intervals for the latter, we assumed that their precision was similar to that of the former. For a given

TABLE 7
Estimated Mean LC_{50} Values (g/m^3) (confidence limits, g/m^3) (sample size)

Material	Well-Ventilated Combustion	Ventilation-Limited Combustion	Oxidative Pyrolysis
Acrylonitrile butadiene styrenes	**17.7 (14.8,20.7) 4		**32.3 (28.2,35.3) 4
Bismaleimide	14.9 (12.8,17.2) 1		41.9 (38.8,45.1) 1
Carpet foam (with nylon)	*108 (47,138) 1		*68.0 (36.0,81.1) 1
Carpet jute backing (with nylon)	*57.0 (35.5,69.4) 1		*90.0 (53.7,99.2) 1
Chlorofluoropolymers	**17.6 (10.2,33.6) 2		**24.6 (17.7,32.1) 2
Epoxy	*7.3 (1.5,15.8) 1		11.0 (8.9,13.1) 1
Fabric, Vinyl	32.0 (28.0, 37.0) 1	19.0 (17.7, 20.9) 1	
Fluoropolymers (data set A)	**27.4 (19.0,35.8) 4		**25.4 (17.8,33.5) 4
Fluoropolymers (data set B)	**0.12 (0.04, 0.93) 6		**0.37 (0.10, 0.96) 4
Modacrylics	**5.6 (4.0,7.2) 3		6.5 (4.6,8.3) 4
Phenolic resin	8.4 (7.3,9.5) 1		5.9 (4.8,7.0) 1
Polyacrylonitriles	**40.2 (37.0,43.4) 2		
Polyesters	**35.6 (31.4,39.4) 4	**40.5 (18.7,56.2) 1	**37.8 (29.2,46.9) 3
Polyester fabric/polyurethane foam	*42.0 (30.9,55.9) 1		*30.0 (25.2,42.2) 1
Polyethylenes	**36.8 (30.1,43.0) 3		5.8 (3.5,8.9) 2
Polyphenylene oxide	*31.5 (22.3,35.6) 1	*24.0 (17.8,36.5) 1	
Polyphenylsulfones	27.2 (20.6,33.7) 4		18.0 (13.1,23.1) 4
Polystyrene foams	**35.6 (33.4,37.9) 7		*43.5 (41.1,45.6) 6
Polyurethanes, Flexible	**35.4 (31.8,38.9) 18	**20.4 (16.0,24.9) 4	**29.9 (26.5,33.0) 15
Polyurethanes, Rigid	**13.0 (11.6,14.5) 12	14.0 (13.4,14.5) 1	**29.5 (25.2,33.9) 10
Polyvinyl chlorides, Plasticized	**26.2 (20.1,33.2) 3	16.0 (13.7, 17.5) 1	**22.9 (11.8,34.4) 3
Polyvinyl chlorides	**20.0 (16.8,23.2) 8		**16.1 (13.2,19.3) 5
Strandboard			47.0 (37.7,57.3) 1
Tempered hardwood	58.1 (40.8,67.0) 1		86.5 (79.4,93.0) 1
Urea Formaldehyde	11.2 (10.4, 12.0) 1		1.20 (1.10,1.30) 1
Wire, PTFE coaxial wire	*9.6 (5.7,25.7) 1		*125 (8.00,25.2) 1
Wire, THHN wire w/ nylon-PVC	55.0 (44.0,66.0) 1		**8 (88.6, 107.2) 1
Wire insulation, NFR crosslinked EVA	51.0 (40.8,61.2) 1		
Wire insulation, FR crosslinked EVA		*25.0 (18.9,33.5) 1	
Woods	**40.2 (34.8,45.1) 14		**36.1 (30.8,41.0) 14
Estimated mean	30.1	24.4	27.8
95% Confidence Interval	(5.1,58.0)	(15.8,40.3)	(1.6,78.4)

*Confidence Interval constructed as described in Section 4.1, case 3.
**Confidence Interval constructed as described in Section 4.1, case 2.

test material, we compiled the results from studies of the same material and combustion mode for which 95% confidence intervals were available, translated each interval into a percentage of the mean value, and assigned the mean value of those percentages to the datum for which no confidence interval was available. The now-complete set of data was then fed into the same model used in case 1. These cells in Tables 7 and 8 are marked with a double asterisk.

3. For the third group of such combinations, there are no studies with reported confidence intervals, but confidence intervals are available for the same generic material under a different combustion method. We assumed the accuracy of results is similar across

TABLE 8
Estimated Mean IC_{50} Values (g/m³) (confidence limits, g/m³) (sample size)

Material	Well-Ventilated Flaming	Oxidative Pyrolysis
Acrylonitrile butadiene styrene	**11.2 (6.1,15.8) 3	**15.4 (7.9,22.0) 3
Bismaleimide	6.8 (5.4,8.3) 1	20.1 (16.3,24.0) 1
Epoxy	6.2 (5.2,7.3) 1	4.1 (3.3,5.0) 1
Fluoropolymers (data set A)	**14.8 (6.9,21.9) 2	**14.9 (7.9,19.9) 2
Fluoropolymers (data set B)	**0.55 (0.10,1.01) 2	**0.68 (0.31,1.49) 1
Modacrylic	**3.0 (0.7,6.0) 2	3.3 (0.2,6.7) 3
Phenolic resin	2.0 (1.6,2.4) 2	*1.5 (1.2,1.8) 1
Polyphenylsulfone	**15.3 (10.0,19.8) 3	**11.6 (6.6,16.8) 3
Polystyrene foam	**20.0 (15.0,24.9) 5	**33.4 (22.4,39.8) 5
Polyurethane, Flexible	**17.4 (10.1,25.2) 8	**15.5 (7.6,22.7) 8
Polyurethane, Rigid	**5.4 (4.0,6.8) 8	**9.5 (5.3,14.00) 8
Polyvinyl chloride, Plasticized	**7.1 (4.9,9.3) 1	**3.4 (2.8,4.0) 1
Polyvinyl chloride	**12.2 (8.6,16.3) 4	**13.5 (6.1,20.4) 4
Urea Formaldehyde	7.4 (6.5,8.3) 1	0.7 (0.6,0.8) 1
Wood	**21.4 (17.5,25.3) 10	**15.3 (12.2,18.5) 12
Estimated mean	11.2	11.5
95% Confidence Interval	(1.4,24.0)	(1.1,25.0)

*Confidence Interval constructed as described in Section 4.1, case 3.
**Confidence Interval constructed as described in Section 4.1, case 2.

combustion methods and used an approach analogous to that described for set 2.These cells in Tables 7 and 8 are marked with a single asterisk.

It appears that, although the data were reported in the source articles to as many as three significant figures, the repeatability of these results is probably not better than ±30%.

It is important to note, however, that the gas yields and toxic potency data from only one of these 12 bench-scale devices (the radiant furnace now used in NFPA 269 and ASTM E1678) has been validated against room-scale experiments [1]. The accuracy of the other bench-scale data is undetermined.

4.2. Generic Toxic Potency Values

A quick scan of Tables 7 and 8 shows a wide range of toxic potencies. A hazard or risk analysis for a known set of combustibles should use toxic potency values appropriate to those products, the expected combustion conditions, and the proper toxicological effect.

In many cases, however, there is a mix of combustibles whose composition and time of entry into the fire are not well known. In those instances, generic values of toxic potency are desirable, ones that can be held constant throughout the analysis.

The last two rows of Tables 7 and 8 contain estimated mean LC_{50} or IC_{50} values for each of the combustion conditions and the estimated 95% confidence interval for the median value obtained using the following Monte Carlo method. For each combustion condition (column), a random sample of size 1500 was drawn from the materials in that column. At each draw, each material present in the column for that combustion condition had an equal probability of being selected. Then, for that draw a random value was picked from a presumed normal

distribution with mean and standard deviation given by the entry for that material and combustion condition. For example, suppose that for well-ventilated combustion the first draw chose "epoxy." The random value would then be from a normal distribution with mean 7.3 and standard deviation of 4.1. These 1500 points were then averaged to obtain an estimated overall mean LC_{50} or IC_{50} value. The 95% confidence interval was determined assuming that the 1500 points represented a normal distribution.

4.3. Comparison among Combustion Conditions

Since the combustion conditions and the products on fire vary within a fire compartment and evolve as the fire grows and ebbs, it is useful to assess the accuracy of using a single toxic potency value in engineering calculations. The following examines lethality data for two pairs of fire conditions and incapacitation for one pair.

Lethality: well-ventilated flaming and ventilation-limited combustion. These data sets in Table 7 were compared in two ways:

- The first generalized approach was a comparison of the mean LC_{50} values for both conditions, including all materials (except fluoropolymers B) in the data set. There is a wide range of LC_{50} values and modest differences between the mean values for the two columns. The broad 95% confidence limits around the two mean values suggest that any difference between the lethal toxic potencies of the smoke generated under these two sets of conditions is not resolvable.

  Examination of the data in the column labeled "Ventilation-limited Combustion" suggests that some of these numbers may be too high for use in evaluating post-flashover fires. Carbon monoxide yields from underventilated flaming fires are generally distinctly higher, so LC_{50} values should fall relative to the same products burning with ample ventilation. Further, the LC_{50} value for post-flashover smoke is about 25 g/m^3 if the only toxicants it contains are CO_2 and CO [1]. The presence of additional toxicants will reduce this. There are six materials with entries in these two columns. Five of these appear to behave as expected. The underventilated LC_{50} value for the polyester sample is above 25 g/m^3. However, even were this "Ventilation-limited" value reflective of the two (above) guidelines for underventilated fires, the mean value for this column would not likely be sufficiently lower that the two confidence intervals would not overlap.
- The second approach was a comparison of LC_{50} values on a material-by-material basis. For three of the six combustibles the 95% confidence intervals overlap. In one of those cases, the ventilation-limited value is lower; in the other two, the reverse is true. This does not constitute strong evidence for a fundamental difference between the data in the two columns.

Thus, while there is reason to expect that the lethal toxic potency of smoke from underventilated fires would be higher than for well-ventilated fires of the same combustibles, the published data do not present sufficient evidence to resolve such a difference. This comparison is especially compromised by the small data set for ventilation-limited combustion.

Lethality: flaming combustion and oxidative pyrolysis. Comparison of the mean LC_{50} values and 95% confidence intervals for the three combustion conditions reveals no statistical difference between them; the mean values are very close and the confidence intervals for

well-ventilated combustion and ventilation-limited combustion are fully contained within those for oxidative pyrolysis.

Incapacitation: well-ventilated flaming combustion and oxidative pyrolysis. Recall there were no reported IC_{50} values for ventilation-limited flaming conditions. The mean values of the two columns are nearly identical and the 95% confidence intervals are essentially congruent. For about half the materials the individual confidence intervals show considerable overlap. The remaining half are split between the flaming value being higher and the reverse. Thus, any possible difference in incapacitating toxic potency between the smoke from these combustion modes is not discernible.

4.4. Comparison between Toxicological Effects

Kaplan and Hartzell [6] had reviewed the literature and found that for exposures to narcotic gases (CO or HCN), the concentrations that caused incapacitation (measured by a variety of devices) were one third to one half of those that resulted in the death of various animal species.

For the smoke data collected here, the mean value of the ratios of IC_{50} values to LC_{50} values and the standard deviation are 0.50 and 0.21, respectively. There is no significant difference between well-ventilated flaming combustion and oxidative pyrolysis.

These results are consistent with the Kaplan and Hartzell ratio, given the uncertainty in the measurements. In addition, since there is a broad set of expected toxic gases (e.g., CO, halogen acid gases, HCN, partially-oxidized organics) in the smoke from this group of materials, it is not unreasonable to generalize that an incapacitating exposure is about half that of a lethal exposure.

4.5. Comparison among Materials and Products

As noted above, it would benefit engineering calculations if there were a single LC_{50} (and thus IC_{50}) value to be used when the mixture of combustibles in a fire is unknown. In HAZARD I [8], the suggested values are 30 g/m^3 and 10 g/m^3, respectively (for 30 min exposures of rats to smoke).

The wide range of toxic potency values in Tables 7 and 8 strongly suggests that any such generic value must be used with caution. However, should such a number be needed, a generic value (from column 2 in Table 7) for lethal toxic potency (30 min rat exposure) in well-ventilated fires (even if much of the smoke were generated from pyrolysis rather than flaming) would be 30 g/m^3 $\pm$ 20 g/m^3. For underventilated fires, the situation is less clear. The data compiled here (column 3 of Table 7) and the value calculated for CO and CO_2 only [1] suggest an upper limit of 25 g/m^3. Data derived from the NFPA 269 radiant furnace [1] suggest a value of 15 g/m^3 $\pm$ 5 g/m^3. [The uncertainty in the underventilated value is much lower because the toxic potency is dominated by the large amount of CO produced during underventilated burning. This CO yield is controlled by the shortage of oxygen more than differences in the fuel chemistry [7]]. The above numbers have been rounded to convey the proper number of significant figures.

From the results in Section 4.4, for well-ventilated fires, a generic 30 min IC_{50} value (for rats) would be 15 g/m^3 $\pm$ 10 g/m^3. For underventilated fires, the corresponding number would be 7 g/m^3 $\pm$ 2 g/m^3.

In all cases, it is important to note that there are some materials with appreciably lower potency values, indicating higher smoke toxicity. If materials like these are expected to comprise a large fraction of the fuel load, a lower generic value should be used. Examples of lower numbers can be found in Tables 7 and 8, but prudence suggests obtaining measured values for the materials under consideration.

Appendix: Toxicological Data

TABLE A.1
LC_{50} and IC_{50} Values for Well-Ventilated Flaming Combustion

Material	Reference	30 min LC_{50} Value (With 14 day Post-Exposure Observation) $g \cdot m^{-3}$	95% Confidence Limits $g \cdot m^{-3}$	30 min IC_{50} Value (With 14 day Post-Exposure Observation) $g \cdot m^{-3}$	95% Confidence Limits $g \cdot m^{-3}$
Acrylonitrile butadiene styrene					
Pellets	1	15.0	12.3, 18.3	10.6	7.4, 15.2
Pellets	1	15.6	13.2, 18.4	6.0	4.1, 8.9
Pellets	1	20.8	15.9, 27.2	17.0	15.0, 20.0
Pellets	1	19.3	16.7, 22.3		
Bismaleimide					
No details provided	2	14.9	12.8, 17.2	6.8	5.4, 8.3
Carpet foam (with nylon)	3	108.0	NA		
Carpet jute backing (with nylon)	3	57.0	NA		
Chlorofluoropolymers					
Ethylene-chlorotrifluoroethylene (39.4% fluorine; 24.6% chlorine)	4	15.1	NA		
Blown ethylene-chlorotrifluoroethylene (39.4% fluorine; 24.6% chlorine)	4	20.0	NA		
Epoxy					
No details provided	2	7.3	NA	6.2	5.2, 7.3
Fabric					
Vinyl	5	32.0	28.0, 37.0		
Fluoroopolymers (data set A)					
Ethylene-tetrafluoroethylene (59.4% fluorine)	4	30.2	22.8, 40.0		
Polyvinylidene fluoride (59.4% fluorine)	4	27.3	17.9, 41.7		
Tedlar—thin opaque	2	40.0	NA	21.0	14.2, 27.8
Fluorenone-polyester—thin clear film	2	13.2	11.8, 14.6	10.7	9.9, 11.5

(Continued on next page.)

TABLE A.1 (Continued).

Material	Reference	30 min LC_{50} Value (With 14 day Post-Exposure Observation) $g \cdot m^{-3}$	95% Confidence Limits $g \cdot m^{-3}$	30 min IC_{50} Value (With 14 day Post-Exposure Observation) $g \cdot m^{-3}$	95% Confidence Limits $g \cdot m^{-3}$
Fluoropolymers (data set B)					
Fluorinated ethylene/ fluorinated propylene—76% fluorine	4	0.075	0.03, 0.27		
Polytetrafluoroethylene-Teflon	6	0.045	0.04, 0.05		
Polytetrafluoroethylene-Teflon	7	0.017	NA		
Polytetrafluoroethylene-powder	1	0.164	0.07, 0.37	0.8	0.06, 1.51
Polytetrafluoroethylene-powder	1	0.400	0.02, 6.81		
Polytetrafluoroethylene-powder	1	0.045	0.04, 0.05	0.25	NA
Modacrylic					
Knit fabric	1	7.1	6.4, 7.9		
Knit fabric	1	4.7	3.2, 6.9	2.8	2.0, 3.0
Knit fabric	1	4.4	3.9, 5.0	3.1	2.2, 4.3
Phenolic resin					
Rigid foam	8	8.4	7.3, 9.5	2.0	NA
Polyacrylonitrile					
No details provided	7	38.7	36.2, 42.4		
No details provided	7	41.8	NA		
Polyester					
NFR Fiberfill	9	30.8	28.2, 33.6		
NFR polyester upholstery fabric	10	37.5	35.3, 39.8		
NFR polyester upholstery fabric with NFR FPU	10	39.0	36.0, 42.2		
NFR laminated circuit boards; polyester resin with $CaCO_3$ filler	11	53.0	NA		
Polyester fabric/PU foam composite	10	42.0	NA		
Polyethylene					
NFR semi-flexible foam	12	35.0	34.0, 41.0		
FR semi-flexible plastic foam	12	31.3	29.3, 33.3		
Wire	1	46.0	NA		
Polyphenylene oxide					
NFR business machine housing	11	31.5	NA		

(*Continued on next page.*)

TABLE A.1 (Continued).

Material	Reference	30 min LC_{50} Value (With 14 day Post-Exposure Observation) $g \cdot m^{-3}$	95% Confidence Limits $g \cdot m^{-3}$	30 min IC_{50} Value (With 14 day Post-Exposure Observation) $g \cdot m^{-3}$	95% Confidence Limits $g \cdot m^{-3}$
Polyphenylsulfone					
Pellets	1	25.3	22.0, 29.2	15.0	NA
Pellets	1	36.0	24.9,39.6	21.8	12.9, 36.7
Pellets	1	11.7	9.1, 15.0	10.0	NA
Pellets	1	19.8	14.8, 26.5		
Polystyrene					
NFR rigid foam; GM-51	1	53.5	NA	30.0	NA
FR foam; GM-49; expanded	13	35.8	23.6, 48.0	17.9	NA
NFR rigid foam; GM-51	1	32.6	30.5, 34.8		
NFR rigid foam; GM-51	1	38.9	37.9, 39.9	28.7	27.5, 30.4
NFR rigid foam; GM-51; extruded	13	33.8	30.7, 36.9	12.7	NA
NFR foam; GM-47; expanded	13	27.8	NA	15.4	12.0, 18.8
NFR TV cabinet housing; high impact polystyrene base formulation	11	40.0	NA		
Polyurethane, Flexible					
NFR FPU #12	9	40.0	NA		
FR FPU #11	9	40.0	NA		
No details provided	5	52.0	46.0, 59.0		
Melamime type foam	5	12.5	9.7–16.1		
Melamime type foam with vinyl fabric	5	26.0	24.0–28.0		
FR FPU #14	9	27.8	23.3, 33.1		
FR foam; 22.3 kg/m^3	14	26.0	NA		
FR GM-23	13	34.5	31.2, 37.8	15.1	NA
FR GM-27	13	33.1	26.5, 39.7	9.6	6.0, 13.2
NFR FPU #13	10	40.0	NA		
NFR foam; 22.3 kg/m^3	14	40.0	NA		
NFR GM-21	1	38.0	NA	9.6	4.1, 22.1
NFR GM-21	1	49.5	NA	49.5	NA
NFR GM-21	1	40.0	NA	37.5	35.8, 39.3
NFR GM-21	13	43.2	39.8, 46.6	8.3	NA
NFR GM-25	13	37.5	NA	14.5	11.3, 17.7
NFR foam	8	43.2	39.8, 46.6	8.1	6.7, 9.5
NFR upholstered chairs with flexible polyurethane padding foam, a cover fabric, and steel frame; density of foam is 25 kg/m^3	11	35.0	NA		

(*Continued on next page.*)

TABLE A.1 (Continued).

Material	Reference	30 min LC_{50} Value (With 14 day Post-Exposure Observation) $g \cdot m^{-3}$	95% Confidence Limits $g \cdot m^{-3}$	30 min IC_{50} Value (With 14 day Post-Exposure Observation) $g \cdot m^{-3}$	95% Confidence Limits $g \cdot m^{-3}$
Polyurethane, Rigid					
NFR foam, 25 mm thick, 96 kg/m^3	15	11.0	10.0–13.0		
FR GM-31	13	14.2	NA	6.7	5.5, 7.9
No details provided	5	22.0	21.6, 22.2		
NFR GM-30	1	38.4	NA		
NFR GM-30	1	13.3	12.2, 14.5		
NFR GM-30	1	11.3	7.6, 16.8	8.9	5.1, 15.6
NFR isocyanurate; GM-41	13	11.4	9.3, 13.5	4.1	3.3, 4.9
NFR isocyanurate; GM-43	13	5.8	5.0, 6.6	2.8	2.3, 3.3
NFR GM-29	13	11.2	9.3, 13.1	5.2	3.4, 7.0
NFR GM-35	13	12.1	8.0, 16.2	5.8	4.5, 7.1
NFR GM-37	13	10.9	9.4, 12.4	3.9	2.9, 4.9
NFR GM-39; sprayed	13	16.6	NA	4.8	2.7, 6.9
Polyvinyl chloride, Plasticized					
Plasticized PVC	16	26.0	NA	7.1	4.9, 9.3
CPVC water pipe	3	16.0	NA		
Commercial rigid 1/2″ PVC conduit	3	29.5	NA		
Polyvinyl chloride, Resin					
Sheets, 12.7 mm thick, 1,490 kg/m^3 density	15	20.0	NA		
No details provided	5	26.0	21.0, 31.0		
Sheets	15	25.0	NA		
Pellets	1	15.0	10.0, 19.0	6.0	4.0, 8.9
Pellets	1	17.3	14.8, 20.2	18.5	17.5, 19.8
Pellets (w/zinc ferrocyanide)	1	9.4	7.2, 12.3	11.8	10.1, 15.1
Pellets (w/zinc ferrocyanide)	1	14.3	12.5, 16.3	13.2	11.3, 15.4
Pellets (w/zinc ferrocyanide)	1	15.0	15.0, 15.5		
Tempered Hardwood					
No details provided	17	58.1	40.8–67		
Urea formaldehyde					
Foam	8	11.2	10.4, 12.0	7.4	6.5, 8.3
Wires and Cable Products					
Commercial PTFE coaxial wire (product)	3	9.6	NA		
Commercial THHN wire with nylon-PVC jacket (product)	3	55.0	NA		
NFR wire insulation made of cross-linked EVA copolymer (product)	11	51.0	NA		

(*Continued on next page.*)

TABLE A.1 (Continued).

Material	Reference	30 min LC_{50} Value (With 14 day Post-Exposure Observation) $g \cdot m^{-3}$	95% Confidence Limits $g \cdot m^{-3}$	30 min IC_{50} Value (With 14 day Post-Exposure Observation) $g \cdot m^{-3}$	95% Confidence Limits $g \cdot m^{-3}$
Wood					
Douglas fir	15	150	NA		
Douglas fir	1	35.8	28.6, 44.9	20.0	16.4, 24.3
Douglas fir	1	45.3	39.0, 52.7	18.4	14.0, 24.1
Douglas fir	1	24.0	19.0, 29.0	14.5	10.0, 19.1
Douglas fir	1	29.6	22.7, 38.6		
Douglas fir	1	38.4	35.2, 41.9	14.0	10.5, 18.6
Douglas fir	1	41.0	33.0, 50.9	21.8	15.5, 30.7
Douglas fir	1	39.8	38.2, 41.4	23.5	23.0, 24.0
Douglas fir	1	29.8	23.9, 37.1	20.9	NA
Douglas fir	18	106.5	NA		
Douglas fir	18	69.4	NA		
Douglas fir	13			13.3	10.1, 16.5
Red oak	1	45.0	39.9, 50.8	40.6	NA
Red oak	1	56.8	51.6, 62.5	34.8	31.1, 39.0
Red oak	1	60.0	56.6, 63.6		

NA: Values not available in literature.

TABLE A.2
LC_{50} Values for Ventilation-limited Flaming Combustion

Material	Reference	30 min LC_{50} Value (With 14 day Post-Exposure Observation) $g \cdot m^{-3}$	95% Confidence Limits $g \cdot m^{-3}$
Fabric, vinyl	5	19.0	17.7, 20.9
Polyester, Resin	11	40.5	NA
Polyphenylene oxide	11	24.0	NA
Polyvinyl chloride, Plasticized	5	16.0	13.7, 17.5
Polyurethane, Flexible			
No details provided	5	18.0	16.9, 18.4
FR upholstered chairs with flexible polyurethane padding foam, a cover fabric, and steel frame	11	23.0	NA
Melamime type foam	5	8.0	7.2, 10.4
Melamime type foam with vinyl fabric	5	15.0	14.7, 16.2
Polyurethane, Rigid			
No details provided	5	14.0	14.3, 14.5
Wires and Cable Products			
FR wire insulation made of cross-linked EVA copolymer (product)	15	25.0	NA

NA: Values not available in literature.

TABLE A.3
LC_{50} and IC_{50} Values for Oxidative Pyrolysis

Material	Reference	30 min LC_{50} Value (With 14 day Post-Exposure Observation) $g \cdot m^{-3}$	95% Confidence Limits $g \cdot m^{-3}$	30 min IC_{50} Value (With 14 day Post-Exposure Observation) $g \cdot m^{-3}$	95% Confidence Limits $g \cdot m^{-3}$
Acrylonitrile butadiene styrene					
Pellets	1	19.3	13.9, 26.9	21.0	15.1, 25.2
Pellets	1	38.4	NA	5.8	2.8, 8.4
Pellets	1	33.3	23.1, 47.9	23.0	18.5, 27.5
Pellets	1	30.9	21.2, 45.0		
Bismaleimide					
No details provided	2	41.9	38.8, 45.1	20.1	16.3, 24.0
Carpet foam (with nylon)	3	68.0	NA		
Carpet jute backing (with nylon)	3	90.0	NA		
Chlorofluoropolymers					
Ethylene-chlorotrifluoroethylene (39.4% fluorine; 24.6% chlorine)	4	20.1	18.4, 22.0		
Blown ethylene-chlorotrifluoroethylene (39.4% fluorine; 24.6% chlorine)	4	28.9	20.3, 41.1		
Epoxy					
No details provided	2	11.0	8.9, 13.1	4.1	3.3, 5.0
Fluoropolymers (data set A)					
Ethylene-tetrafluoroethylene-59.4% fluorine	4	3.3	NA		
Polyvinylidene fluoride-59.4% fluorine	4	24.3	19.1, 31.2		
Tedlar–thin opaque	2	34.0	NA	18.8	12.0, 25.6
Fluorenone-polyester-thin clear film	2	17.2	NA	10.9	NA
Fluoropolymers (data set B)					
Fluorinated ethylene/fluorinated propylene – 76% fluorine	4	0.05	NA		
Polytetrafluoroethylene-powder	6	0.045	0.02, 0.12		
Polytetrafluoroethylene-powder	1	0.125	0.08, 0.19	0.68	0.31, 1.49
Polytetrafluoroethylene-powder	1	0.235	0.05, 1.20		
Modacrylic					
Knit fabric	1	5.2	4.9, 5.5	2.7	2.1, 3.4
Knit fabric	1	7.8	6.3, 9.7		
Knit fabric	1	7.0	5.0, 9.7	3.0	2.0, 4.0
Knit fabric	1	5.3	4.0, 7.1	3.2	2.8, 3.7

(*Continued on next page.*)

TABLE A.3 (Continued).

Material	Reference	30 min LC_{50} Value (With 14 day Post-Exposure Observation) $g \cdot m^{-3}$	95% Confidence Limits $g \cdot m^{-3}$	30 min IC_{50} Value (With 14 day Post-Exposure Observation) $g \cdot m^{-3}$	95% Confidence Limits $g \cdot m^{-3}$
Phenolic resin					
Rigid foam; GM-57	8	5.9	4.8, 7.0	1.5	NA
Polyester					
Fabric	10	5.0	NA		
NFR polyester upholstery fabric	10	39.0	38.4, 39.5		
NFR polyester upholstery fabric with NFR FPU	10	47.5	43.0, 52.5		
Polyester fabric/PU foam composite	10	30.0	NA		
Polyethylene					
NFR semi-flexible polyethylene foam	12	5.3	4.4, 6.6		
FR semi-flexible plastic polyethylene foam	12	6.1	5.3, 6.9		
Polyphenylsulfone					
Pellets	1	18.7	15.2, 23.0	8.8	6.8, 11.2
Pellets	1	32.2	27.7, 37.5	19.0	10.2, 35.3
Pellets	1	10.7	8.4, 13.6	7.0	NA
Pellets	1	9.5	9.1, 10.1		
Polystyrene					
NFR rigid foam; GM-51	1	50.0	NA	50.0	NA
FR foam; GM-49; expanded	13	40.0	NA	30.9	26.2, 35.6
NFR rigid foam; GM-51	1	46.2	NA		
NFR rigid foam; GM-51	1	40.0	NA	40.0	NA
NFR rigid foam; GM-51; extruded	13	40.0	NA	40.0	NA
NFR foam; GM-47; expanded	13	40.0	NA	27.2	23.0, 31.4
Polyurethane, Flexible					
NFR FPU #12	9	37.8	36.6, 39.0		
NFR FPU #13	10	37.0	29.8, 46.0		
NFR foam; 22.3 kg/m^3	14	33.0	NA		
NFR GM-21	1	27.8	16.9, 45.8	7.0	3.6, 13.6
NFR GM-21	1	40.0	31.2, 51.3	20.2	8.6, 47.3
NFR GM-21	1	26.6	15.3, 46.2	53.0	
FR FPU #11	9	17.2	13.2, 22.4		
FR FPU #14	9	40.0	NA		
FR foam; 22.3 kg/m^3	14	23.0	NA		
FR GM-23	13	12.6	10.5, 14.7	7.3	5.5, 9.1
FR GM-27	13	30.5	23.1, 37.9	25.2	4.7, 45.7
NFR GM-21	13	13.4	NA	3.2	1.6, 4.8
NFR GM-25	13	36.9	30.9, 42.9	15.1	12.4, 17.8
NFR foam	8	14.3	11.9, 16.7	4.2	3.3, 5.1
NFR GM-21; 2 PCF	3	34.7	NA		

(Continued on next page.)

TABLE A.3 (Continued).

Material	Reference	30 min LC_{50} Value (With 14 day Post-Exposure Observation) $g \cdot m^{-3}$	95% Confidence Limits $g \cdot m^{-3}$	30 min IC_{50} Value (With 14 day Post-Exposure Observation) $g \cdot m^{-3}$	95% Confidence Limits $g \cdot m^{-3}$
Polyurethane, Rigid					
NFR GM-30	1	34.0	NA		
NFR GM-30	1	39.6	NA		
NFR GM-30	1	35.1	NA	29.3	NA
FR GM-31	13	40.0	NA	9.0	6.8, 11.2
NFR isocyanurate; GM-41	13	8.0	7.1, 8.9	3.0	2.7, 3.3
NFR isocyanurate; GM-43	13	5.0	4.6, 5.4	3.4	2.8, 4.0
NFR GM-29	13	40.0	NA	8.9	5.1, 12.7
NFR GM-35	13	36.7	NA	10.8	NA
NFR GM-37	13	36.7	NA	6.8	3.4, 10.2
NFR GM-39; sprayed	13	10.9	9.3, 12.5	4.0	2.4, 5.6
Polyvinyl chloride, Plasticized					
CPVC water pipe	3	9.1	NA		
Plasticized PVC	16	21.0	18.8, 23.2	3.4	2.8, 4.0
Commercial rigid 1/2″ PVC conduit	3	37.0	NA		
Polyvinyl chloride, Resin					
Pellets	1	16.0	14.0, 19.0	9.4	NA
Pellets	1	20.0	14.7, 27.2	30.0	NA
Pellets (w/zinc ferrocyanide)	1	7.6	5.5, 10.5	5.4	5.1, 10.1
Pellets (w/zinc ferrocyanide)	1	13.3	11.5, 15.4	11.7	10.3, 13.2
Pellets (w/zinc ferrocyanide)	1	11.3	8.5, 14.9		
Strandboard					
Oriented Strandboard	18	47.0	37.7, 57.3		
Tempered Hardwood					
No details provided	17	86.5	79.4, 93		
Urea formaldehyde					
Foam	8	1.2	1.1, 1.3	0.7	0.6, 0.8
Wires and Cable Products					
Commercial PTFE coaxial wire (product)	3	12.5	NA		
Commercial THHN wire with nylon-PVC jacket (product)	3	100.0	NA		
Wood					
Douglas fir	1	16.7	14.5, 19.3	15.0	12.3, 18.2
Douglas fir	1	27.6	22.9, 33.3	10.1	7.2, 14.2
Douglas fir	1	26.8	21.3, 33.7	5.6	3.1, 9.9
Douglas fir	1	24.0	19.9, 29.0	22.0	13.2, 36.7
Douglas fir	1	25.9	20.0, 33.5	10.1	7.2, 14.2
Douglas fir	1	20.4	16.4, 25.3	18.3	14.5, 23.0
Douglas fir	1	22.8	20.2, 25.8	13.5	12.0, 14.2

(*Continued on next page.*)

TABLE A.3 (Continued).

Material	Reference	30 min LC_{50} Value (With 14 day Post-Exposure Observation) $g \cdot m^{-3}$	95% Confidence Limits $g \cdot m^{-3}$	30 min IC_{50} Value (With 14 day Post-Exposure Observation) $g \cdot m^{-3}$	95% Confidence Limits $g \cdot m^{-3}$
Douglas fir	1	18.5	17.3, 19.8	14.7	13.3, 16.2
Douglas fir	18	100.8	NA		
Douglas fir	18	64.6	60.6, 77.1		
Douglas fir	13	14.6	8.1, 21.1	4.8	3.8, 5.8
Red oak	1	25.0	18.7, 35.5	25.0	NA
Red oak	1	30.3	26.0, 35.4	23.0	NA
Red oak	1	35.0	24.5, 50.1	24.1	NA

NA: Values not available in literature.

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