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prices. In this analysis, the potential impacts of the expanded use of plastic pipe must always be considered in comparison with impacts traceable to the continued use of metal and other currently approved pipe materials that might be displaced by plastic pipe under the proposed code changes. Furthermore, the narrow action of approving limited new uses of plastic plumbing pipe must be seen in the broader context of plastic pipe and metal pipe manufacture and use in general.

The proposed action technically covers only piping used in dwellings and other residential structures such as hotels and motels; it does not affect the piping allowed in public water distribution and wastewater collection systems, mobile homes and recreational vehicles, or commercial and industrial applications. Nor does it affect uses of plastic conduit for electrical wiring applications or any other applications of plastic tubing. However, action by the DHCD to allow plastic pipe for residential applications also may stimulate use in commercial buildings, which are covered by the UPC. Specifically, the proposed action concerns cold and hot potable-water (PW) supply lines from the water meter to the plumbing fixtures, and drain, waste, and vent (DWV) lines from the fixtures to the local sewer line, septic tank, or cesspool.

Five types of plastic have been used or are proposed for residential use in California in water supply and DWV applications: acrylonitrile-butadiene-styrene (ABS), polybutylene (PB), polyethylene (PE), polyvinyl chloride (PVC), and chlorinated polyvinyl chloride (CPVC). PE, a relatively flexible pipe often sold in black coils, is currently allowed by the state code only for cold water supply outside a building, and no expanded use is proposed. At the opposite extreme, neither PB, another flexible black polyolefin pipe, nor CPVC, a rigid, usually gray or tan pipe, has been allowed by the state code previously. Both types of plastic are proposed for use in exterior and interior hot and cold water supply but not in exposed locations in buildings that are of fire-rated construction. (PB is specifically named in the 1982 UPC; CPVC would fall in the "other approved materials" local option.) In addition, CPVC is proposed for DWV applications outside buildings, inside buildings that are not fire-rated, and inside fire-resistive construction in fire-rated buildings. ABS and PVC are the most commonly used materials in plastic pipe today: ABS, usually black, is currently allowed for DWV applications in all but fire-rated buildings. The new code would allow ABS for DWV use in fire-resistive construction in fire-rated buildings, but would not permit its use for water supply. PVC, the white pipe used extensively in sprinkler systems, is currently allowed for cold water supply outside buildings and for DWV applications except in fire-rated construction. As in the case of ABS, the proposed changes would allow PVC use in fire-resistive construction in fire-rated buildings. Table II-1 summarizes the existing and proposed applications of plastic pipe; Exhibit II-1 shows the detailed changes in the UPC that are proposed for the state code.

Strictly speaking, changing the state plumbing code provides only the potential for environmental impacts. Before such impacts are realized:

- The California Building Standards Commission must ratify DHCD's action.
- Local jurisdictions must adopt or amend the provisions of the code, as required by Section 17958 of the Health and Safety Code, State Housing Law.
- Manufacturers must decide to manufacture and market in California the types of plastic pipe newly approved.
- Plumbing contractors or homeowners must decide that the newly approved types of plastic piping are preferable to existing metal or plastic piping for selected applications.
- Actual manufacture, installation, and use must occur.

Figure II-1 shows the flow of decisions required for expanded use of plastic pipe.

No one can predict with complete accuracy whether and to what extent these events will occur. Most communities will adopt the state code routinely, but a community may elect to forbid some or all of the expanded uses, or may have already permitted some of the expanded uses in amending previous versions of the code. Furthermore, some of the expanded uses may

Table II-1

PLASTIC PIPE USE MATRIX

Application	ABS	PB	PE	PVC	CPVC*
Inside a building					
Not fire-rated					
Cold water		New+			New
Hot water	Pres#	New			New
Drain, waste, vent				Pres	New
Fire-rated**					
Cold water		New			New
Hot water		New			New
Drain, waste, vent	New			New	New
Outside a building					
Cold water		New	Pres	Pres	New
Hot water	Pres	New			New
Drain, waste, vent				Pres	New

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*CPVC is not mentioned by name in the UPC and would be approved only under the "other approved materials" local option.

+New: Proposed new approved use.

#Pres: Presently approved use.

**Within fire-resistive construction; no plastic pipe is approved for exposed locations.

Exhibit II-1

PROPOSED CODE CHANGES*

Section 401 - Materials (from Chapter 4, Drainage System, p. 37 of UPC)

(a) Drainage pipe shall be cast iron, galvanized steel, galvanized wrought iron, lead, copper, brass, ABS, PVC or other approved materials having a smooth and uniform bore, except: 1. That no galvanized wrought iron or galvanized steel pipe shall be used underground and shall be kept at least six (6) inches (152.4 mm) above ground. 2. ABS or PVC DWV piping installations shall be limited to those structures where combustible construction is allowed.+ [residential construction, not more than two (2) stories in height.]

(b) Drainage fittings shall be of cast iron, malleable iron, lead, brass, copper, ABS, PVC or other approved materials having a smooth interior waterway of the same diameter as the piping served and all such fittings shall conform to the type of pipe used.

1. Fittings on screwed pipe shall be the recessed drainage type. Burred ends shall be reamed to the full bore of the pipe.

2. The threads of drainage fittings shall be tapped so as to allow one fourth (1/4) inch per foot (20.9 mm/m) grade.

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* Underlines indicate additions to the 1979 UPC and [brackets] indicate deletions to the 1979 UPC to produce the 1982 UPC.

\+ DHCD is proposing to allow ABS, PVC, and CPVC DWV piping in fire-resistive construction.

Exhibit II-1 (Continued)

Section 503 - Materials (from Chapter 5, Vents and Venting, p. 45 of UPC)

(a) Vent pipe shall be cast iron, galvanized steel, galvanized wrought iron, lead, copper, brass, ABS, PVC or other approved materials; except:

1. That no galvanized wrought iron or galvanized steel pipe shall be used underground and shall be least six (6) inches (152.4 mm) above ground.
2. ABS or PVC DWV piping installations shall be limited to those structures where combustible construction is allowed. [residential construction, not more than two (2) stories in height.]

(b) Vent fittings shall be cast iron, galvanized malleable iron or galvanized steel, lead, copper, brass, ABS, PVC, or other approved materials, except that no galvanized malleable iron or galvanized steel fittings shall be used underground and shall be kept at least six (6) inches (152.4 mm) above ground.

(c) Changes in direction of vent piping shall be made by the appropriate use of approved fittings and no such pipe shall be strained or bent. Burred ends shall be reamed to the full bore of the pipe.

Exhibit II-1 (Concluded)

Section 1004 - Materials (from Chapter 10, Water distribution, p. 75 of UPC)

(a) Water pipe and fittings shall be of brass, copper, cast iron, galvanized malleable iron, galvanized wrought iron, galvanized steel, lead or other approved materials. Asbestos-cement, PB, PE, or PVC water pipe manufactured to recognized standards may be used for cold water distribution systems outside a building. PB water pipe and tubing may be used for hot and cold water distribution systems within a building. All materials used in the water supply system, except valves and similar devices shall be of a like material, except where otherwise approved by the Administrative Authority.

(b) Cast iron fittings up to and including two (2) inches (50.8 mm) in size, when used in connection with potable water piping shall be galvanized.

(c) All malleable iron water fittings shall be galvanized.

(d) Piping and tubing which has previously been used for any purpose other than for potable water systems shall not be used.

(e) Approved plastic materials may be used in water service piping provided that where metal water service piping is used for electrical grounding purposes then replacement piping thereof shall be of like materials.

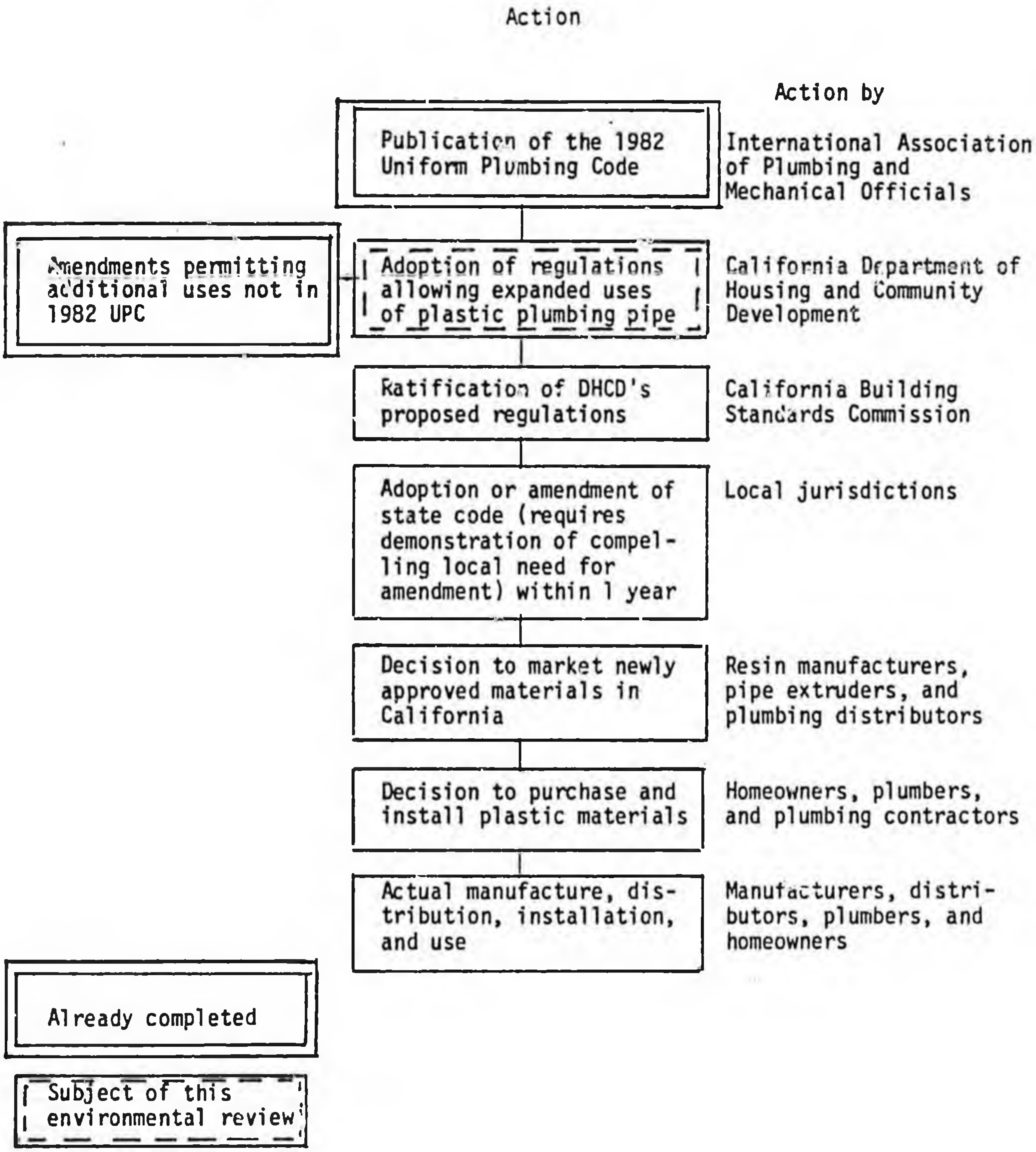

FIGURE II-1 DECISIONS LEADING TO EXPANDED USE OF PLASTIC PLUMBING PIPE already be permitted in the locally adopted versions of other codes, such as the Uniform Building Code. Because manufacturers seek profits and believe that plastics are competitive, they are highly likely to make them available. Because the total cost of installation (labor and materials) is generally agreed to be less for plastic pipe than for metal pipe, plastic pipe is also likely to be in demand. However, complete replacement of metal by plastic piping is unlikely because of concerns about durability, special installation conditions, the need to match materials in replacing or repairing old systems (e.g., to retain an electrical ground through metal pipe), or simple personal preference. Moreover, the amounts of plastic or metal pipe installed under the proposed new code will depend strongly on the pace of new construction and (less so) on replacement rates. Lower plumbing prices might stimulate overall construction rates as well. Looking at the plastics alone, PB and CPVC (if it were less expensive) could make inroads in the markets for PE and PVC in cold water supply applications, and CPVC could compete, although at a cost disadvantage, with ABS and PVC for DWV in non-fire-rated construction.

Consequently, the description of the proposed "project" must to some extent be hypothetical, a scenario rather than a prediction. The projections and assumptions presented below are thought to be reasonable, but the true outcomes could be quite different in many cases. Where conclusions about the significance of environmental impacts would depend markedly on the level of pipe use or the frequency of external events (fires, earthquakes, and so on), a range of projections or assumptions has been considered.

B. Projected Changes in Pipe Use

The magnitude and significance of the impacts likely to occur will depend on the changes in the level of use of plastic and conventional plumbing materials precipitated by state adoption of the proposed regulations allowing expanded uses of plastic plumbing pipe. These comparative use levels will in turn depend on the number of local jurisdictions that adopt the plastic pipe amendments to the state plumbing code, the willingness of contractors and consumers to use the various plastics in the newly permitted applications, and the willingness of suppliers to respond to the consumer demand by producing and marketing the newly approved materials.

Local jurisdictions must either adopt or amend the state code within 1 year of its adoption by the state. Jurisdictions that fail to act on the state code by the end of the year adopt it by default. Jurisdictions wishing to amend the state code must demonstrate a compelling local need for the amendment.

For discussion, we assume that final approval for the new uses will be given by DHCD in 1984 and will be adopted by local jurisdictions by early 1985. Use of plastic pipe in the new applications would begin with local adoption of the code changes. The nature and magnitude of impacts resulting from such use in 1985 will be representative of impacts that would occur in all subsequent years.

In practice, some jurisdictions have amended the state code without showing a compelling need, e.g., Hayward's ban on plastic DWV. In general, however, local jurisdictions to date have tended to adopt those portions of the state code allowing use of plastics in specific applications, as evidenced by the widespread local adoption of state regulations allowing the use of ABS and PVC for DWV. Some jurisdictions also have allowed practices not permitted by the state code; e.g., some unincorporated areas of Los Angeles County permit CPVC to be used for water supply, and at least three major metropolitan areas in the state permit the use of PB. Given the apparent local tendency to allow the use of plastics, we assume that 90% of the local jurisdictions in the state, including all major metropolitan areas, will adopt--directly or by default--the state regulations allowing expanded uses of plastic plumbing pipe.

A consumer's decision to purchase and use the newly approved plastic pipes will be based on the price, performance characteristics, and availability of these plastics compared with currently approved plumbing materials. We assume that state and local approval of expanded uses of plastic pipe will allay any concerns regarding the health and environmental effects of these new uses that may be aroused in consumers during the regulatory decisionmaking process. We also assume that producers (i.e., resin manufacturers, pipe extruders, and plumbing materials distributors) will respond to any consumer demand for the newly approved plastic plumbing, materials, so that these materials will be readily available for purchase and use. Therefore, a consumer's decision to use the newly approved plastic plumbing materials will depend on their price and performance characteristics relative to those of plumbing materials currently in use.

Typical plumbing systems in new residential construction currently consist of a combination of plastic and metal pipe and fittings. Copper or galvanized steel is usually used for the water supply system inside the building, and PVC or copper for water supply outside the building. The principal materials for the DWV system inside and outside the building are ABS, PVC, no-hub cast iron, copper, and occasionally, especially for vents, galvanized steel. In general, two or more dissimilar metals are not used within one system (i.e., water supply system or DWV system) because electrolytic corrosion problems are likely to result. A metal is commonly combined with a plastic within a given system, with the metal typically used inside the building and the plastic used outside the building. Two different plastics are rarely used within a given DWV system because of differences in cost and performance capabilities.

Remodeling jobs and renovations may pose exceptions to these guidelines. For example, a metal may be combined with plastic for DWV inside a building being remodeled, and renovations will often use the original plumbing materials regardless of their cost or performance characteristics.

In selecting the materials for a plumbing system, an individual will typically choose the material that provides the required performance characteristics for the lowest cost. The cost consists of two components:

the cost to purchase the necessary materials that comprise the system and the cost of the time required to install the system. Copper is commonly used for water supply inside new residences and PVC outside the building because these are the least costly (materials and labor costs combined) materials approved for these applications. For the same reason, ABS is typically used for DWV inside and outside new homes at least in California; elsewhere, [illegible] often the material of choice for DWV. No-hub cast iron is, however, [illegible] cost (materials and labor) to ABS and is often used, particularly [illegible] where the local policy regarding use of ABS is unclear or uncertain.

The newly approved plastics will be used instead of these currently approved materials if they are less expensive or offer performance characteristics better suited to the conditions at hand. Materials selection decisions that are not based on these factors under the current code would not be affected by the proposed code changes.

For water supply outside a building, PB or CPVC would probably be used in place of copper. Prices on PB pipe and fittings run 40% to 60% of those for copper materials, and CPVC materials prices are about 10% to 25% greater than copper prices (Adams, 1982; NAHB, 1981). Installation times for PB and CPVC are similar: approximately 80% of the time required to install copper (NAHB, 1981; GCES, 1976-77). CPVC is a rigid plastic capable of handling high temperatures (210°F), and fittings must be special ordered. PB is more flexible, and fittings are readily available. The choice between the two depends on the use to which they will be put. Both, however, generally are less expensive (materials and labor costs combined) than copper.

For cold water supply outside the building, PB is likely to be substituted for PE (a flexible plastic like PB) because PB materials prices are about 25% lower than PE prices and the installation time is comparable.* Use of CPVC in place of PVC (a rigid plastic capable of handling temperatures up to 140°F) is very unlikely because CPVC pipe is at least twice as expensive as PVC pipe (Service Plumbing, 1979; Plumbing Suppliers Survey, 1983).

For the DWV system outside buildings and inside non-fire-rated buildings, CPVC is not likely to replace the currently permitted, widely used, and much cheaper ABS except under special conditions requiring greater heat and chemical resistance than is afforded by ABS. For the DWV system inside fire-rated buildings (within fire-resistive construction), ABS--and, to a limited extent, PVC and CPVC--would probably be used in place of no-hub cast iron in at least 50% of plumbing jobs because ABS pipe and fittings are about half the price of cast iron pipe and fittings and ABS takes less time to install (Plumbing Suppliers Survey, 1983; Service Plumbing, 1979). The only buildings that are fire-rated, however, are residential and commercial structures having three or more stories and structures of any height whose occupants might not be capable of rescuing themselves in the event of a fire (e.g., schools, hospitals, and nursing homes). Therefore, fire-rated buildings account for only a very small portion of total new residential and commercial construction.

When remodeling structures, selections of materials for the waste supply and DWV systems will be similar to those discussed above if the entire system inside or outside the structure is to be replaced. We assume that 25% of remodeling jobs involve replacing the plumbing system. In cases requiring only partial replacement of a plumbing system, replacement materials will probably be the same as the materials originally used in the system. Renovations are likely to use the original plumbing materials in replacing part or all of the plumbing systems.

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* Wholesale prices on 1-inch water supply pipe from Plumbing Suppliers Survey (1983).

To summarize, the proposed changes to the state and presumably local codes expanding the allowable uses of plastic plumbing materials are likely to result in the following substitutions of plumbing materials:

- PB and, to a limited extent CPVC, would replace copper for water supply inside most new residential and commercial construction.
- PB would be used in place of PE for cold water supply outside new buildings.
- The above two substitutions would also apply to 25% of remodeling jobs.
- ABS and, to a limited extent PVC and CPVC, would be used in lieu of no-hub cast iron for DWV inside about 50% of new fire-rated buildings and in 10% of remodeling work on fire-rated buildings.

These substitutions would have the following implications for the use of plastics and metals in California. Let us first assume that by 1984 the housing market recovers from the slow activity characterizing the last 2 years, growing at a rate like that in 1980: about 90,000 single-family and 60,000 multiple-family dwelling units per year (Harwich, 1983). Let us further assume that commercial construction will account for the same proportion of residential construction in 1984 as it did in 1980, which would amount to about 55,000 commercial units. Last, let us assume that 100% of the new single-family dwelling units, 75% of the new multiple-family units, and 50% of the new commercial establishments are of non-fire-rated construction.

A typical moderately large single-family residence may require about 250 to 300 feet of DWV pipe, typically 1-1/2 to 3 inches in diameter, and about 300 to 400 feet of water supply pipe, typically 1/2 to 1 inch in diameter. For subsequent calculations, we assume that the schedules shown in Tables II-2 and II-3 are typical. The average dwelling may require less, and apartments much less per unit. Table II-4 converts the schedules to weights of materials.

Table II-2

DWV SYSTEM: CURRENT CODE

Materials: ABS	Size	Quantity	Wholesale Price
Comb Wye	3"	2	$6.50
Wye	3"	1	1.75
Wye	2"	1	1.25
San Tee	3"	1	1.68
San Tee	2"	4	7.20
San Tee	2x1 1/2"	5	7.15
San Tee	2x1 1/2x2"	1	1.52
San Tee	2x1 1/2x1 1/2"	2	2.86
San Tee	1 1/2"	1	1.30
Upright Wye	3"	1	2.25
1/4 Bend L.S.	3"	2	3.26
1/4 Bend L.S.	2"	7	5.60
1/4 Bend L.S.	1 1/2"	4	1.72
1/4 Bend M.S.	2"	8	3.68
1/4 Bend M.S.	1 1/2"	6	2.40
1/8 Bend	3"	1	1.08
1/8 Bend	2"	5	1.50
1/8 Bend	1 1/2"	2	0.74
C.O. Adaptor	2"	2	0.76
C.O. Plugs	2"	1	0.24
C.O. Plugs	1 1/2"	1	0.20
1/4 Bend H.O.	3 x 2"	2	6.56
Double Fixtures	2 x 1 1/2"	2	5.72
Closet Bends	4 x 3"	3	8.76
Closet Flngs	4"	3	8.61
Couplings	3"	5	2.85
Couplings	2"	8	1.92
Couplings	1 1/2"	8	1.44
D.S. Trap	2"	1	1.67
Tub Trap	1 1/2"	2	1.84
Pipe	3"	71'	84.49
Pipe	2"	115'	65.55
Pipe	1 1/2"	92'	39.56
Pipe	4"	60'	104.40
Subtotal			387.99
Sales tax (@6%)			23.28
TOTAL			$411.27

Source: Plumbing Suppliers Survey (1983).

Table II-3

WATER SUPPLY SYSTEM: CURRENT CODE

Materials: ABS	Size	Quantity	Wholesale Price
Pipe (Type M Copper)	1/2"	165'	$51.15
Pipe (Type M Copper)	3/4"	134'	65.66
Solder (50/50)	lb.	2 lbs.	11.00
Flux	oz.	6 oz.	2.75
Elbows			
45° Ftg x C	1/2"	2	1.28
90° C x C	1/2"	39	3.90
90° Ftg x C	1/2"	4	2.56
Drop Ear C x FIP	1/2"	4	2.76
45° Ftg x C	3/4"	1	0.84
90° C x C	3/4"	26	5.98
Tees			
C x C x C	1/2"	3	0.54
C x C x C	3/4"	2	0.46
C x C x C, reduce on run	3/4"	12	4.92
C x C Couplings	1/2"	3	0.30
Drive Straps (J-hooks)		36	14.11
Pipe (Schedule 40 PVC)	1"	60'	24.60
Subtotal			192.81
Sales tax (@6%)			11.57
TOTAL			$204.38

Source: Plumbing Suppliers Survey (1983).

Table II-4

TYPICAL WEIGHTS OF PIPE AND FITTINGS FOR A MODERATELY LARGE HOUSE

DWV Materials

Size	Lineal Ft	Pounds of Pipe		
		PVC	ABS	Cast Iron
4 inch*	60	130	90	500
3 inch	70	105	70	420
2 inch	115	90	70	400
1-1/2 inch	90	45	30	225
Fittings+		55	40	230
Total		425	300	1,775

PW Materials

Size	Lineal Ft	Pounds of Pipe			
		PB	CPVC	Copper	Galv Steel
1 inch#	60	8.2	12.0	30	96
3/4 inch	135	11.0	18.2	40	162
1/2 inch	165	7.8	13.2	35	148
Fittings+		4.0	6.5	15	60
Total		31.0	49.9	120	466

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* Building sewer line.

\+ Weight estimated at about 15% of pipe weight.

\# Water service line.

If the newly permitted plastics are substituted for copper or other metals for water supply inside and for currently allowed plastics for water supply outside new non-fire-rated single-family dwelling units, use of newly approved plastics per dwelling unit would increase by about 33 pounds, replacing 8 pounds of currently approved plastic (PE) and 90 pounds of metal per dwelling unit.* Assuming that multiple-family dwelling units use about half the amount of pipe and fittings used in a single-family unit, each new non-fire-rated multifamily unit would use about 13 pounds of newly approved plastic in place of 4 pounds of PE and 45 pounds of metal. Let us assume that non-fire-rated commercial units would use roughly the same amount of pipe and fittings as single-family units. Then the proposed code change would result in a total increase of 3.5 million pounds in use of plastic, a transfer of 1.2 million pounds in use of one plastic to use of another, and a decrease of 12.6 million pounds in use of metal for non-fire-rated buildings in California.

In new fire-rated single-family dwelling units, substitution of the newly permitted plastics for metals and other plastics as assumed above would increase the use of newly approved plastics per dwelling unit by 230 pounds, shift 8 pounds of currently approved plastic to newly permitted plastic, and decrease metal use by 1,325 pounds.+ Using the same assumptions regarding use of pipe and fittings in multifamily and commercial units, the proposed code change would result in a total increase of 8 million pounds in use of newly approved plastics, a shift of 0.3 million pounds in use of one plastic to another, and a decrease of 46.4 million pounds in use of metal in fire-rated buildings in California.

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* Pipe use per 2-1/2 bath dwelling unit from NAHB (March 1981). Weight of plastic based on PB data from Shell (1983). Weight of metal based on data for Type M copper from "Energy Costs Versus Installed Costs of Piping," (DHCD, 1979)

\+ Pipe use per 2-1/2 bath dwelling unit for DWV. Weight of plastic for DWV based on ABS, weight of metal based on weight of cast iron. Data from "Energy Costs Versus Installed Costs of Piping," (DHCD, 1979).

To summarize, if the proposed code change is adopted by 90% of the local jurisdictions in the state and these jurisdictions account for 90% of construction activity in California, it could result in a total annual increase of 10.4 million pounds in use of the newly approved plastics, a transfer of 1.4 million pounds from use of currently approved plstics to newly approved plastics, and a decrease of 53.1 million pounds in the use of metals in fire-rated and non-fire-rated construction in California. These figures may be overestimated because the new construction levels assume economic recovery of the housing market by 1984, and because some of the proposed new plastics are already allowed and used in many local jurisdictions. These factors are somewhat offset by the exclusion of material substitutions in remodeling jobs from the figures. Because total expenditures on plumbing additions, alterations, and repairs, including expenditures for plumbing fixtures, account for 1% and 3% of the total value of new residential and commercial construction in the state respectively, their exclusion should not significantly affect the substitution figures.[*]

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[*] According to the U.S. Census Construction Reports (April 1981), expenditures on plumbing additions, alterations, and repairs, including expenditures for plumbing fixtures, accounted for 5% of total expenditures on alterations and repairs of residential properties the United States in 1980. Assuming that plumbing expenditues account for a similar proportion of the total value of alterations and additions in California, they amounted to $62,000,000 for residential properties and $104,800,000 for commercial properties in 1932 (Harwich, 1983). Assuming that plumbing fixtures account for 50% of these plumbing expenditures, that 90% of the residential and 50% of the commercial properties are of non-fire-rated construction, and that 25% of the jobs in non-fire-rated structures and 10% of the jobs in fire-rated structures would substitute the newly approved plastics for the currently approved materials, the current total value of the materials substitution would amount to $17,000,000.

C. Growth of Population Living in Dwellings with Plastic Water Pipe

If about 150,000 new units are built per year, and an average of about 2.75 people occupy each unit, then about 400,000 people might move each year into new or replumbed units in California. Suppose that about 75% of the units were in communities that changed their code to permit the new uses of plastic pipe, and that about 80% of those were in fact plumbed with plastic water pipe. Then about 240,000 people might move into homes with new plastic water pipe each year. To account for growth of the population and uncertainties, we assume a round figure of 300,000 per year, or about 8 million by the year 2010. By that time, California's population may grow from less than 24 million in 1980 to over 30 million. Thus, by the early 21st century, over one-quarter of Californians may live in dwellings plumbed with plastic water pipe. Figure II-2 shows a very conceptual chart of the increase in the number of people living in such dwellings.

If any adverse consequences due to plastic pipe (or any reductions in the consequences of metal pipe systems) are to be felt, the rise will tend to parallel the use levels, although possibly displaced in time. For example, if any cancers are caused by the ingestion of leachates, they would not be expected to occur until several years after first exposure to the water from pipes. Even if the rate of cancer initiation were to become significant by 2010, any possible cancer epidemic might not be observed until 2030 or later.

D. Other Major Assumptions

As we discuss in more detail in Section VI on information gaps, probably the most critical assumptions have to do with compliance with installation and worker safety standards. Many potential impacts that would be insignificant if all standards were completely observed could become significant if they were not, both for plastic and for metal pipe systems. The principal compliance questions are:

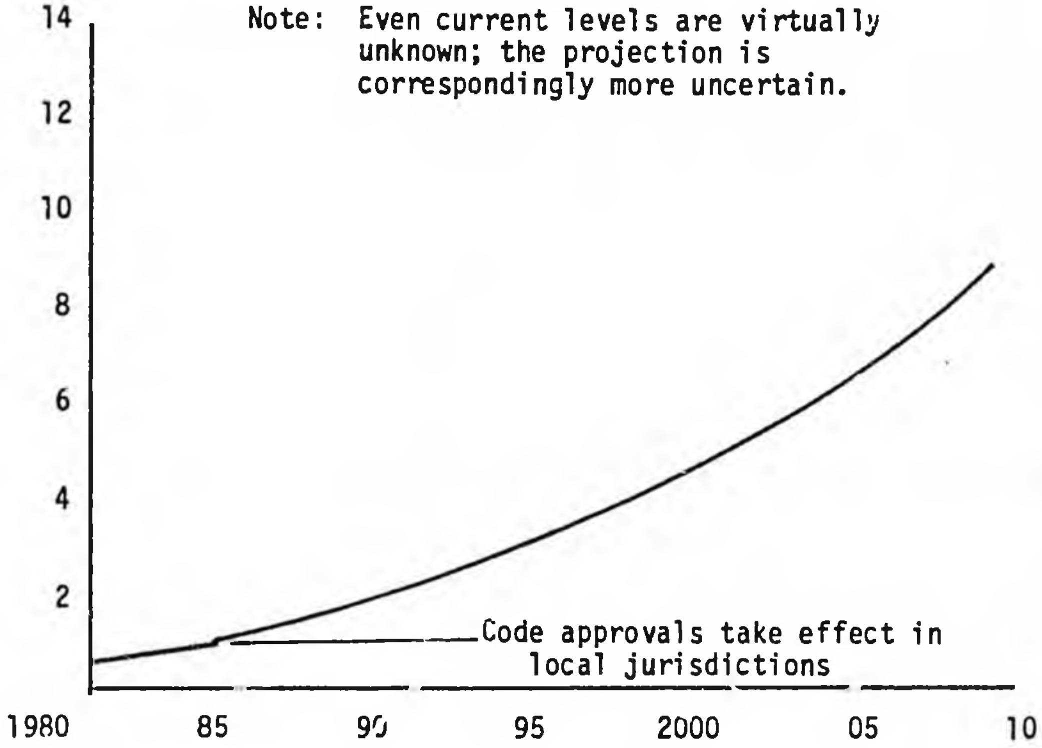


FIGURE II-2 POTENTIAL GROWTH OF POPULATION IN PLASTIC-PLUMBED DWELLINGS

- Will plumbers and do-it-yourself owner-installers follow all recommended precautions, such as use of impermeable gloves, eye protection, and proper ventilation?

- Will they install pipe properly, including cleaning and deburring pipe sections; applying indicated amounts of solvent cement, solder, or pipe joint compound; joining materials in indicated times; and allowing proper suspension for expansion and contraction?

- Will they follow required procedures for installing pipe, especially DWV, in fire-resistive construction and avoid installation in exposed areas of fire-rated construction? Specifically, will they use approved metal sleeves and other devices to reduce the probability of fire spread?

- Will voluntary standards organizations, such as the National Sanitation Foundation, catch the majority of errors in manufacturing pipe and related materials?

- Will building inspectors catch and correct the majority of installation errors?

- Will fire fighters observe proper protective measures when combating fires in which plastics might be involved?

- Will plumbing systems be properly flushed by contractors and homeowners before use for potable water?

- Will building inspectors prohibit use of plastic water supply lines in soils contaminated by materials that could permeate plastic pipe?

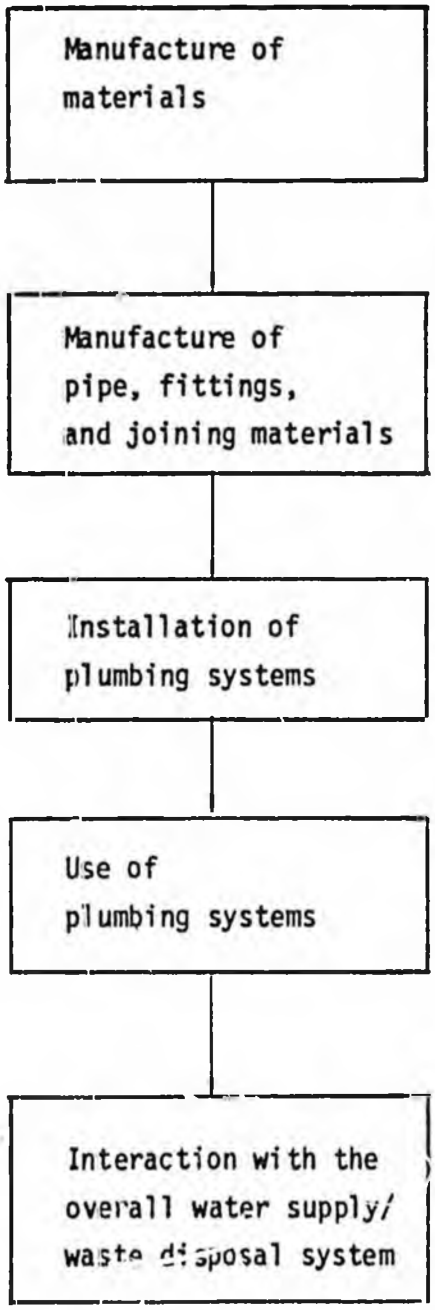
Our analysis attempts to indicate the consequences of deviation from ideal practice but cannot predict the incidence of such deviations.

III ENVIRONMENTAL SETTING: PIPE AND PLUMBING

In a conventional EIR, this section would describe the specific geographic setting for a project in terms of its ecologic resources, air and water quality, degree of development, and so on. In this environmental review document, it is more appropriate to describe the manufacture of pipe and its constituents, the installation of pipe (plumbing), the use of plumbing systems, and the overall water supply/waste disposal system in which they fit in California. The overall structure of our analysis is shown in Figure III-1. With each major activity related to the use of plastic and metal pipes, we have listed the major issue areas that have been raised as criteria for the decision on expanded uses of plastic pipe. The following activities all influence the environmental consequences of the proposed action to allow expanded use of plastic pipe:

- Manufacture of basic materials for pipe systems--for example resins and solvents for use in plastic pipe and pipe joining, or copper and acids for metal systems.
- Manufacture of pipe, fittings, joining materials--including solvent cements, solder, and pipe joint compounds--and attendant materials such as primers for plastic or cutting oils for galvanized steel pipe.
- Installation of pipe and fittings--with attention to plumbing, building, and fire codes--by plumbers and homeowners.
- Use of plumbing systems, including flushing before use, inspection before approval for use, usual system use, and unusual situations such as fire or earthquakes.
- Interaction of plumbing systems with the overall water distribution and waste collection systems, placing residential plumbing in perspective.

Each of these major activities will be described in a separate section below.



Major Issues

Manufacture of materials:
- Constituents and contaminants of pipe system materials
- Air and water quality
- Energy use

Manufacture of pipe, fittings, and joining materials:
- Constituents and contaminants of pipe system materials
- Fiscal impacts/employment
- Standards

Installation of plumbing systems:
- Safety and health of plumbers
- Cost of installation and materials
- Inspection

Use of plumbing systems:
- Public health impacts of potable water from pipe systems
- Fire spread and smoke toxicity
- Water quality and other impacts

Interaction with the overall water supply/ waste disposal system:
- Cumulative impacts
- Water quality

Figure III-1 STRUCTURE OF ANALYSIS AND MAJOR ISSUES

A. Manufacture of Basic Materials

This environmental review requires a comparison of two basic classes of piping systems--traditional metals and more recent (although in some cases decades-old) plastic materials. Table III-1 shows a matrix of the principal system types used in each class by application.

Table III-1

MATRIX OF PIPE SYSTEMS

Use	Metal Pipe	Plastic Pipe
Potable water	Copper/soldered joints	PB and PE*/mechanical joints
	Galvanized iron/threaded joints	CPVC and PVC*/cemented joints
Drain, waste, and vent	Cast iron/mechanical joints	ABS/cemented joints
	Copper+/soldered joints	PVC#/cemented joints

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* Cold water only.

\+ Used mainly in smaller diameters because of cost.

\# CPVC is also proposed but generally is too expensive.

These are by no means the only materials allowed to be used or in use in California, but they are by far the most common. Understanding them will provide all the understanding needed to determine the environmental significance of the proposed code revisions.

The components/materials contributing to the systems listed in Table III-1 are shown in Table III-2.

Table III-2

COMPONENTS AND MATERIALS OF MAJOR SYSTEMS

Metal	Copper	Copper pipe fittings Solder Soldering flux
	Galvanized iron	Galvanized iron pipe and fittings Cutting oils Pipe joint compounds or tape
	Cast iron	Cast iron pipe Fittings and seals Cutting oils
Plastic	PB and PE	Basic polymer Pipe compound additives
	ABS, PVC, and CPVC	Basic polymer Pipe compound additives Primers and solvent cements

The manufacturing processes for the pipe materials are described by system type below.

1. Copper

Copper ore is mined and smelted to yield an ingot stock for later conversion to pipe. Copper makes up the vast majority of the metal (|99.9%); minor constituents include antimony, arsenic, cadmium, lead, manganese, mercury, selenium, tellurium, tin, and zinc, none greater than 10 ppm (Copper Development Association, no date b). So much copper is used in applications other than residential plumbing that the effect of decreased use of copper pipe would lead to negligible environmental improvements. No production or processing of copper occurs in California. The most common solder for joining copper pipe consists of a tin (40% to 50%) and lead (50% to 60%) alloy; a tin (95%) and antimony (5%) solder is also satisfactory and enjoying increasing favor as an environmentally superior alternative in spite of its greater cost. Interest is growing in tin-silver solder for the same reason. Soldering fluxes basically clean the copper thoroughly and prevent oxidation to allow a quick and effective solder joint. They contain a mixture of inorganic salts such as zinc and ammonium chlorides, as well as inactive ingredients such as petrolatum or resin to provide adhesion to the pipe. None of these solder or flux materials is so unique to pipe systems that a change in use would significantly affect the environmental impacts of their manufacture.

2. Galvanized Steel

Steel for the pipe rolling process is produced by the usual mine to blast furnace to Bessemer converter or electric furnace methods, and residential plumbing pipe is a negligible use of steel. Zinc, at least 98% pure but containing arsenic, cadmium, lead, and manganese as trace contaminants, is the galvanizing material used for a thin external and internal layer that protects the pipe from corrosion. Little if any steel or zinc is produced in California for the pipe market. When pipe is cut and threaded during installation, a cutting oil is often used to lubricate the saw and threading die. The oil contains sulfur, animal fats, and sometimes mineral oils, none of which is unique to pipe use.

3. Cast Iron

Cast iron for residential DWV pipe also comes from iron ore mines and iron blast furnaces, and is again a negligible portion of all iron and steel produced. Little if any iron for pipe is produced in California. Cutting oils may also be used for cast iron installations. The pipe is usually joined with "hubless connectors" (see section on installation below), but in now rare instances may be welded or joined with gasket or lead seals. None of these materials is unique to pipe systems, and negligible changes in environmental impacts in manufacturing should occur through reduced demand for cast iron DWV systems.

4. PB and PE

Polybutylene and polyethylene are olefin polymers created by joining ethylene ($CH_2 = CH_2$) and butene-1 ($CH_2 = CH - CH_2 - CH_3$) molecules end-to-end, respectively. Some branching of the polymer chains occurs, but in pipe-grade resins it is not great. The polymerization of these gases takes place in a vessel containing organic solvents such as isobutane or isopentane and catalysts such as chromium oxide, silica, titanium tetrachloride, and alkyl aluminum, minor residues of which can remain in the polymer.

Polymer characteristics such as viscosity, average molecular weight, strength, and so on, are controlled by standards like those of the American Society for Testing and Materials (ASTM). These standards are in general performance standards rather than identity standards; however, they are sufficiently specific, especially for pipe-grade materials, that little variation in chemical content can be tolerated. An estimated 95% or more of the polymers intended for potable-water pipe are also submitted for acceptance to the National Sanitation Foundation (NSF) (McClelland, 1983). PB resin (the polymer itself) is made only by the Shell Chemical Company. PE is made by a variety of manufacturers; however, no change in the code with respect to PE is contemplated, so the only effects would be its possible displacement by other plastics that would "spill over" from indoor to outdoor applications.

Pipe compounds are made by adding various processing aids and other materials to the basic resin, which makes up well over 95% of the final product. The principal additives for the polyolefins PB and PE are antioxidants, which prevent the degradation of the polymer, especially when heated for extrusion; UV stabilizers, which prevent breakdown of the polymer under the ultraviolet wavelengths of sunlight; and pigments--usually carbon black--for coloring the pipe and further UV protection. In PB, carbon black is the only UV stabilizer. Polyolefin pipe compounds also contain tracers, which are metals, metal carbonates, or metal oxides that serve to identify the producer of a specific batch of resin and prevent unauthorized use of reworked material from other producers (McClelland, 1983). Neither PB nor PE is produced in California (SRI, 1982).

Polyethylene is produced for so many different uses that changes in its use for pipe will lead to negligible changes in the environmental impacts of its manufacture. Although about 15% of PE resin goes to the "pipe" market, relatively little of that appears to be for potable water. Polybutylene has much more limited applications than PE, but as pipe material it is used extensively throughout the United States and elsewhere, including in some California communities. About 40-50 million pounds of PB are produced annually, but information on the current level of use for pipe was not found. Increased use in California will lead to only minor changes in environmental impacts at producing facilities. Shell has no producing facilities in California. Because PB and PE are not joined with solvent cements, such materials are not affected.

5. PVC and CPVC

Polyvinyl chloride is produced by end-to-end polymerization of vinyl chloride ($CH_2 = CHCl$) in a water suspension of an oil-soluble catalyst. The resulting structure is regular:
$...CH_2 - CHCl - CH_2 - CHCl....$ CPVC is produced by postchlorination of PVC by introducing gaseous chlorine into the PVC polymer, either in solution or as a suspended solid in water. Formerly, the PVC was "swelled" first with chloroform ($CHCl_3$), but this process is no longer used, at least domestically. The chlorine attaches randomly to the polymer chain, replacing hydrogen, but the final chlorine concent is around 2/3 by weight, implying that there is about one chlorine atom for every carbon atom. The suspension aids for PVC and CPVC are typically cellulose ethers or polyvinyl alcohol, and the polymerization catalysts are typically organic peroxides; both types of material may occur in small residual amounts in the finished polymer. The peroxides will rapidly degrade to other compounds.

Some PVC and CPVC pipe compounds contain other polymers as impact modifiers, because without them the impact strength of the pipe in low temperatures is too limited. However, relatively small amounts (15% total) are needed to perform the function. The chlorinated polymers also need a thermal stabilizer to prevent polymer breakdown and scorching during extrusion, and the usual pigments for color--often titanium dioxide, a white pigment. PVC may also contain a filler (e.g., calcium carbonate) for reasons of production economics. PVC and CPVC need a lubricant for extrusion, often a fatty acid-metal salt or oxidized polyethylene wax.

PVC is used in a great variety of plastic products, many of them heavily plasticized for flexibility. PVC pipe compound, however, is intended to be rigid and is rarely if ever plasticized, because plasticizers severely affect its strength and resistance to sagging. About 30% of the PVC manufactured is used for pipe and fittings of all types. PVC resin is manufactured by at least three manufacturers in California. CPVC is not manufactured in California; B.F. Goodrich is the sole U.S. producer (SRI, 1982; Dunnigan, 1983). One or two foreign firms import CPVC into the United States for use in pipe. As with the polyolefins, over 95% of the CPVC resins sold for potable water pipe are accepted by the NSF (McClelland, 1983). PVC resins intended for potable water would also be so controlled; a significant fraction of the DWV PVCs might not be submitted to NSF, although these would be mainly from firms selling into a narrow local market (McClelland, 1983).

In terms of potential environmental impacts at the manufacturing level, PVC changes would be negligible, whereas CPVC changes would be minor.

PVC and CPVC systems are both joined by solvent cements, frequently preceded by a primer that cleans and presoftens the polymer. The primer is a mixture of relatively pure solvents, while the cement contains solvents and resin or complete pipe compound of the appropriate type. Most of the solvents are commonplace and manufactured widely in the United States, so changes in impacts will be negligible. However, nationwide, PVC cement use accounts for a significant fraction (perhaps 40%) of all tetrahydrofuran made. None of the solvents is manufactured in California (SRI, 1982).

Solvent cements and primers for potable-water PVC and CPVC are also generally submitted to NSF for approval.

6. ABS

ABS is a terpolymer of acrylonitrile ($CH_2 = CH - CN$), butadiene ($CH_2 = CH - CH = CH_2$), and styrene (vinylbenzene). The relative amounts of the materials are variable, but typically about half by weight is styrene, with each of the others at about 25%, implying a 1:1:1 molecular ratio. Blends or graft copolymers of styrene-acrylonitrile and styrene-butadiene polymers may also be present. The final system probably consists of polybutadiene dispersed in a rigid styrene-acrylonitrile copolymer matrix. The polymer is typically produced by suspending the monomers in water with, for example, polyvinyl alcohol with free radical initiators such as benzoyl peroxide. These materials may become residuals in the polymer, but the peroxide should degrade to simpler forms. Pipe demands about 200 million pounds of ABS each year nationally, about a fourth of all ABS produced. Two-thirds (about 140 million pounds) is DWV. Truckload quantities of ABS resin cost around 60 cents per pound for pipe grades, 90 cents for molding grades.

The additives for ABS are similar to those for the other polymers: antioxidants, lubricants, pigments, and fillers. Typically, ABS uses carbon black as a pigment.

At least one firm manufactures ABS in California (Dunnigan, 1983). Since ABS has already extensively penetrated the California DWV market, changes in environmental impacts for manufacturing due to the code changes would be minor.

ABS pipe and fittings are joined with solvent cements. Primers for ABS seem to be rarer than for PVC. The same general solvents are used for ABS as for the chlorinated materials, although ABS is more accepting of lower-quality, cheaper solvents, and reports of a wider variety being used are frequent. Because ABS is not used for potable water in California, it is less likely to have NSF approval than are the PW plastics, and the same is true for the solvents specifically marketed for ABS.

A summary of materials found in various plastic pipe systems appears as Table III-3.

B. Manufacture of Pipe, Fittings, and Associated Materials

Although "pipe" is a generic term for all plumbing, the small pieces that join straight, cylindrical pipe together (couplings), change its direction (elbows), or provide branches (tees and wyes), are known as "fittings," as are special pieces such as traps, valves, and the like. "Fixtures" are sinks, tubs, toilets, and so on; the plumbing is attached to their faucets or drains. Fixtures are not affected by the proposed code change. ASTM and other standards apply to the size and strength of all kinds of pipe; standards of identity and sanitary performance apply only to plastic pipe for potable water and are administered through the NSF.

The manufacturing process used for pipe and fittings depends on both the starting materials and the specifics of the pieces manufactured. Table III-4 gives an overview of the principal manufacturing processes involved.

1. Copper

Copper ingots are heated and the molten copper is drawn through a U-shaped ceramic mold, in which it cools and solidifies into the pipe (normally referred to as tubing). The tubing is drawn upward through sizing rollers, allowing more molten copper to flow into the mold. Some smaller-diameter tubing is made by rolling copper into thin sheets, then bending it into a tube and soldering the seam. Little such tubing is used for plumbing. Copper fittings are made by deforming heavy-gauge tubing to the proper shape. No copper tubing or fittings are made in California (Brown, 1983). The changes in environmental impacts with a reduction in manufacture of copper pipe and fittings would be minor. Producer costs for

Table III-3

COMPONENTS OF PLASTIC PIPE SYSTEMS

Product	Function	ABS	%	PB	%	PE	%	PVC	%	CPVC	%
Pipe and Fittings	Resin (polymer)	Acrylonitrile-butadiene-styrene terpolymer 25-25-50	>96	Poly(butene-1) (polybutylene)	>98	Polyethene (polyethylene)	>95	Polychloroethene (polyvinyl chloride)	>80	Chlorinated PVC (~ 2/3 chlorine by weight)	>80
	Impact modifiers	None		None		None		Chlorinated polyethylene Acrylonitrile-butadiene-styrene Methylmethacrylate-butadiene styrene Alpha-methyl styrene	< 5	Chlorinated polyethylene Acrylonitrile-butadiene-styrene (fittings) methyl-methacrylate-butadiene-styrene-alpha-methyl styrene	< 3 <15
	Stabilizers/ antioxidants	Dilauryl thiodipropionate,4-di-2-methyl-6-t-butyl phenol (Topanol) Naphthyl amines	<0.2 <0.6	Tetrakis (methylene (3,5-di-tert-butyl-4-hydroxy-hydrocinnamate methane) (Irganox 1010)	<0.5	Irganox 1010 Bis (2-methyl-4-hydroxy-5-t butylphenyl)sulfide (Santonox R) 2,6-di-tert-butyl-p-cresol (Ionol)	<0.5	Organotins Organoantimonys Barium carbonate-barium alkyl phenolate Mineral oil (FDA generally recognized as safe)	< 2 <0.4 <1.0 <1.0	Organotins (e.g., dibutyl tin bis (isooctyl thioglycolate)	<3.5
	Lubricants	Acrawax C Magnesium stearate or other fatty acid salts	<3.0 <0.3	None		None		Oxidized polyethylene wax Paraffin wax Calcium stearate	<1.5 <2.0 <2.5	Oxidized polyethylene wax	<1.5
	Pigments/ fillers/UV stabilizers	Titanium dioxide Carbon black Others	<1.0	Titanium dioxide Carbon black Talc	<2.0 <0.5 <2.0	Carbon black Calcium carbonate	<4.5 <3.0	Titanium dioxide Carbon black Others	<2.0 <0.5 <1.0	Titanium dioxide Carbon black Others	<5.0 <0.05 <0.1
	Mold release agent	Silicone oil (fittings) surficial	trace					Silicone oil (fittings) surficial	trace		
Solvent Cement	Solvents	2-butanone (methyl ethyl ketone) Others	~15	None		None		Tetrahydrofuran Cyclohexanone 2-butanone (methyl ethyl ketone) N,N-dimethyl formamide	80-90	Tetrahydrofuran Cyclohexanone 2-butanone (methyl ethyl ketone) N,N-dimethyl formamide	80-90
	Resin/compound	ABS or ABS pipe compound	<15					PVC or PVC pipe compound	<20	CPVC or CPVC pipe compound	<20
	Pigments	Carbon black	<0.5					Titanium dioxide Carbon black Others	<0.5	Titanium dioxide Carbon black Others	<0.5
Primers	Solvents	Toluene as an example	≤100	None		None		Tetrahydrofuran Cyclohexanone 2-butanone (methyl ethyl ketone) N,N-dimethyl formamide	<99.5	Tetrahydrofuran Cyclohexanone 2-butanone (methyl ethyl ketone) N,N-dimethyl formamide	80-90
	Pigments							Titanium dioxide Carbon black Others	<0.5	Titanium dioxide Carbon black Others	<0.5

Sources: McClelland, 1983; SRI estimates.

Table III-4

PIPE AND FITTING MANUFACTURING PROCESSES

	Processes	
	Pipe	Fittings
Metal		
Copper	Drawing	Forming/soldering
Galvanized steel	Rolling/welding Galvanizing	Forming/welding Galvanizing
Cast Iron	Casting	Casting
Plastic	Extrusion	Injection molding

copper pipe are in the vicinity of $1.50 per pound, but markups bring it over $3 at the wholesale level.

2. Galvanized Steel

Steel is rolled flat and then formed into cylinders, welded, and passed through pinch rollers for sizing. Fittings are also made by forming and welding. Both are machine-threaded at this stage. The pipe then goes into a galvanizing plant in which first the rust and mill scale are removed in an acid bath and then the pipe is fluxed in a zinc ammonium chloride solution. Next the pipe is passed through a molten-zinc bath (or electroplated with zinc), then cooled in dilute sodium dichromate. If this is done properly, the zinc forms a very thin continuous coating over the entire pipe or fitting. At present, no firm in California manufactures galvanized steel pipe, but one is considering doing so (Torrance Tube, 1983). Both steel rolling and galvanizing operations are so commonplace that negligible impacts would be expected from a change in the plumbing code. Galvanized steel has a producer cost of around 30 cents per pound of pipe.

3. Cast Iron

Pig iron is remelted in a foundry's cupola furnace and is poured into ceramic (sand) molds to produce cast iron pipe and fixtures. No cast iron pipe is made in California, but it still captures perhaps a minor fraction of the total DWV market, principally for fire-rated construction and replacement applications. Cast iron has the lowest producer costs among the materials used for pipe and fittings--about 20 cents per pound. Since pipe represents a small fraction of all cast iron used, changes in this use would have negligible environmental impacts associated with manufacturing.

4. Plastic

This section is based heavily on descriptions in the Encyclopedia of PVC (NASS, 1976) and on a conversation with staff of R&G Sloane (Blumenkranz, 1983). Polymer resins are mixed with additives--often combined as a "master batch"--to form a pipe compound. The compound may be made and sold by the resin manufacturer, by so-called "special compounders" who buy resin and additives and sell compound to molders, or by the manufacturers of plastic pipe and fittings themselves. It is common for pipe manufacturers to make their own compound, while fitting manufacturers will sometimes buy compound from special compounders or the resin manufacturer. Compounds are in the form of pellets or granules of completely mixed polymer, stabilizer, pigment, lubricant, and so on; after compounding, these components are not ordinarily separate. The compound is solid at ordinary temperatures.

The compound is fed into a screw conveyor and heated so that it softens and coalesces into a viscous fluid; then it is either forced through a screw-extrusion die (Figure III-2) for pipe or injected into molds (Figure III-3) for fittings. The compound will be somewhat different for pipe than for fittings, both because the processing conditions are different and because the fitting must generally have higher impact resistance than the pipe. For some manual release of molds for fittings, a mold release agent--typically a silicone oil--may be used. Only small quantities will be

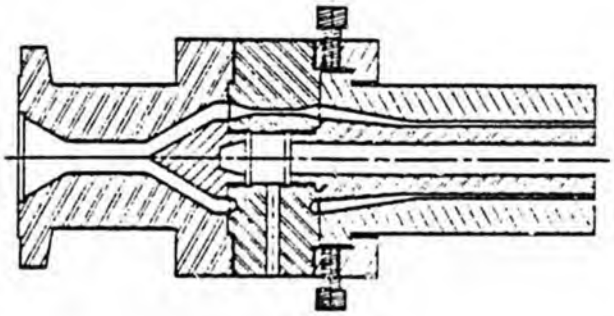


FIGURE III-2 PIPE DIE FOR SINGLE-SCREW EXTRUDER

Source: Nass, 1978

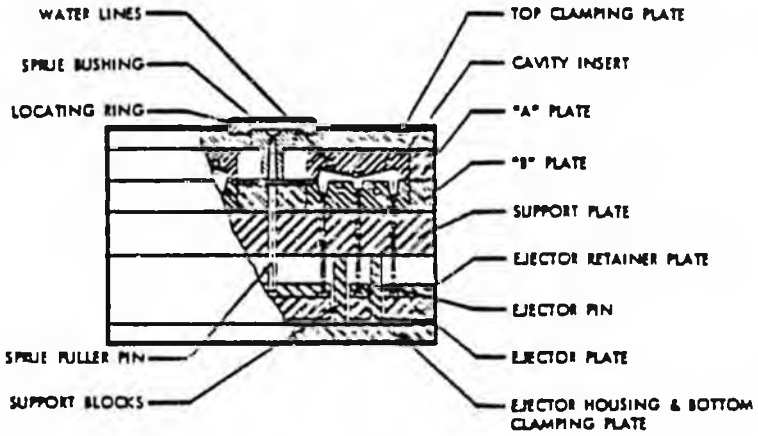
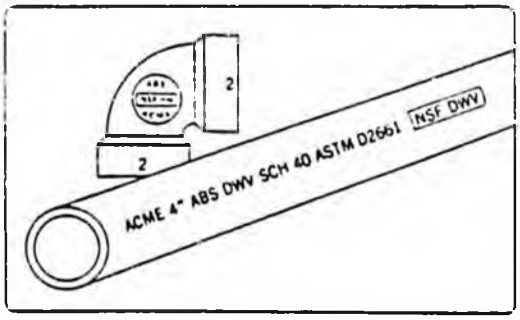


FIGURE III-3 COMPONENT PARTS OF A TYPICAL MOLD

Source: Nass, 1978



Source: McGuiness, 1980

ACME	The name of the manufacturer.
4 in.	Diameter of the pipe.
ABS	Acrylonitrile-Butadiene-Styrene, the material.
DWV	Suitable for drainage waste and vent
SCH 40	Schedule 40. This identifies the wall thickness of the pipe.
ASTM D2661	"Standards Number" assigned by the American Society for Testing Materials.
NSF DWV	Tested by the National Sanitation Foundation Testing Laboratory. The pipe meets or exceeds the current standards for sanitary service.

FIGURE III-4 TYPICAL IDENTIFICATION SYMBOLS ON PLASTIC PIPE used so that they do not interfere with the fusing of the streams of material at the end of the mold. They are not used if unmolding is automated.

Various markings are placed on the pipe or fitting to indicate its intended use and what standards it meets. Figure III-4 shows the marking for a potable-water plastic pipe; it is applied by an inked marking wheel after the pipe has cooled. The labeling for fittings is generally molded in raised lettering on the fitting, but smaller fittings may not be marked. Pipe is bundled and shipped, whereas fittings are boxed and shipped.

Both pipe and fittings of various plastics are made in California. Table III-5 shows a partial list, taken from the NSF list (1982) of firms having NSF authorization for at least some of their products. There are also California firms that make pipe and fittings, especially for DWV applications, that do not seek NSF approval (Gaspar, 1983; Dunnigan, 1983) Little information is available on total plastic pipe production in California; limited evidence (California Manufacturers, 1982) suggests that the total value might be about $50 million annually; at $1 per pound this would mean around 50 million pounds of pipe, much of which would not enter the residential market.

5. Joining Materials

The polyolefin plastic pipes (PB and PE) are joined mechanically or sometimes (PE only) by thermal welding. PVC, CPVC, and ABS all are joined by solvent cements except when they are threaded for connecting to metal systems or for special assemblies. The solvent cements are simply blended from the raw solvents and pipe polymer or pipe compound. Thus, a typical cement will have at least two solvents, less than 20% resin, and small amounts of pigment and stabilizer. They will ordinarily not contain lubricant or filler. The two solvents are necessary to provide both a "fast set" and a "slow cure" behavior for the joint, in which the polymer molecules are loosened and intertwined between the two parts. The joint is frequently described as a "weld," implying that the pieces become

Table III-5

SELECTED COMPANIES MAKING PLASTIC PIPE AND FITTINGS IN CALIFORNIA*

Company	Location(s)	Types	Pipe	Fittings
PW Maclin Co.	City of Industry	PVC		(compound)
American Rahn Corp.	Tracy	PB	X	
Apache Plastic Products	Stockton Santa Ana Lindsay	PVC PE	X X	
Barnes Plastics	Gardena	PVC		X
Carlon	Woodland	PVC	X	
Certain-teed	Cameron Park	PVC	X	
Colby Plastics	Anaheim	PVC	X	
Dura Plastic Products	Beaumont	PVC		X
Extended Plastics Co.	Santa Ana	PVC	X	
Flo-Control Inc.	Burbank	PVC CPVC		X X
Gifford-Hill & Co.	Visalia	PVC	X	X
Hancor	Patterson	PE	X	
Johns Manville	Stockton	PVC	X	X

Table III-5 (Continued)

Company	Location(s)	Types	Pipe	Fittings
PW (concluded)				
Lasco Industries	Anaheim Montebello	PVC CPVC	X	X X
Mirada Enterprises	La Mirada	PVC		X
Orangeburg Industries+	Los Angeles	PE	X	
Pacific Plastics	Orange	PVC	X	
Phillips Driscopipe	Watsonville	PE	X	
R&G Sloane	Sun Valley Bakersfield	PVC CPVC	X X	X X
Spears Mfg. Co.	Sylmar	PVC		X
Wesflex Mfg. Co.	Richmond	PB PE	X X	
Western Plastics Corp.	Downey Union City	PVC	X	
DWV				
Maclin Co.	City of Industry	PVC		(compound)
R&G Sloane	Sun Valley	PVC ABS		X X
Univco Plastics	Pasadena	ABS		X
Cements				
Ameron	Brea	Epoxy	X	

Table III-5 (Concluded)

Company	Location(s)	Types	Pipe	Fittings
Cements (concluded)				
Craig Plastic Products	Vista	PVC	X	
Industrial Polychemical Services	Gardena	PVC	X	X
		CPVC	X	X
		ABS	X	
Permalite Plastics Corp.	Newport Beach	PVC	X	X
		CPVC	X	X
		ABS	X	
R&G Sloane#	Sun Valley	PVC	X	X
		CPVC	X	X
		ABS	X	

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*Companies have NSF approval; not all may be in current production.

+May not manufacture in California.

#Purchase from Industrial Polychemical Services and resell.

Source: NSF, 1982.

essentially one unit. Anecdotal evidence suggests, however, that joints are sometimes imperfect, perhaps through inadequate preparation or excessive working, and will separate under strong forces.

A few California producers have NSF approval for solvent cements; they are also listed in Table III-5. Their total output is less than $10 million annually, which at $1 to $2 per pound would yield 5 million to 10 million pounds of cement and primers, far more than is needed for the 50 million pounds of pipe produced in the state. SRI estimates that less than 1 pound of cement would be needed for 100 pounds of pipe.

6. Role of Standards in Materials Manufacture

As explained in the "Project Description" (Section II), expanded uses of plastic pipe will depend on adoption of building code changes by local jurisdictions, stimulated by the proposed changes in the state plumbing code. These two levels of approval are the only official, mandatory controls on pipe systems except where they are superseded by health-oriented regulations. However, the state code is built on a whole framework of voluntary standards and consensus agreements.

The state code is an adaptation of a model plumbing code (the "Uniform Plumbing Code," or UPC), which is revised on a 3-year schedule by the IAPMO. The UPC, in turn, refers extensively [illegible]roved acceptable standards" and "recognized standards," as well [illegible]cifically to a variety of size, strength, and identity standards published by such groups as the American Society for Testing and Materials, the American National Standards Institute, and the American Water Works Association.

It is generally understood that the UPC's reference "manufactured to recognized standards" means listing by the National Sanitation Foundation, at least for potable-water applications. NSF, a not-for-profit voluntary standards organization, provides control over plastic pipe--but not over metal pipe--through its Standard 14 (NSF, 1980). Every manufacturer of pipe, fittings, pipe ingredients, or solvent cements who desires the NSF seal ("listing") must agree to use NSF-accepted ingredients in an NSF-qualified formulation and to submit to frequent NSF monitoring of its product.

NSF "accepts" ingredients by standard tests for extraction of the ingredient from the proposed product and by testing the substance for toxicity by feeding it to laboratory animals for 90 days if the ingredient is not already sanctioned by the U.S. Food and Drug Administration. Complete disclosure of chemical identity for ingredients is required by NSF. The formulation is qualified if it passes the extraction tests with each specified extractant below its "maximum permissible level" (MPL). The product can maintain its listing as long as it continues to pass the extraction test and other size and strength tests, for example, impact resistance and static water pressure/rupture tests.

NSF samples from plants about three times a year and also inspects the plants for conformance to formulations, quality control, and other sanitary practices. The samples for pipe and fittings are subjected to a standard extraction protocol and the water is analyzed for nine metals, phenolic substances, and suspended solids. The choice of substances to be analyzed is based on EPA drinking water regulations and other considerations. Taste and odor are also evaluated subjectively. For PVC and CPVC, the pipe is ground up and then analyzed for residual vinyl chloride monomer. No other organic materials are routinely sampled because EPA drinking-water standards have not been established for them. NSF is beginning a program to detect trihalomethanes, such as chloroform, in extractant samples and in solvent cements. The major constituents of solvent cements and primers are already being checked by gas chromatography and mass spectroscopy.

If samples fail a test, the manufacturer is given a short time to correct the problem and is then resampled. If problems persist, the product is delisted, and the company's other products may be delisted in extreme cases. If a failure disqualifies a product for use, NSF requires the manufacturer to destroy the defective inventory. Destruction is much more frequently a result of performance failures than extraction failures.

NSF detects both errors in manufacturing and failures to pass the extraction and performance testing of samples. Tables III-6 and III-7 show summaries of NSF experience for their testing and inspections, respectively.

Because NSF covers most PW applications in California and because the NSF seal will be withdrawn for repeated failures, long-term average levels in drinking water will almost surely be below NSF MPLs for the substances analyzed. However, until NSF substantially expands its list of substances into the organics area, NSF will affect the quality of pipe with respect to them only through attention to consistent formulation and good manufacturing practice.

Table III-6

SUMMARY OF TESTING RESULTS FOR
PLASTIC PIPE AND FITTINGS
January-September 1982

Substance*	MPL**	Failures***	
		Number	Percent
Antimony	0.05	0	0
Arsenic	0.05	0	0
Barium	1.0	0	0
Cadmium	0.01	1	0.2
Chromium	0.05	0	0
Lead	0.05	1	0.2
Mercury	0.002	1	0.2
Selenium	0.01	4	0.7
Tin	0.05	8	1.5
RVCM****	10.0	0	0

---

*Results from 541 samples, except for RVCM with 303 samples.

**NSF Maximum Permissible Level, mg/l.

***Samples in excess of MPL: PW pipe is subjected to extraction as well as performance testing; DWV pipe receives only performance testing.

****Residual vinyl chloride polymer--level in plastic.

Source: Adapted from McClelland (1983).

Table III-7

SUMMARY OF INSPECTION RESULTS
FOR PLASTIC PIPE AND ASSOCIATED MATERIALS

Nature of Deficiencies	1979*	1980+	1981#
Dimensional variations	91	88	81
Unauthorized formulations**	16	15	17
Incomplete/illegible markings	35	52	57
Lack of quality control			
Equipment	34	28	17
Records	63	45	31
Failures witnessed	56	70	76

---

*782 inspections.

+797 inspections.

#725 inspections.

**Usually entail use of unauthorized materials; most such materials are later accepted by NSF and the product is released for sale.

Source: Adapted from McClelland, 1983.

To the extent that local jurisdictions adopt the UPC via the state code, all of California's potable-water pipe should be covered by the NSF listing procedure. Some pipe intended for other use may be installed--by homeowners, for example--and escape inspection, but less than 5% of the total is probably involved. Considerably more DWV pipe would not carry the NSF seal, but more than half probably does. The NSF seal is an important marketing advantage for most markets, especially for PW pipe and fittings, so loss of the seal is an important deterrent to poor manufacturing practice. Moreover, because the only incentive for intentionally departing from NSF standards would be lower manufacturing cost, other high-quality manufacturers, at a competitive disadvantage, have an incentive to report their competitors' wrongdoings and do so. Departures from NSF standards therefore are likely to be limited to relatively short production runs before either inadvertent departures are corrected or deliberate departures are punished by NSF actions.

7. Total Production of Plastic Pipes

About 2.5 billion pounds of plastic pipe and fittings were sold in the United States in 1981. This quantity breaks down approximately as shown in Table III-8.

Table III-8

QUANTITY OF PLASTIC PIPE PRODUCED
(Millions of Pounds)

Type	Water Supply	DWV	Other
ABS	--	--	30
PB	5	--	2
PE	230	--	5
PVC	880*	250	770
CPVC	7	--	2

---

*Much of this quantity may be non-structural, e.g., agricultural.

Source: SRI estimates

C. Installation of Plumbing Systems

Whether installation of plumbing systems is done properly or not is a key question in determining the environmental consequences of either plastic or metal pipe. This subsection describes plumbers' practices in installing both potable-water supply piping and drain, waste, and vent piping in residences, using both plastic and metal materials.

The blocked quotes below have been taken from McGuinness, et al. (1980).

1. Water Supply Piping

> The conveying of water through buildings to locations of use implies the design of a system of piping or tubing efficient for its purpose, easily maintained and interfering as little as possible with the interior architectural form. It may be assumed that, except in basements, utility rooms, and at point of access to controls, the system will usually be concealed. Stud and joist construction provides space for concealment but, in fireproof buildings, vertical and horizontal furred spaces must often be provided.
>
> The corrosive effects of water and the resistance of metal to corrosion are usually matters for the attention of chemists and metallurgists. In general, however, public or private treatment should be provided to correct corrosive qualities. Theoretically, when this is done, it is sometimes suitable to use a cheaper piping material--steel; yet, prudence suggests that a better material be selected. In the nonferrous group, red brass and copper tubing are effective in corrosion resistance. Copper tubing is a very popular choice. It is less expensive than brass, assembles more easily, and is not subject to dezincification, which is the attack by acids on the zinc in brass. For use in handling aggressive waters, plastic is often a good choice. Like copper, it is light in weight and assembles with great ease.

(See Table III-9 for a listing of common metal pipe materials.)

> Plastic Pipe. Most of the plastic pipes and fittings now produced are synthetic resins. These do not appear in nature but are derived from such materials as coal and petroleum.
>
> Rapid increase in the development, acceptance, and use of plastics for water piping, fittings, and indeed, for drainage systems suggests a separate discussion of this family of material.
>
> Selection of Material. The chemistry of plastics is quite intricate and the material can appear in a great variety of forms, a few of which, especially suitable for water piping, are listed in Table III-10.

Plastic pipe has been widely accepted in the industry, as witnessed by its acceptance under a wide variety of codes:

- BOCA Basic Plumbing Code, Building Officials and Code Administrators International.
- National Standard Plumbing Code, National Association of Plumbing, Heating, Cooling Contractors.
- Southern Standard Plumbing Code, Southern Building Code Congress.
- Uniform Plumbing Code,* International Association of Plumbing and Mechanical Officials.

2. Drain, Waste and Vent (DWV) Service Piping

> The principal materials used for soil and waste piping and for venting are cast iron, copper, and plastic. Galvanized steel is sometimes chosen for vents and for tall stacks in high-rise structures.
>
> Cast Iron. Supplanting the tubing and culverts of early epochs that employed clay, lead, bronze, and wood, cast iron was the earliest of the modern materials used for piping. Used first in Germany around 1562 and appearing in the United States about 1813, its durability and resistance to corrosion has made it eminently suitable for the components of sanitary drainage systems. Its suitability ranges from its use in small residential work to the stacks and branches of tall buildings.
>
> Copper Tube. Like cast iron, copper is a material that has a history of use in ancient installations. Updated and highly developed in recent decades, its use is now widespread. There are several tube classifications [of different wall thickness] for the copper products used in plumbing systems. K, L, and M are the choices for water systems and DWV for use in drainage, waste, and vent installations (as the initials indicate).
>
> Plastic Materials. Along with copper and cast iron, plastics are also very suitable for sanitary drainage systems. They comprise a family of materials. Table III-11 lists the three kinds of plastics most suitable for drainage, waste, and vent. One of these materials, acrylonitrile-butadiene-styrene (ABS) is...

the most widely used in California, and is under consideration in this environmental review.

Table III-9

CHARACTERISTICS OF PIPE AND TUBING FOR WATER SERVICES

Kind of Pipe	Material of Manufacture	Connections	Qualities	Notes
Steel	Butt welded to 2 in. diameter, seamless large sizes	Threaded	Basic	Should be used when water is not corrosive
Brass, red	85% copper 15% zinc	Threaded, "IPS," (iron pipe size)	Corrosion-resistant	Bulky because of need for threading
Copper tube type "K"	Seamless, hard or soft temper	Soldered fittings	Corrosion-resistant and easy to fabricate	Thinner-walled than brass, easy to put together and dismantle
Copper tube type "L"	Seamless, thinner walls than type "K," hard or soft temper	Soldered fittings	Corrosion-resistant and easy to fabricate	Thinner-walled than brass, easy to put together and dismantle
Plastic*	See Table B**	Solvent cement weld	Very easy to fabricate	Not subject to electrolytic corrosion
Nickel silver and chrome	Copper, nickel, and zinc, steel and chromium	Threaded	Corrosion-resistant	Special application
Galvanized steel	Zinc-coated steel	Threaded	Moderately corrosion-resistant	Suitable for mild acid waters

---

*Upper limit of temperature, hot water, 180° F.
**For ABS and PVC.

Source: McGuinness, 1980

Table III-10

SUITABLE CHOICES OF MATERIAL FOR PLASTIC PIPING IN WATER SERVICES

Symbol	Material	Cold Water	Hot Water
PE	Polyethylene	X	
ABS	Acrylonitrile-Butadiene Styrene	X	
PVC	Polyvinyl Chloride	X	
PVDC	Polyvinyl Dichloride	X	X*
PB	Polybutylene	X	X*

---

*Developed recently for this special use. Other plastic materials not currently approved for hot water piping.

Source: Adapted from McGuinness, 1980

Table III-11

SUITABLE CHOICES OF MATERIAL FOR PLASTIC PIPING IN DWV (DRAINAGE, WASTE, AND VENT) AND SEWER SYSTEMS

Symbol	Material	DWV	Sewer
ABS	Acrylonitrile-	X	X
	Butadiene-Styrene	X	X
PVC	Polyvinyl Chloride	X	X
SRP	Styrene Rubber Plastic		X

Source: Progressive Architecture

3. Pipe Joining

The materials of importance in the plumbing trade are not limited to the piping alone. Indeed, it is the methods used to join the lengths of pipe that govern the nature of chemical exposures to the plumber. The joints between pipe sections may be made by any of a variety of means.

Although there are major differences within the categories of water and drain piping, it is convenient to continue the differentiation on that basis.

a. Pipe Joining--Water Service

i. Threaded Joints--Threaded joints are used for all galvanized steel joints as well as other ferrous pipe and "iron pipe size" brass. The tapered thread on the pipe is covered with pipe compound (Teflon tape is often used now as well), and then made up tight against the internal tapered thread of the coupling or other fitting. The chemical exposure is limited to the pipe compound ("pipe doping," see Table III-12) as well as any cutting oils that may be needed in the cutting of the pipe to length, and threading it. Figure III-5 shows some of the wide variety of pipe fittings used by plumbers to join pipe and bring it to the fixture.

ii. Soldered Joints--The differences between soldered and threaded joints are shown in Figure III-6. McGuinness (1980) states:

> The solder-joint connection in copper depends on capillary attraction that draws the solder into a cylinder of clearance between the mating surfaces of tube and fitting. This occurs after polishing and fluxing the surfaces and placing the parts together in final position. They are then heated and molten solder is applied to the circular opening where the fitting-edge surrounds the tube with a small clearance. It is then drawn into the cylindrical connection by capillary action. Solders are tin-lead or tin-antimony alloys. This kind of joint permits the advantageous setting up of an entire tubing assembly without turning the parts as in threaded installations and before the soldering commences. For the same strength, copper tubing may have thinner walls because no threads need to be cut into it. Its smooth interior surface offers less friction to flowing water.

Table III-12

REPRESENTATIVE PIPE JOINT COMPOUNDS

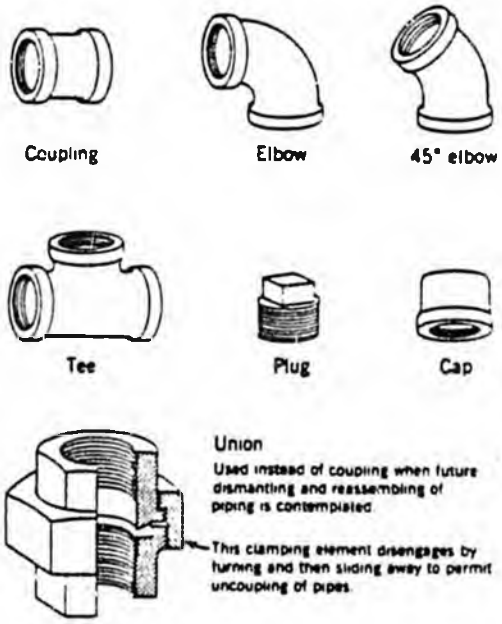
MATERIAL	Percent
Compound A[1]	
Chalk	32
Kaolin	33.5
Linseed Oil	33
Litharge (PbO)	1.5
Compound B[1]	
Black strap molasses	40-50
Amorphous graphite	40-50
Vermiculite	0-30
Bentonite	0-15
Lithopone	0-15
Sodium pentachlorophenate	1

(may contain Linseed Oil, Slate, or Titanium Dioxide)

PERMATEX^{R} Pipe Joint Compound, Part No. 51 [2]
"Polymerized vegetable oil and wood-derived resin with inert fillers dissolved in isopropyl alcohol." (isopropanol less than 20% by weight)

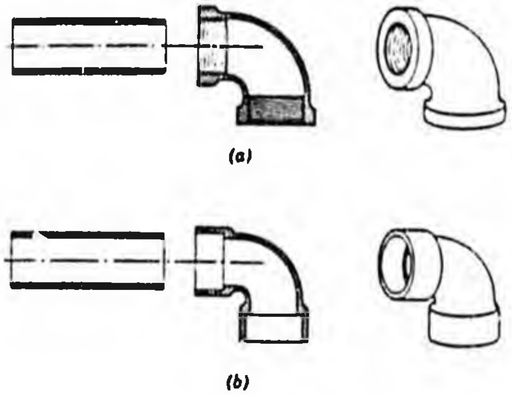
PERMATEX^{R} Thread Sealant with Teflon^{R}, Part No. 14 [2]
"A proprietary polymeric material containing dispersed PTFE and isopropyl alcohol." (isopropanol less than 40% by weight; PTFE = polytetrafluoroethylene)

Sources: Gosselin et al. (1976)
Technical Data Bulletins and Material Safety Data Sheets from Loctite Corporation.



Source: McGuiness, 1980

FIGURE III-5 EXAMPLES OF THREADED PIPE FITTINGS FOR FERROUS OR BRASS PIPE



Source: McGuiness, 1980

FIGURE III-6 METHODS OF CONNECTING PIPES AND FITTINGS, AND TUBES AND FITTINGS (a) Threaded: For ferrous pipe fitting and for "iron pipe size" (IPS) brass. (b) Soldered: For copper tubing and fittings. A sliding fit similar to that of (b) is used for the solvent weld of plastic connections.

The process of making a joint is best described by a direct quotation from the Copper Tube Product Handbook (Copper Development Association, no date):

> Measure length of tube
> Cut tube square
> Ream cut end
> Clean tube end
> Clean fitting socket
> Apply flux to tube end
> Apply flux to fitting socket
> Assemble
> Remove excess flux
> Apply heat
> Apply solder
> Allow joint to cool.

iii. Solders and Fluxes--Tables III-13 and III-14 show the composition of typical solders and fluxes. One omission from those tables is the measurable cadmium content in silver solder, which has caused extensive occupational disease in past years when the cadmium fume was inhaled. It is rarely found at present in general soldering work and is usually on any list of prohibited compounds in any well-run establishment. Only the 50/50 tin-lead and 95/5 tin-antimony solders would be commonly found in current residential plumbing. About 1 pound of solder and 2 ounces of flux would be used in a typical house (Copper Development Association, undated).

iv. Other Joints--As McGuinness (1980) has stated:

> While threaded- and solder-joint connections are the most common in small work, there are many other types. Ferrous pipes in the larger sizes are often welded or connected by bolted flanges.

In addition, of course, the joining of plastic pipes requires different techniques. These are discussed in the section below--on DWV joints--because of the greater extent of use of plastics in this service. An exception is the method used to join polybutylene pipe (PB). PB is relatively flexible, and is frequently joined by barbed hose nipples if two lengths of pipe are to be joined. The general nature of the joint is shown

Table III-13

COMPOSITION OF A NON-ACID SOLDERING FLUX APPROVED BY IAPMO [LA-CO REGULAR SOLDERING FLUX] FOR COPPER WATER PIPE

	Percent
Active Ingredients	45%
Ammonium chloride	
"Amine hydrochloride"	
Inert Ingredients	55%
"Microcrystalline wax"	
"Non-ionic surfactant" (water dispersible)	

Source: Shedroff, 1983.

Table III-14

SOLDERS IN MODERN USE FOR COPPER ALLOY SOLDERING

Composition %				Solidus	Liquidus	
Tin	Lead	Antimony	Silver	°F	°F	Remarks
50	50			361	421	General Purpose
60	40			361	374	General Purpose-"Fine Solder"
63	37			361	376	General Purpose-"Fine Solder"
95			5	452	464	General Purpose
96.5			3.5	430	430	Fine Instrument Work
95		5		430	473	Fine Instrument Work
1.0	97.5		1.5	588	588	General Purpose-Torch Heating
	97.5		2.5	579	579	Susceptible to Corrosion
	94.5		5.5	579	689	Susceptible to Corrosion

Source: NASA (1969)

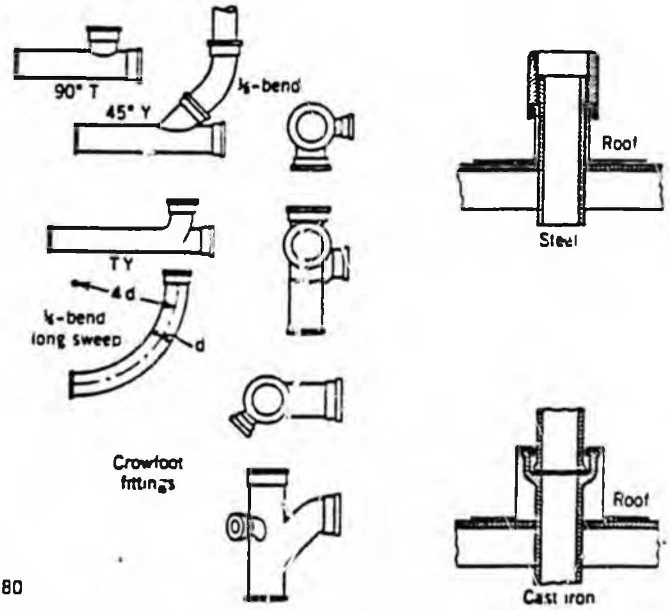
in Figure III-7. Polyethylene is frequently joined in a similar manner, but can also be joined by thermal "welding."

b. Pipe Joining--DWV Service

i. Cast Iron Pipe Joints--Until recently, cast iron pipe has been the most common material in DWV piping but it has been rapidly supplanted by ABS pipe in residential applications. One supplier (Gaspar, 1983) estimates that 95% of new one and two story residential buildings are plumbed with ABS. The three major types of joints currently used for cast iron are shown in Figure III-8 (McGuinness, 1980). The lead and oakum joint ("bell and spigot") is principally of historical interest now, although it is occasionally needed in the repair or restoration of older systems. When needed, the lead is usually not poured (which requires molten lead with--usually--excessive exposure to lead fumes) but is formed of lead wool which is calked into the joint. By far the most common joint in modern cast iron installations is the "no-hub" joint, which requires no chemical exposure, is fast, and can be installed by (relatively) unskilled personnel.

ii. Copper Pipe Joints--The methods for joining copper pipe (which is most commonly used in DWV systems for vent pipe) have been discussed above. The major difference is that the pipe and coupling, being larger, are more difficult to heat evenly (so as to draw the solder into the joint) and thus greater skill is required than in joining the usually smaller water pipe.

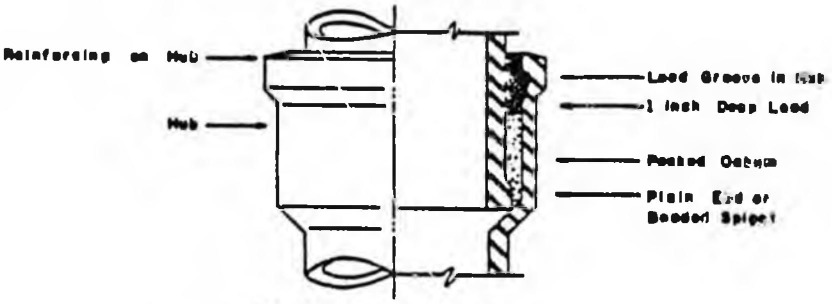
iii. Plastic Pipe Joints--The general procedure for joining plastic pipe is as shown in Figure III-9 (McGuinness, 1980). The pipe end and the fitting to which it is to be joined are "painted" externally and internally respectively with the appropriate solvent-based cement; twisted together in the proper position; and then held in place for a few seconds until the cement "sets." The usual solvents nominally recommended for the several kinds of pipe are shown in Table III-15. Tables III-16 and III-17 indicate the composition of cements found in the field.



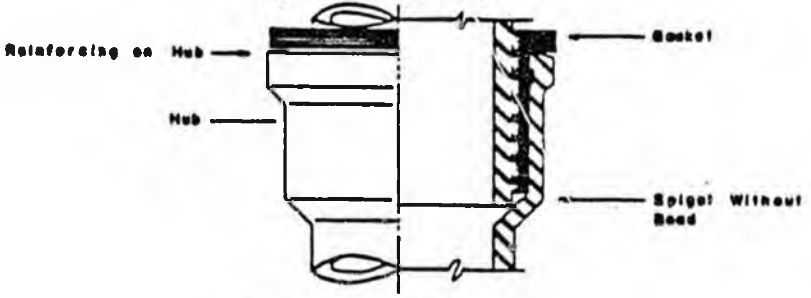
Source: McGuiness,1980

FIGURE III-7 CAST-IRON FITTINGS--PRINCIPAL TYPES AND METHOD OF FLASHING AT ROOFS

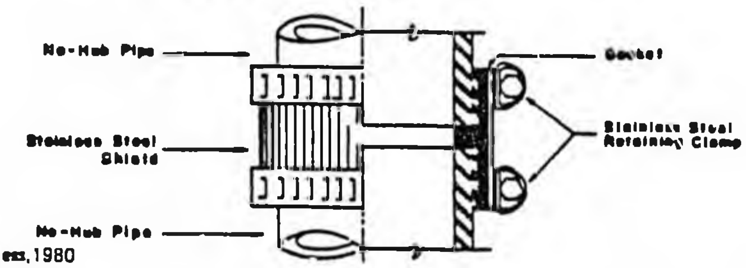
(a) LEAD AND OAKUM JOINT:



(b) COMPRESSION JOINT:



(c) NO-HUB JOINT:



Source: McGuiness,1980

FIGURE III-8 THE VARIOUS JOINTS PRESENTLY BEING USED TO CONNECT CAST-IRON SOIL PIPE AND FITTINGS

Table III-15

MOST COMMONLY USED SOLVENTS IN PLASTIC PIPE CEMENTS AND PROPERTIES OF SOLVENTS USED IN SOLVENT CEMENTS FOR PLASTIC PIPE

Most Commonly Used Solvents in Plastic Pipe Cements

Type of Cement	Primary--Major Solvent	Secondary or Minor Solvent
PVC	Tetrahydrofuran (THF)	Methyl Ethyl Ketone (MEK) Cyclohexanone
CPVC	Tetrahydrofuran (THF)	Cyclohexanone
ABS	Methyl Ethyl Ketone (MEK)	None
Styrene	Methyl Ethyl Ketone (MEK)	None

Properties of Solvents Used in Solvent Cements for Plastic Pipe

Chemical	Boiling Point °F	Evaporation Rate BUAC=1*	Flash Point	Threshold*** Limit Value (TLV) PPM	Odor** Detection Level PPM	Comments
Tetrahydrofuran	151	8.0 Very Fast	6	200	25-50	Distinct etheral odor
Methyl Ethyl Ketone	175	5.7 Very Fast	22	200	25-50	(Acetone like) Mint-like sharp odor
Cyclohexanone	312	0.2 Very Slow	110	25	Very Low	Distinct peppermint sharp odor

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*BUAC = Butyl Acetate

**Odor detected by most individuals

***Threshold limit values refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect. It refers to time-weighted concentrations for a 7 or 8 hour workday and 40 hour workweek. Reference: The American Conference of Governmental Industrial Hygienists, "Threshold Limit Values of Airborne Contaminants."

Source: Letter from Naresh D. Patel, Technical Director of Industrial Polychemical Service, Gardena, CA, to Myron Moskovitz, November 16, 1979.

Table III-16

ABS PLASTIC PIPE CEMENTING CHEMICALS AT JOB SITES

Company and Product	Chemicals Listed On Label	Chemicals by Laboratory Analysis
Oatey Cement	MEK	100% MEK
E-Z Weld	No label available	98% MEK 2% THF
Rectorseal TFE-Fluorocarbon Threaded Sealing Paste	None	No analysis available
ABS Rectorseal Solvent Cement	MEK	No analysis available
Weld-On 773	None	MEK
Hercules ABS Plastic Pipe Cement	MEK	MEK, THF, and Cyclo (trace amounts)

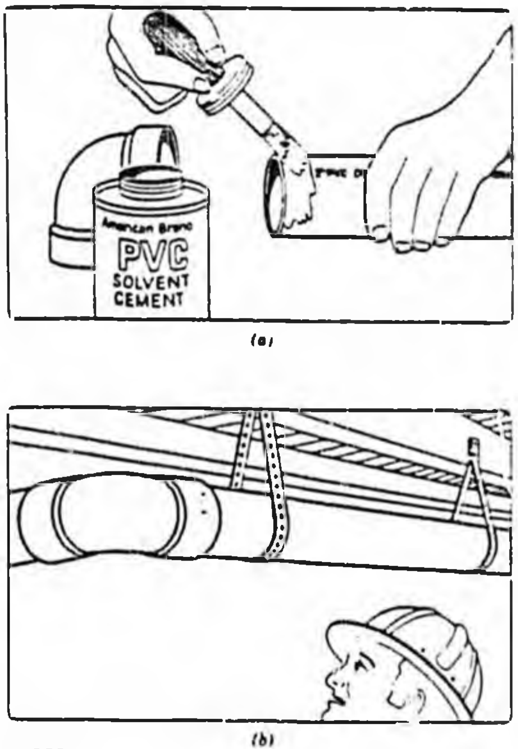
Source: CDHS--Interim Report, April 29, 1980

Table III-17

PVC PLASTIC PIPE CEMENTING CHEMICALS AT JOB SITES

Company and Product	Chemicals Listed On Label	Chemicals by Laboratory Analysis
Weld-On 710 PVC	MEK, THF, Cyclo	No analysis available
Weld-On Primer P-70	No label available	MEK, THF, Cyclo, DMF
Weld-On 717	No label available	MEK, THF, Cyclo
Oatey PVC Glue	No label available	MEK, THF
Weld-On 711	No label available	MEK, THF, DMF
PIP-P470 PVC Primer	THF, ketones	THF, MEK
Celanese PVC Solvent Cement	THF, Cyclo, MEK	THF, MEK

Source: California Department of Health Services-
Interim Report, April 19, 1980



(a)

(b)

Source: McGuiness, 1980

FIGURE III-9 DETAILS IN THE USE OF PLASTIC PIPE. (A) One of the steps in making a "solvent weld" of a plastic pipe to a plastic fitting. (B) In wood frame construction, plastic pipe assemblies can be supported by metal straps nailed to the wood joints. Flexibility of the plastic material suggests that the supports be more closely spaced than in the case of metal piping. Courtesy of the Plastic Pipe Institute.

iv. Other Joints--DWV--As with water service piping, a wide variety of other joints have been used. Many of these are of historical interest only, such as the "wiped" joint. Some use is made of welding; the extent of such use at this time is unknown. Similarly, where cement or vitrified clay pipes are allowed in sewer service (prior to the street main) joints using grouting compound may be found. Threaded fittings (for cast iron and galvanized steel) are also occasionally used.

4. Plumbing in Residences

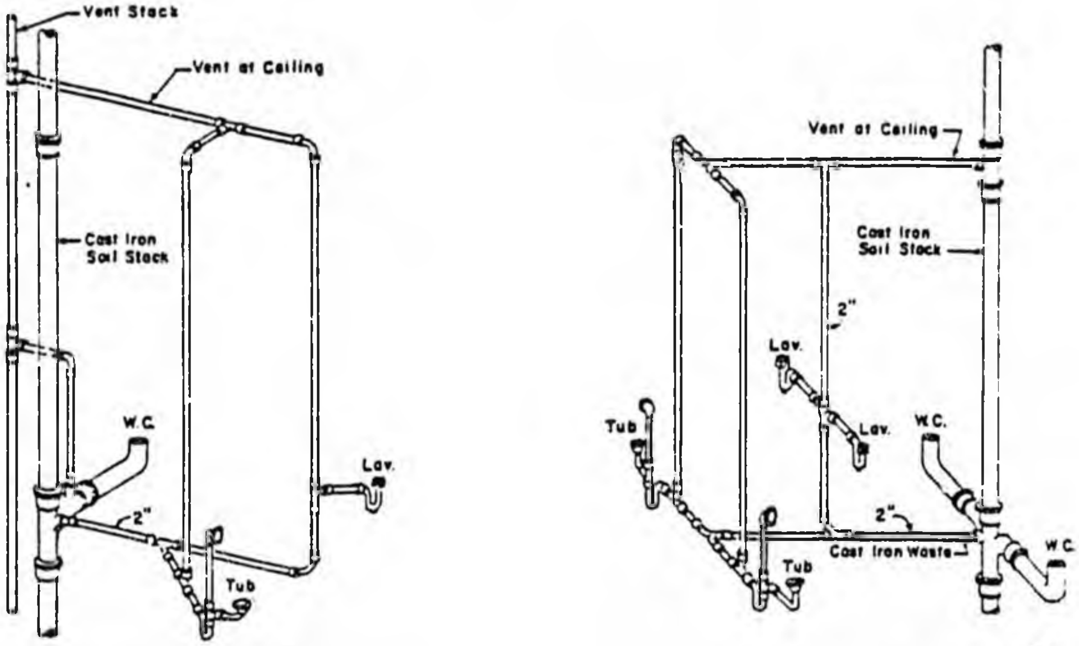
Figure III-10 shows a diagram of where plastic pipe might be found in a typical house. This idealized view is not reflective of the actual complexity of modern plumbing, which must fit (with reasonable exactitude) into an architect's drawing realized in wood, steel, and cement. Figure III-11 shows how the plumbing is part of the building structure, with complexities in both elevation and plan views.

5. Plumbing Trade Practices

The plumbing trade can be divided into three main segments: new construction, remodeling/replacement, and repair. The last-named (characteristically performed by a neighborhood plumbing shop) has very little exposure to chemicals, since most of the work involves simple replacement of fixtures, washers, and the like. It is in the first two that significant chemical exposures may be found; they differ in both the time-course and intensity of exposure, as will be discussed later in Section IV.C.

Regardless of the age of the building being plumbed, there will be four major operations that must be performed by the plumber. These are: layout, pipe-cutting, preassembly (sometimes not performed--see below), and installation.

Layout is the marking of joists and studs for holes to accept pipes (and often the cutting of the holes), measurement of pipe lengths needed,

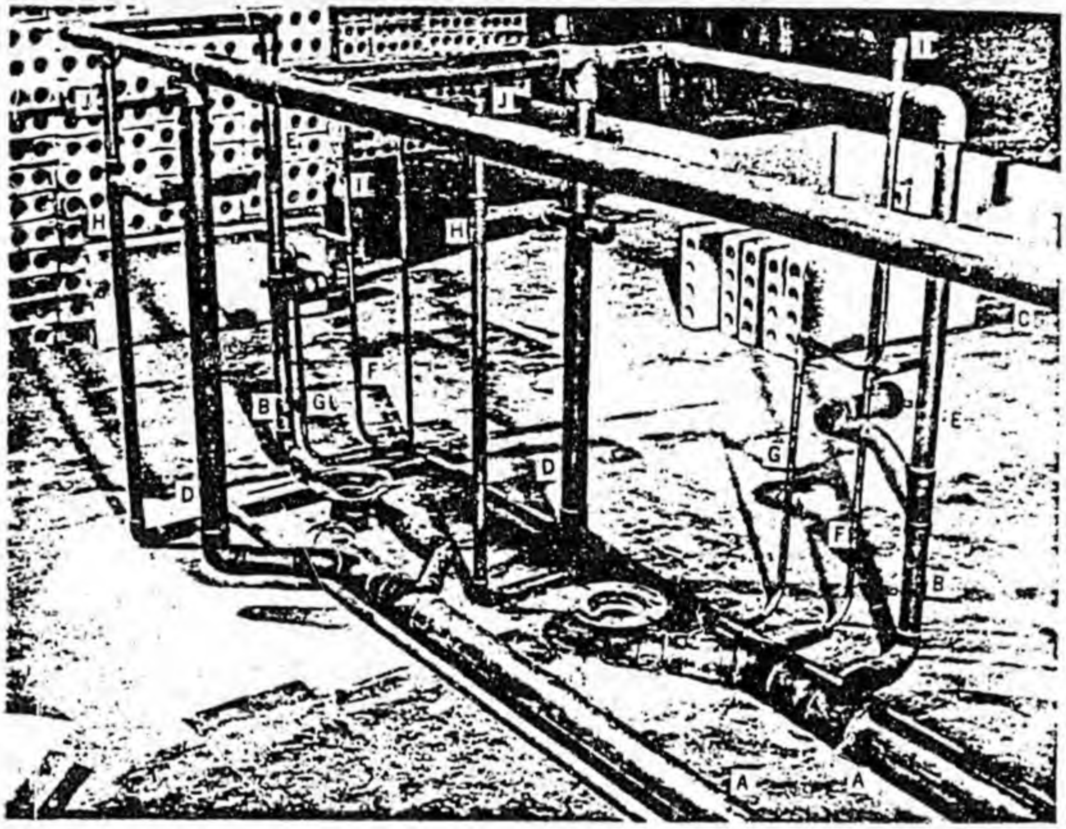


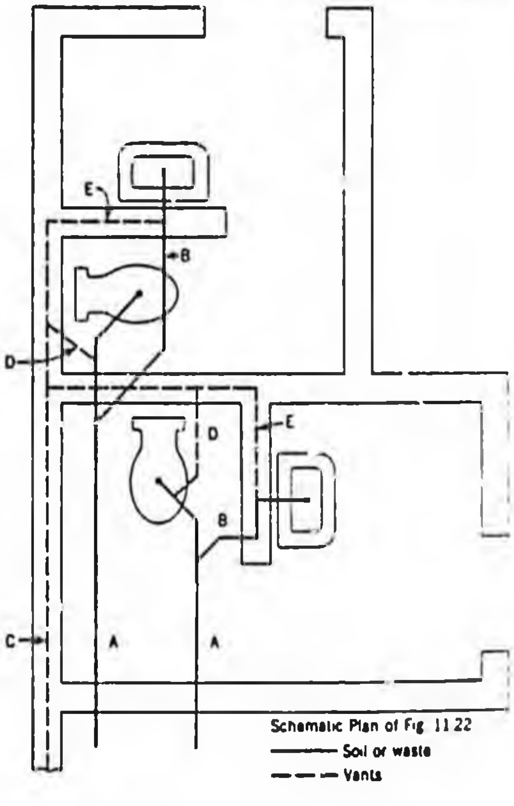
Piping for Tub, Lavatory and Water Closet with each fixture vented.

Typical Piping, Water Closet, Lavatory and Tub Back to Back.

Source: McGuiness, 1980

FIGURE III-10 TWO TYPICAL PIPING ARRANGEMENTS FOR WATER CLOSET, LAVATORY, AND TUB





Drainage	Water
A *Branch soil*	F *Hot*
B *Lavatory waste*	G *Cold*
C *Branch vent*	H *Flushometer supply* ($1\frac{1}{4}$ *in.*)
D *Water closet vent*	I *Capped air chamber*
E *Lavatory vent*	J *Capped air chamber* (*flushometer*) (*I and J absorb expansion and shock*)

FIGURE III-11 AN EXAMPLE OF PLUMBING ROUGHING FOR TWO LAVATORY ROOMS IN A FIREPROOF OFFICE BUILDING

Source: McGuiness, 1980

and planning for the complete plumbing job to turn the design into reality. This is the task requiring the greatest skill, and often is the most time-consuming part of the job. Horizontal runs of drain pipes must have minimum slopes (to prevent pooling of wastes in the lines), and the holes in joists and studs must be drilled precisely if rigid pipe is to be inserted (see Table III-18). The senior man on the crew will almost always perform the layout, which involves no chemical exposure.

In addition to the potential for exposure to chemicals, it must be recognized that there are substantial safety hazards involved with the various plumbing operations--as indicated in the introduction to this section. Plumbers work with heavy materials in enclosed spaces; they must place sections of pipe in position and then use saws, torches, and other dangerous instruments; they are at risk of fires set by torches (or accelerated in spread by combustible solvents) and they are at risk of all of the safety hazards associated with construction sites.

After layout is completed, and the journeyman plumber has made measurements of the lengths of pipe required, then the 10 or 20 foot long lengths of pipe, commercially supplied, must be cut to lengths suitable for the intended use and threaded if necessary. This task is usually assigned to a new apprentice (when a large crew is on-site) or will be done by the plumber as he works through the layout or the installation. The cutting will be done by hack saw (steel pipe, some iron, and occasionally plastic), hammer and chisel (cast iron--this is a vanishing art), tubing cutter (copper and rigid plastic tubing), knife or bolt cutter (some plastics).

a. Preassembly-Prefabrication

As noted above, preassembly of components is not always done--particularly on small jobs (see discussion below on new construction activities). However, when a large number of similar installations are planned, as in a large commercial building (or set of similar buildings) or in a residential tract where identical layouts for fixtures are found, then

Table III-18

MINIMUM SLOPES FOR HORIZONTAL DRAINAGE PIPES

Diameter of pipe in inches	1-1/4	1-1/2	2	2-1/2	3	4	5	6	8	10	12
Minimum slope recommended by "Plumbing Manual"* (inches per feet)	1/4	1/4	1/4	1/8	1/8	1/8	1/16	1/16	1/16	1/16	1/16
Minimum slope recommended by "Housing Code,"** (inches per feet)	1/4	1/4	1/4	1/4	1/4	1/8	1/8	1/8	1/8	1/16	1/16

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*"Plumbing Manual," Report BMS66, National Bureau of Standards, 1940.

**"The Uniform Plumbing Code for Housing," Housing and House Finance Agency, February, 1948 preassembly of significant complex pieces of the plumbing array can be cost-effective. This work will sometimes be done in the shop, although field pre-fab on the job site is more common, and some plumbers specialize in this aspect of the trade. The potential exists for substantial chemical exposures to any materials used in the preassembly plumbing array.

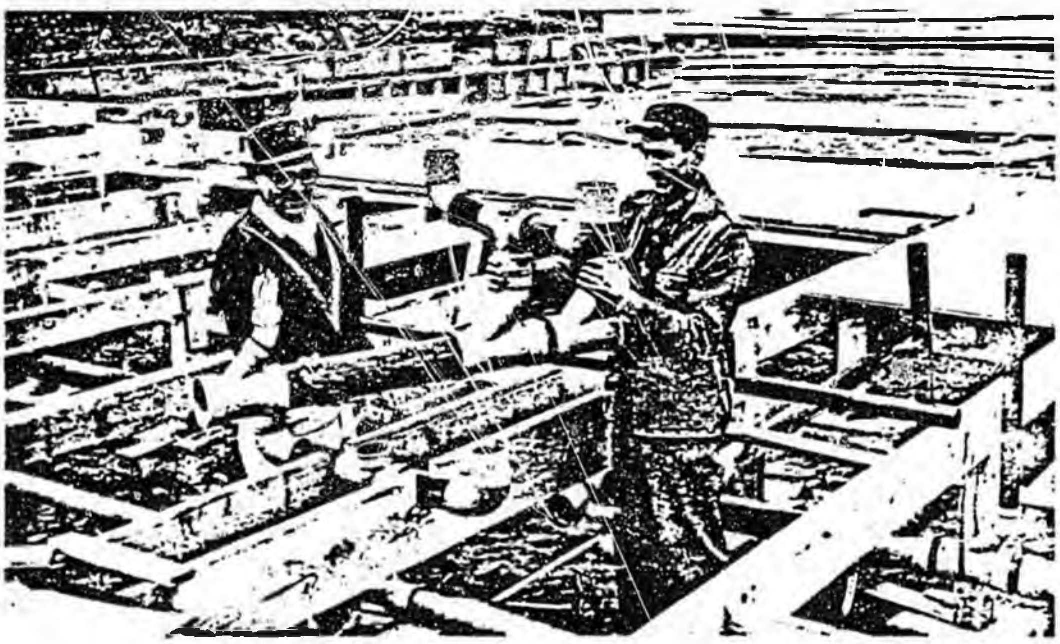
Figures III-12 and III-13 show the complexity of typical preassemblies. Substantial preassembly is usually limited to copper or plastic (and some small cast iron arrays) because of the weight factor; it is desirable to limit the weight of the assembly to that which can be handled by one plumber.

b. Roughing, Topping Off, and Finishing

There are three major phases of the actual installation: "roughing," "topping off," and "finishing work" (CDHS, 1980). The "roughing" phase consists of the installation of the pipes leading from the main city sewer and water lines to and throughout the crawl space or basement of the building. This is usually done in the open at the point when the building construction consists of the foundation and floor studs.

Following the roughing phase, floor boards are laid and walls are constructed, although not covered. The next phase, "topping off," is the installation of the pipes branching off from the floor board pipes, up through the walls and ceiling of the structure to the point where fixtures will be installed.

Finally, the "finishing work" is the connection of plumbing after the fixture and cabinets, vanities, and wet bars have been installed. This involves the attachment of the fixture to the pipes in the wall--usually inside cabinets under the sinks or other fixtures.



Source: Mc Guiness, 1980

FIGURE III-12 PLASTICS LEND THEMSELVES TO PREASSEMBLY OF SECTIONS OF DWV PIPING

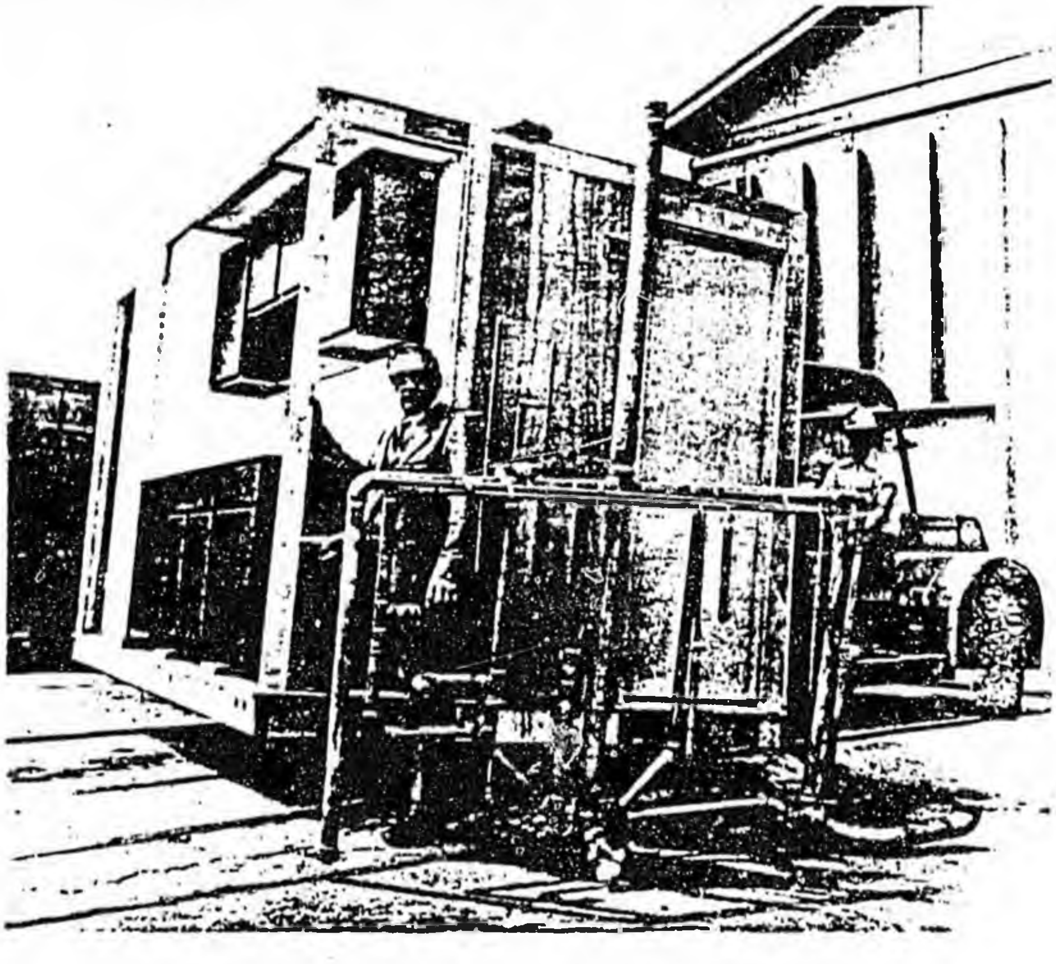


FIGURE III-13 PREASSEMBLY--A COPPER PLUMBING TREE

Source: McGuiness, 1980

D. Use of Plumbing Systems

1. Water Use

Water is drawn from the potable water supply, used, and often returned to the drain and waste system. The total water withdrawn is termed "consumptive use." The system's delivered water enters various categories of end use:

- Domestic
    - Drinking, culinary
    - Washing, bathing
    - Laundering, auto washing
    - House cleaning
    - Heating, air conditioning
    - Sanitary flushing
    - Lawn and garden watering
    - Wading pool and swimming pool make-up water
- Commercial and industrial
    - Process
    - Cooling
    - Steam generation
    - Washdown
- Municipal
    - Street cleaning
    - Parks and recreation, including irrigation, fountains, and the like
    - Fire fighting
    - Public buildings
- Water unaccounted for (mainly losses due to leakage).

Total water consumption per capita, for the purposes noted above, can have a wide range of values. Differences around the state are subject to climate, delivery pressures, amount of sewerage available, standards of living, types of commercial/industrial activity, ratio of single-family residences to apartment houses ratio, degree of metering, cost of water, and public attitude (e.g., toward water conservation, among other factors). Nevertheless, to gain some sense of magnitude, Table III-19 can help.

Table III-19

WATER CONSUMPTION IN VARIOUS MAJOR USES

Class	Gallons Per Capita Per Day Normal Range	Average	Percent
Domestic	15 - 70	50	33
Commercial/industrial	10 - 100	65	43
Public	5 - 20	10	7
Water unaccounted for	10 - 40	25	17
Total	40 - 230	150	100

Source: Fair et al. (1966).

Though still using rough averages, we can further quantify the domestic portion of the supplied water (see Table III-20). The 2.5 gallons indicated for Drinking is the amount coming through the tap; the ingested quantity is only a portion of this. Further explanation of the use of water and plumbing systems is included in Section IV-A.

2. The Role of Building Inspection

Standards for the proper choice of plumbing materials and proper installation of plumbing, whether plastic or metal, provide little protection unless they are observed much more often than not. Plumbing codes and standards could easily be ineffective if there were no provision for enforcement. The principal agents of code enforcement are the building inspectors, who can deny permission to continue construction or to occupy a building if they find code violations. In the case of fire-rated construction, the fire inspectors can also deny permission to occupy. The existence of a strong building inspector capability is thus an effective deterrent to use of substandard materials or faulty installation practices. However, at present building inspectors tend to look more for practices that would degrade performance than for ones that would cause environmental problems.

Building and fire inspectors can detect the following types of improper practices:

- Use of unapproved pipe, fittings, and fixtures. By inspection for the NSF-PW seal on water pipe, and various markings on DWV pipe, this type of error can be relatively easily detected.
- Poor mechanical installation practices. Inspection for too sudden bends, improper suspension and clearances, contact of drain pipe with wallboard, and so on, can detect these deficiencies relatively easily and can reduce failure rates and noise problems.
- Poor joining techniques. Excessive or careless use of cements, solders, pipe joint compounds, and the like can sometimes be detected by external inspection after the fact. Inspection during installation, however, would be more likely to detect such problems.

Table III-20

DISTRIBUTION OF DOMESTIC WATER CONSUMPTION

Use	Percentage	Average Consumption*
Flushing toilets	41	20.5
Washing/bathing	37	18.5
Kitchen	6	3
Drinking	5	2.5+
Washing clothes	4	2
Household cleansing	3	1.5
Garden watering	3	1.5
Auto washing	1	0.5
Total	100	50.0

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*Based on Table III-19.

+Through tap--see text.

Source: U.S.G.S. (1964).

- Inadequate flushing. In principle, building inspectors could require flushing to be conducted while they are present. This practice is rarely, if ever, done at present.

- Fire Protection. Regular building inspection will detect inadequate fire blocking and excessive clearances around pipe. In fire-rated buildings, inspectors could look for features such as metal sleeves or guillotines in use with plastic pipe that would preserve the fire rating of fire-resistive structures. However, at present there do not appear to be specific observable features that would assure a fire inspector that a fire wall would retain its rating with plastic plumbing.

It is believed that most new construction and major interior renovations, replacements and repairs undergo inspection. However, certain homeowner-installed piping, especially for external use in gardens, can escape inspection (Nelson, 1983). Nelson also believes that do-it-yourselfers often do a good job of installation, however.

E. Water Distribution and Waste Water Collection

1. Purpose

This section first provides an overview of how fresh water arrives at dwellings and structures and how spent water is handled on leaving them. Then, it describes material, installation, and cost factors that constitute the plumbing network in dwellings--the plumbing system element of prime concern of this environmental review.

2. General

a. A Macro Look at the Water Supply/Wastewater Disposal System

Although there are differences between rural and urban settings and between small and large systems, Figure III-14 illustrates generally the flow of consumer water from source through consumption and then its return again to the source to repeat the cycle. For simplicity, the return of

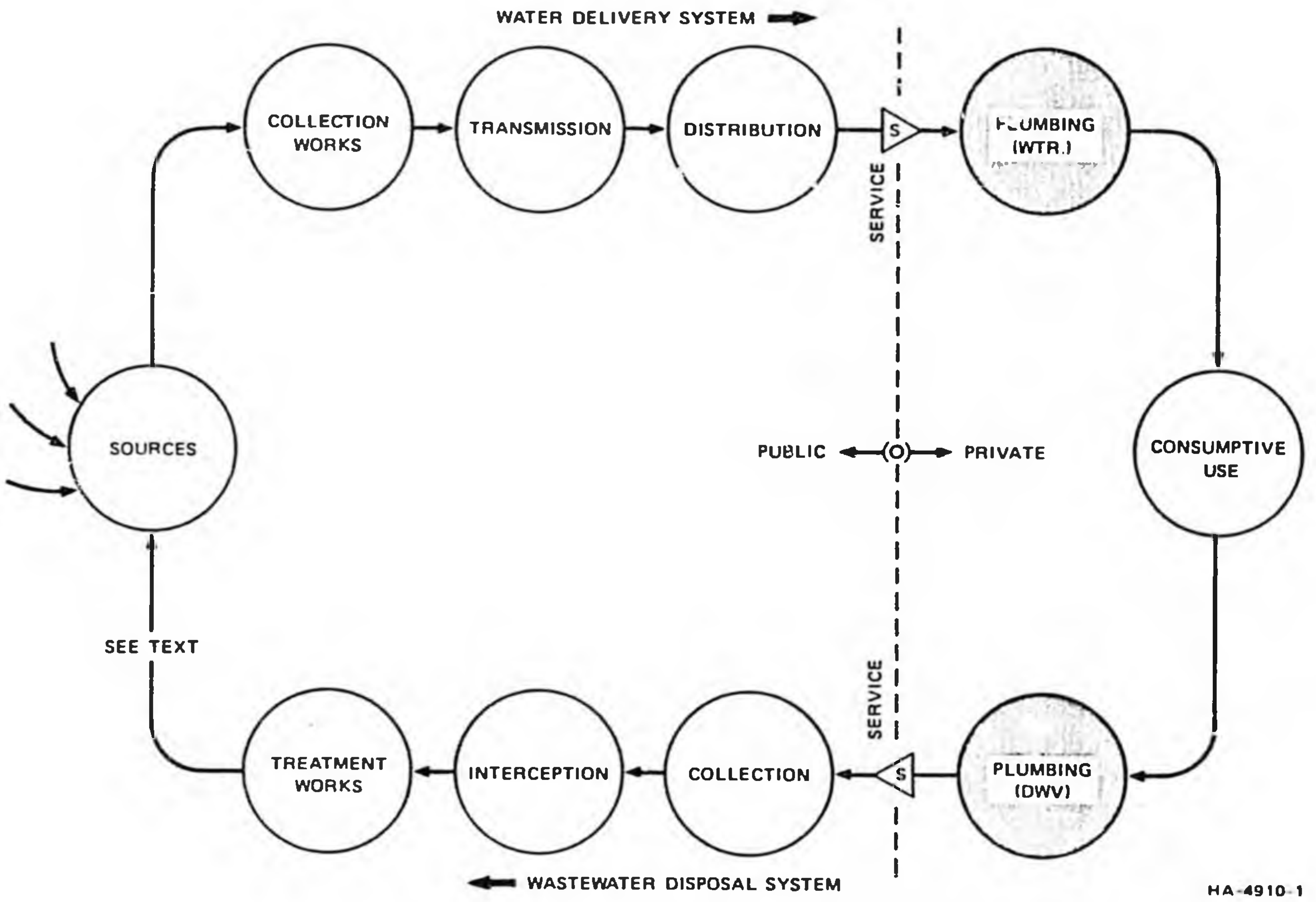

FIGURE III-14 WATER DELIVERY AND WASTEWATER DISPOSAL SYSTEM spent water is shown as a single pathway to the source. Clearly, in a more detailed presentation, the hydrological cycle and hydrogeologic phenomena come into play.

To place the environmental impacts of the plumbing system itself in perspective, it is useful to understand the many materials that a molecule of consumer-used water comes in contact with outside that system--e.g., contact with a wide array of thermoplastic materials and polymer-based compounds.

The "Service" notation shown merely represents the physical interface between public-agency and (generally) private-sector elements. On the water delivery side of the cycle, this would consist of the connection to the public water main, a relatively short reach of pipe, a curb stop (i.e., property line valve), and a recording flow meter. On the wastewater side, it will generally be the wye branch connection to a public collection pipe in a street, alley, or public easement and a run of sewer pipe (i.e., the sewer lateral) to the property line. In Figure III-14, it is the right side of both these interfaces that is the primary issue here.

b. Features of the System Elements

i. Sources of Supply--It is often the source of supply that will determine the nature of the collection, transmission, and distribution works. This is especially true for purification facilities--not only as to their process but to where in the "supply" chain they are most effectively located. Fresh-water sources are generally categorized as (1) surface waters (e.g., streams, rivers, ponds, lakes, and snowpacks) and (2) groundwaters (e.g., springs, groundwater table, shallow and relatively deeper aquifers, subterranean reservoirs, etc.).

ii. Collection Works--These works include infiltration galleries, pumps, wells, and impounding reservoirs (natural and dammed), and may include some purification capability, depending on the distance to and size of the first users off the transmission line.

iii. Transmission--Included in this system element are open channels (e.g., earthen, lined), covered and open aqueducts (e.g., concrete, rock), and totally closed pipelines (for pipeline materials see Table III-21). Often booster pumps and associated mechanical features are necessary along the transmission route.

iv. Distribution--This element has several important parts or functions. These are (1) the piping networks serving consumer purposes, (2) piping or system capacity, (sometimes separate from the above, e.g., in high-value mercantile districts) for firefighting purposes, and (3) terminal storage--sometimes referred to as distribution storage--to accommodate peak demands and firefighting capacity. This latter may include open and covered reservoirs, elevated and ground-level tanks, standpipes, and the like.

v. Plumbing (Water Supply)--Four functional subelements are distinguishable for analysis:

(1) Cold water piping--generally characterized by greater throughput (i.e., volume) than hot water piping.

(2) Hot water piping--characterized by the need to accommodate higher temperatures than cold water piping.

(3) Hot water storage--the tank system used to provide both the heating vessel and a stored supply of hot water.

(4) Cold water storage--not as universal as hot water storage, yet equally important when elevated storage is required for purposes of system pressure or fire safety in multistory buildings.

vi. Plumbing (Wastewater)--Basically, the two primary components of the wastewater plumbing system are:

(1) Sewage and liquid waste drainage pipes--carrying sanitary wastewaters (e.g., from toilets, urinals), what is sometimes referred to as "grey wastes" (e.g., wastewaters from lavatories, sinks, tubs, and wash-down drains), food wastes (e.g., from garbage disposals), and process and other water-borne wastes.

(2) Air vent pipes--provide flow of air to and from the drainage system to protect trap seals from siphoning and backpressure.

Table III-21

MATERIALS OF CONSTRUCTION
WATER DELIVERY SYSTEM

Piping*:	Cast iron
	Ductile steel
	Concrete (pressure type)
	Asbestos-cement
	Thermoplastic (e.g., PVC, PE)
	Composite plastic (e.g., epoxy-cased fiberglass)
	Plastic bonded steel (e.g., IPM watermain pipe)
Pipe linings:	Cement mortar
	Heat fused polyethylene (e.g., "Polybond")
	Polypropylene
	Coal tar
	Other bituminous materials (cold applied)
	Epoxies
	Mineral-based compounds
Storage vessels:	Earth, concrete, steel, wood, membrane-lined
Membrane Linings:	Polychloroprene
	Chlorinated polyethylene
	Chlorosulfonated polyethylene
	Polyisobutylene
	Polyolefin
	EPDM (ethylene propylene diene monomer)

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*Not listed are a wide range of materials used in valves, seals, fittings, joints, and other miscellaneous castings, or the materials used for channels and aqueducts.

vii. Collection--This system element consists of a network of pipes, manholes, cleanouts, lift stations (i.e., pumping facilities to increase the system pressure head), and possibly temporary holding basins. Its function is to carry spent waters as well as water-borne solid wastes from the plumbing system to the nearest interceptor or, in smaller cities, directly to the point of disposal. Types of pipe used for this purpose are indicated in Table III-22.

viii. Interception--This is relatively large diameter pipe or other form of conduit that collects, in a single carrier, the outflows of several collection networks.

ix. Waste Treatment Works--This element in the water supply and return cycle generally consists of one or more of the following processes:

- Aeration (surface to air contact)
- Screening (removal of bulky floating matter)
- Skimming (oils and grease flotation)
- Settling (removal of settlable solids)
- Flocculation/precipitation (removal of suspended and dissolved solids)
- Digestion (removal of colloidal and dissolved organic matter)
- Biological filtering (transformation of solids)
- Disinfection (removal of pathogenic bacterial or other organisms)

Depending on location, policy, costs, and other factors, treatment of wastewater will vary from none to the most sophisticated.

Table III-22

MATERIALS OF CONSTRUCTION
WASTEWATER DISPOSAL SYSTEMS

Piping:	Vitrified clay (VCP)
	Concrete sewer pipe
	Asbestos-cement
	Thermoplastic
	Composite (fiberglass-reinforced epoxy resin)
	Ductile and cast iron (more for pressure mains; requires lining)
	Steel (more for interceptors; requires lining)
Lining:	Cement mortar
	Coal tar
	Coal tar epoxy
	Other bituminous coatings
	Epoxy mortars
	Polyethylene (e.g., ductile and cast iron pressure pipe)
	Glass (e.g., industrial waste treatment applications)
	Slip lining (actually a polyethylene or other pipe slipped into older metal pipes for rehabilitation)

c. Additional Flows of Concern

Figure III-15 illustrates some additional water and waste flows that, in effect, suggest that:

- Not all water produced reaches the consumer because of leakage.
- Not all water spent reaches its otherwise prescribed destination.
- Spent water emanating from the plumbing systems of the state's dwelling units may in some cases represent only a portion of total wastes disposed of.
- There is a high degree of wastewater dilution when discharge is handled via combined sanitary- and storm-sewer systems.

3. The Plumbing Systems

a. General

Figure III-16 illustrates how the basic residential water and waste plumbing systems connect to the external water supply and sewer systems. As can be seen in Table III-23, the plumbing in residences may run from about 3% to over 10% of housing cost, comparable to the range seen for commercial buildings.

b. Water Supply Plumbing

As indicated in Section III.C, the majority of this system is inside, installed within walls and ceiling-joist framing. A smaller amount occurs in open crawl space and basement areas. The outside cold water service pipe is relatively short, varying from only a few feet to possibly 50 feet in length in deep-setback districts. On the other hand, the outdoor plumbing for garden, lawn, swimming pool, and wash down can be extensive.

Because of service piping water heater cold-side piping, and external plumbing, the size of the cold water system will always exceed that of the

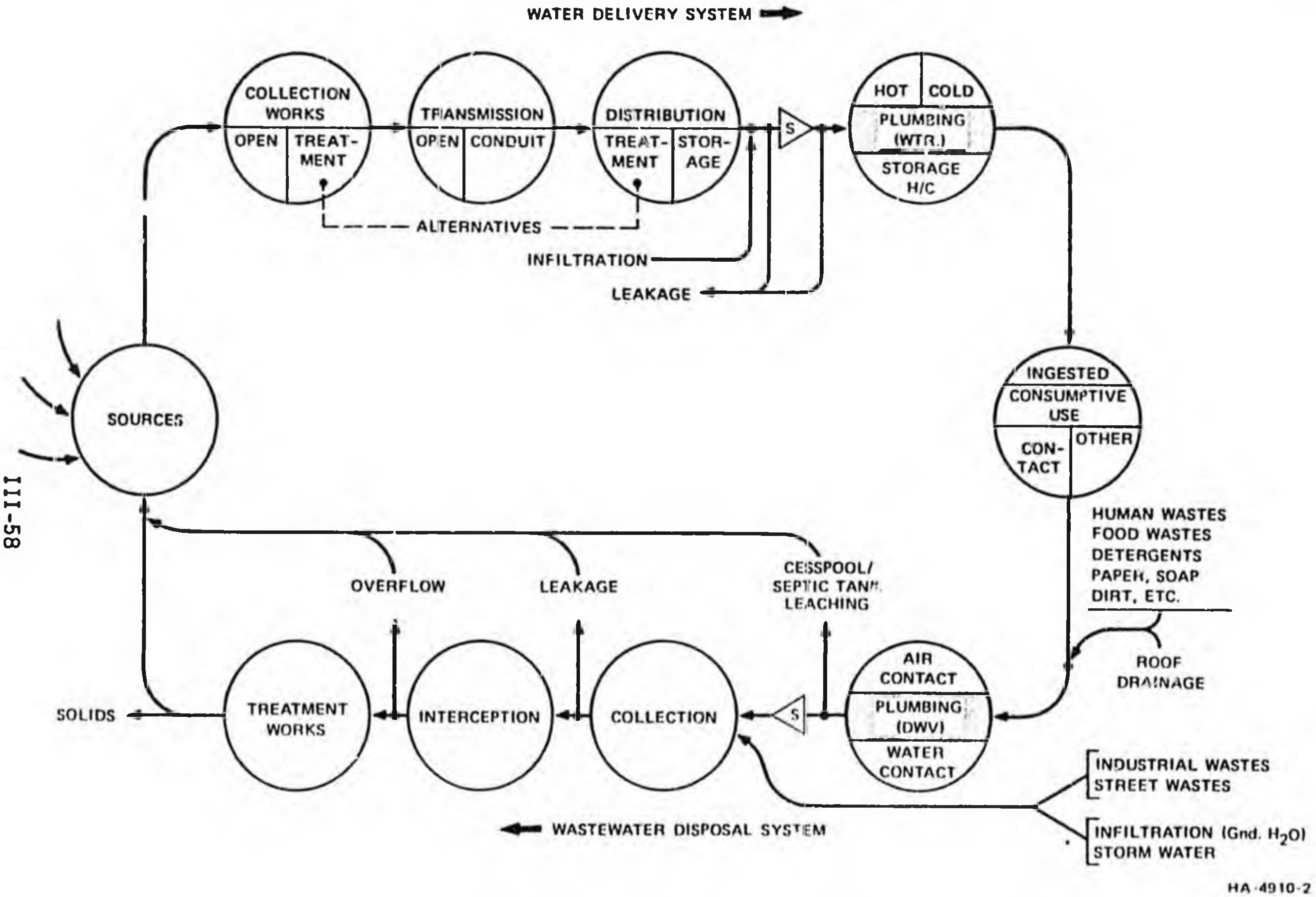

FIGURE III-15 DETAILS OF WATER DELIVERY AND WASTEWATER DISPOSAL SYSTEM

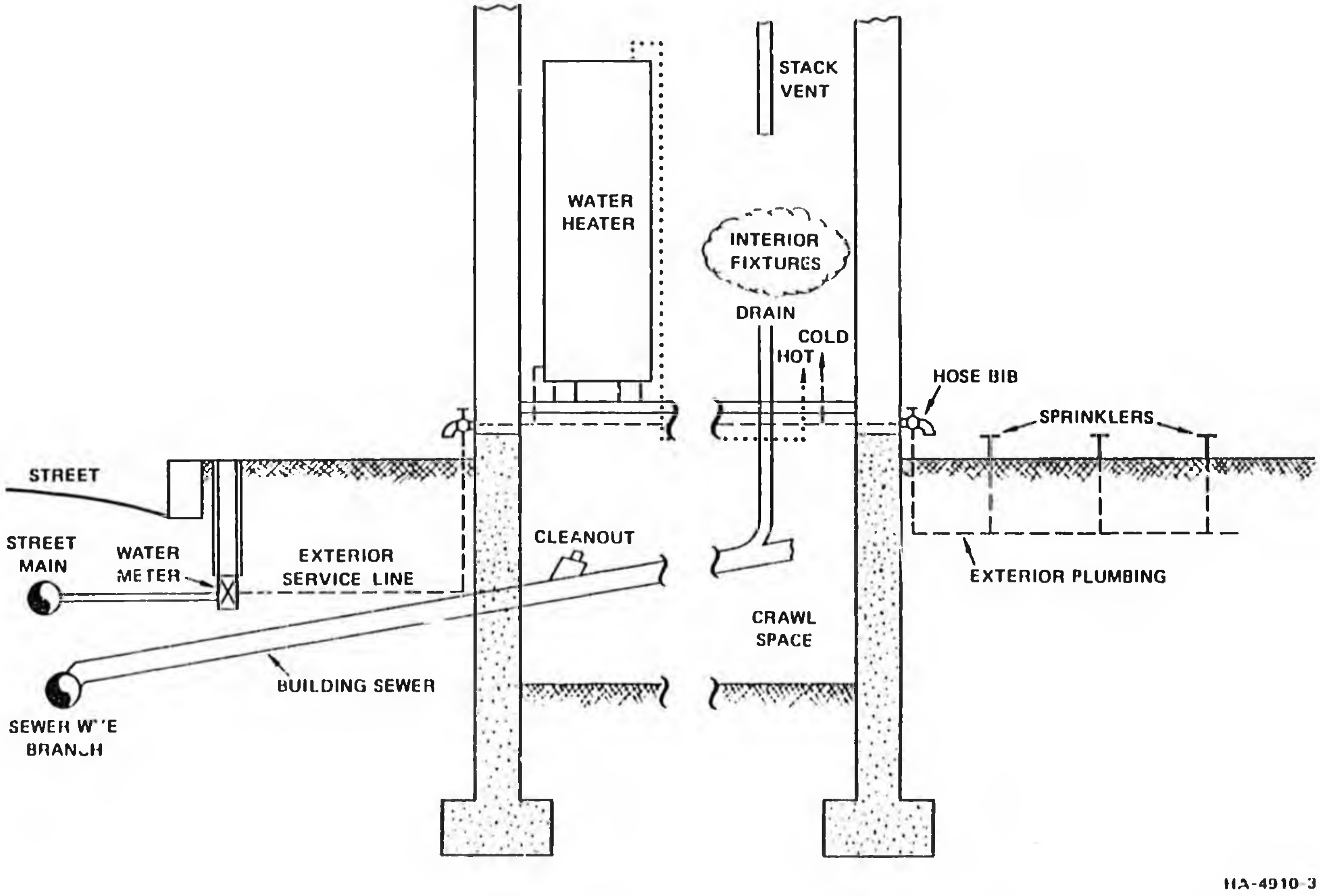

FIGURE III- 16 ILLUSTRATIVE CONNECTIONS TO WATER DISTRIBUTION AND WASTE COLLECTION SYSTEMS

Table III-23

PLUMBING COSTS AS A PERCENT OF CONSTRUCTION COSTS

Building Type	Range (%)	Mean (%)	Number of Samples
Retail Store	2 - 7	3.6	7
Church	2 - 7	4.0	5
Theater	4 - 5	4.3	3
Bank	3 - 7	4.5	8
Warehouse	3 - 7	4.7	6
Residence (W/Swimming Pool)	3 - 7	5.3	4
Gymnasium	4 - 11	6.7	3
Office	3 - 11	7.0	8
Supermarket	5 - 10	7.2	6
School (Elementary)	4 - 11	7.3	6
Restaurant	6 - 14	9.0	8
School (High School)	4 - 11	9.3	7
Garage (Vehicle Repair)	7 - 13	9.7	3
Apartment	9 - 11	10.2	6
Motel/Hotel	9 - 11	10.5	4
Clinic	7 - 15	10.8	6
Nursing Home	7 - 20	11.5	6
Low Rent Housing	8 - 14	11.5	4

Source: Dodge Digest of Building Costs and Specifications; McGraw-Hill, New York; 1977 hot water system--possibly accounting for 60% to 70% of the total supply installation.

Pipe sizing is a function of: (1) the number of fixture units served (Table III-24), (2) the supply pressure, and (3) the length of run to the farthest outlet. These parameters are those easily understood in the industry and serve as rough surrogates for quantity of flow, rate of flow, and head loss due to pipe friction. For example, a 3/4-inch inside supply pipe (i.e., exclusive of the outside system) would be required for the basic system shown in Figure III-16, given 16 fixture units (i.e., the indoor fixtures shown plus two hose bibs), a pressure range of 40 to 60 pounds, and no run longer than 100 feet.

Pipe cost differences are covered in Section IV.F of this report. As to the cost of installation, Table III-25 provides some insights into the influence of different piping materials on labor costs. The table is based on installation units of 100 feet. As noted, the times indicated do not include the installation of fittings, valves, and hangers. Though far more complex, precise cost-comparative analysis would be likely to consider such features.

c. Wastewater Plumbing--Drainage and Venting

As with the water supply system, drainage and vent pipe sizes are based on the number of connected fixture units (Table III-26). Although satisfactory for venting purposes, sizes below 2 inches in diameter tend not to be used for waste piping because of their tendency become clogged.

Table III-27 provides an indication of installation time differences between DWV piping types. Polypropylene pipe is included in the table only as a basis for comparing plastic pipe with the metal types shown, not to imply its use in the situation at hand. Table III-28 provides some additional comparisons of water pipe installation times.

Table III-24

FIXTURE UNIT VALUES FOR COMBINED HOT AND COLD WATER DEMANDS

Fixture	Number of Fixture Units
Bathtub (with or without shower over)	2
Hose bib or still cock (standard type)	3
Laundry tub or clothes washer (each pair of faucets)	2
Lavatory	1
Lawn sprinklers (standard type, each head)	1
Shower	2
Sink or dishwasher	2
Water closet (flush tank)	3

Table III-25

INSTALLATION TIMES FOR WATER SUPPLY PIPE
(Manhours per 100 Feet of Pipe)*

	Galv. Steel (A-120, Std. Wt.)			Copper (Type K Outside-Type L Inside)		
	Outside	Inside+	Inside#	Outside	Inside+	Inside#
1/2, 3/4, 1 inch	2.4	4.0	5.0	2.0	3.4	4.3
2 inch	3.1	5.3	7.0	2.6	4.5	6.0
3 inch	4.0	6.5	8.5	3.4	5.5	7.2
4 inch	4.8	8.0	10.0	--	--	--

	Red Brass (Sch. 40)			CPVC Plastic (Sch. 40 Hi-Temp)		
	Outside	Inside+	Inside#	Outside	Inside+	Inside#
1/2, 3/4, 1 inch	3.1	4.0	5.0	1.6	3.2	4.0
2 inch	3.1	5.3	7.0	2.1	4.2	5.6
3 inch	4.0	6.5	8.5	2.7	4.2	5.6
4 inch	4.8	8.0	10.5	3.2	6.4	8.0

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*Horizontally or vertically installed; maximum ceiling height of 12 feet. Does not include fittings, valves, and support devices. Outside lengths 20 feet.

+Single-story buildings.

#Multi-story buildings.

Source: General Construction Estimating Standards, Vol. 3; 1976-77, Richardson Engineering Services, Inc., California

Table III-26

FIXTURE UNIT VALUES FOR DRAIN AND WASTE LINES

Type of Fixture	Fixture Unit Value (d.f.u.)	Min. Trap and Fixture Drain size (in.)
Automatic clothes washer (2 inch standpipe)	3	2
Bathroom group consisting of a water closet, lavatory, and bathtub or shower stall:		
Flushometer valve closet	8	
Tank-type closet	6	
Bathtub (with or without overhead shower)	2	1-1/2
Combination sink with food waste grinder	2	1-1/2
Combination sink and tray with separate 1-1/2 inch traps	3	1-1/2
Dishwasher	2	1-1/2
Kitchen sink, with one 1-1/2 inch waste	2	1-1/2
Kitchen sink, with or without food waste grinder	2	1-1/2
Lavatory	1	1-1/4
Laundry tray (1 or 2 compartments)	2	1-1/2
Shower stall, domestic	2	2
Water closet, tank-operated	4	3
Water closet, valve-operated	6	3

LISTS MAXIMUM LOADING OF DRAINAGE AND VENT PIPING
Based Upon 1/4 In./Ft. Slope

Size of Pipe (Inches)	1-1/4"	1-1/2"	2"	3"	4"
Drainage Piping	1	3	12	42	180
Vent Piping	2	10	24	100	300