The Vinyl Institute

A Division of The Society of The Plastics Industry, Inc.

RECEIVED
JUL 24 1991
Sherry M.

Roy T. Gottesman
Executive Director

July 19, 1991

TO: Pipe Resource Organization
Electrical Materials Council

RE: 1991 Update of Cost/Benefit Study

As you may be aware, we commissioned Dr. Joseph Zicherman of IFT Technical Services to do an update of the Cost/Benefit Study on In-Place Costs and Technical and Regulatory Constraints to Use of PVC Based Pipe, Tube and Conduit in Construction. The original report was based on data gathered in 1988 and published in September 1989.

We had asked for an updating so that the paper that Dr. Zicherman presented at the Construction Specifiers Institute Meeting in San Diego on June 29 would be based on current information.

Enclosed is a copy of the report just received from IFT giving the results of the update. Essentially, the data confirms the findings in the earlier report about the economic advantages that accrue from the use of PVC although all of the cost numbers have changed due to changes in material prices and labor rates. This is for your information and files.

Separately I have asked Nora Jacobs and Dan Stanowick at Edward Howard & Company to advise me of the costs involved in preparing an update of the 4-page summaries that were issued in July 1990 that were based on the original cost/benefit study.

Roy

RTG/pmb

CTL027045

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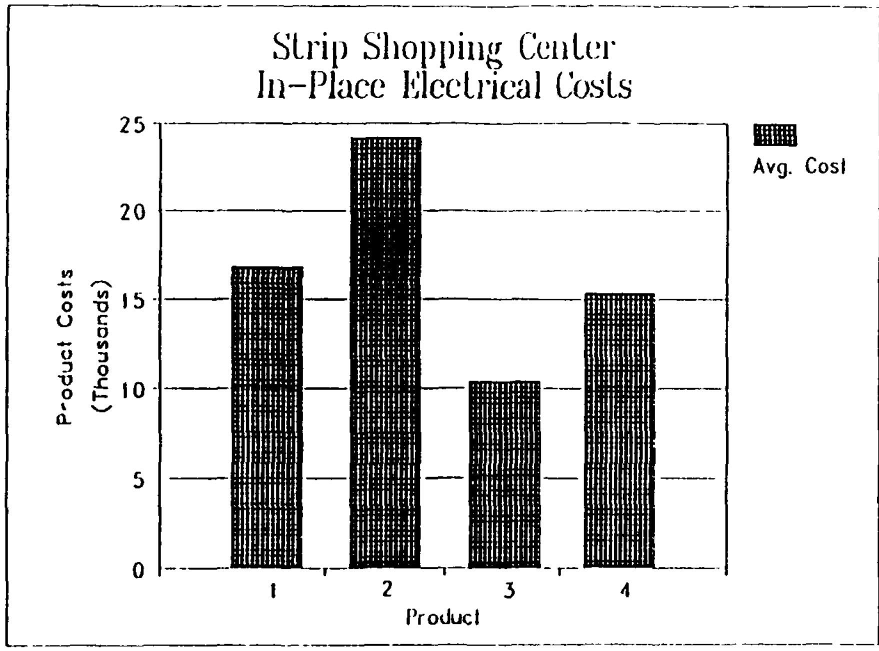

Legend

1 – ENT Concealed – Lighting

2 – EMT Concealed – Lighting

3 – ENT Concealed – Outlets

4 – EMT Concealed – Outlets

3.4.5 Strip Shopping Center In-Place Electrical Costs (in Dollars) - 1991

CSI SECTION NO.	DESCRIPTION	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	PROJECT COST AVERAGE
16.0510 16.0511	ENT Concealed-Lighting ENT with #12 CU Wire	19,104	18,566	16,536	14,925	16,238	15,462	16,805
16.0510 16.0512	EMT Concealed-Lighting EMT with #12 CU Wire	28,118	27,342	23,700	21,014	22,984	21,909	24,178
16.0510 16.0513	ENT Concealed-Outlets ENT with #12 CU Wire	11,998	11,614	10,205	9,095	9,949	9,436	10,383
16.0510 16.0514	EMT Concealed-Outlets EMT with #12 CU Wire	18,190	17,635	15,030	13,108	14,518	13,749	15,372

3.4.4 Strip Shopping Center
Ratio of In-Place Costs
CPVC/Copper DHCW - 1991

CSI SECTION NO.	DESCRIPTION	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	PROJECT RATIO AVERAGE
15.4160/15.4150	CPVC - DHCW - PROPRIETARY FIRE STOPPING/COPPER TYPE "M"	0.6483	0.6319	0.6161	0.5948	0.6232	0.6018	0.6193
15.4170/15.4150	CPVC - DHCW - GENERIC FIRE STOPPING/COPPER TYPE "M"	0.6430	0.6260	0.6096	0.5874	0.6170	0.5947	0.6130

3.5 Assemblies Analyzed

The table below lists the various fire-rated assemblies in the four types of buildings studied (walls and floor/ceilings and their construction elements) which included penetrations requiring fire-resistive detailing.

ASSEMBLIES ANALYZED

I WALLS

A) FRAMING
- Wood Studs 2" x 4" through 3" x 6"
- Metal Studs 1-5/8" deep through 5-1/2" deep

B) CLADDING (one or both sides)
- 5/8" Type "X" gypsum wallboard
- 1" gypsum core board
- 1/2" fiberglass mesh with mortar under tile
- 1/2" fiberglass mesh with mortar under marble
- wire reinforced stucco veneer
- plywood sheathing
- 7/8" metal furring with 1/4" marble facing
- 1/2" metal channel with 5/8" Type "X" gypsum wallboard

C) MONOLITHIC
- 5-5/8" concrete block
- 7-5/8" concrete block
- 12" concrete slab

II FLOOR/CEILING ASSEMBLIES

A) SLABS
- Minimum 4-1/2" thick

B) WOOD FRAME
- 2" x 8" wood joists with 5/8" plywood decking and 5/8" Type "X" gypsum wallboard on 1/2" metal channels

III INSULATIONS

R-8 through R-11 fiberglass batt-2" through 6" in thickness

IV PENETRATING ELEMENTS

A) DWV - 3/4" (condensate) through 8" PVC Schedule 40
B) DHCW - 1/2" CPVC through 6"
C) Sprinkler Risers - various sizes
D) ENT, RNMC, - 3/4" and 1" PVC

3.4.6 Strip Shopping Center
Ratio of In-Place Costs
ENT/EMT - 1991

CSI SECTION NO.	DESCRIPTION	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	PROJECT RATIO AVERAGE
16.0510 16.0511/16.0512	ENT/EMT Concealed-Lighting with #12 CU Wire	0.6794	0.6790	0.6977	0.7102	0.7065	0.7057	0.6964
16.0510 16.0513/16.0514	ENT/EMT Concealed-Outlets with #12 CU Wire	0.6596	0.6586	0.6790	0.6939	0.6853	0.6863	0.6771

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4.0 CODE APPROVALS

4.1 Building Codes

In terms of building code acceptance and approval, all three model building codes permit unlimited use of combustible (i.e., PVC) piping, tube, and conduit products in all construction types. Each code contains somewhat different caveats with regard to the use of these products, but all depend on the ASTM E-814 fire-test method to demonstrate adequate thru-penetration fire performance. ASTM E-119 may be invoked as well to express overall construction assembly performance when PVC pipe, tube and/or conduit are included. Recent favorable review of a revised edition of the PPFA installation manual by CABO-NES will enhance acceptance of NC piping products by the building code community.

Relative to building codes, no bars exist to unlimited use of PVC pipe, tube, or conduit, provided the appropriate subsidiary code (electrical or plumbing) allows for their use. Such Building Code acceptance, however, is often based on demonstrations of satisfactory performance in E-814 or E-119 testing mandated by the alternate materials and/or installation methods language found in each code.

Restrictions to the use of combustibles in concealed spaces and/or return air plenums do affect use of PVC products. These are appropriate if the space is used for an HVAC function, but have no technical merit in other cases.

4.2 Plumbing Codes

While the Standard (SBCCI) and National Building Code (BOCA) both utilize plumbing codes which do not restrict use of PVC pipe, this is not the case with the Uniform Plumbing Code which is promulgated by IAPMO (The International Conference of Plumbing and Mechanical Officials) for ICBO (International Conference of Building Officials).

Thus, in geographic areas where the IAPMO code is the adopted plumbing code, use of plastic pipe is restricted to buildings which are three stories or less in height. Because of this specific restriction, "alternative materials and methods interpretations" found in the building code are typically unavailable to the end-user/specifier since the building official would be required to overrule both his plumbing inspector and the adopted plumbing code. Thus, existence of specific acceptance criteria which will allow use of PVC materials in the Uniform Building Code is rendered moot at this time where

A total of eight combustible assemblies (i.e., those including wood framing members) were analyzed. Non-combustible, fire-rated assemblies requiring fire-resistive detailing analyzed included twenty-one different configurations with metal stud-based framing. Four monolithic walls and floor/ceilings based on concrete slabs or block were also analyzed.

Many of the metal-framed walls (as well as wood-framed ones) differed only in the presence or absence of fiberglass batt insulation (usually for sound control) or in thickness of walls. For example, walls containing plumbing chases varied in thickness as related to sizing of DWV found in a particular chase. Conversely, while walls with electrical service only were of minimum thickness, all walls were considered to contain the minimum number of outlets required by the applicable code for the number of outlets in each room.

Additionally, several of the wall configurations were non-conventional, e.g.,

- gypsum wallboard on one side of metal studs and tile or marble over mesh/grout on the other.
- plumbing chases bounded by a concrete slab (shaft) wall on one side and gypsum wallboard on the other.

5.0 TECHNICAL CONSTRAINTS

The types of fire-rated construction assemblies occurring in the buildings analyzed in this study are quite broad. Thus, they present a good vehicle for reviewing available technical data as it relates to construction assemblies in general being used with PVC products.

They range from relatively standard assemblies being penetrated by PVC piping from 3/4" in diameter (condensate drains) through 1-1/2" or 2" DWV lines and sprinkler lines. Such walls also include piping as large as 4", with greater diameters typically passing through slabs. They all contain ENT and most have openings for electrical boxes. Overall, the expanded efforts by manufacturers of thru penetration firestopping materials and devices have been fruitful as expressed in the hundreds of such systems found in UL handbooks, as well as in CABO-NER Research Committee recommendations.[3]

5.1 Plumbing Walls

Of the wall types, the most common, in terms of available supporting test data, were stud walls based on 2" x 6" (nominal) wood and metal studs for plumbing uses. Both have been fire endurance tested with and without fiberglass insulation. Because these walls were tested with <u>both</u> thru-penetrations and simulated drain lines and vent stacks, such walls containing either PVC thru-penetrations and/or drain lines and/or vents should be acceptable to code authorities.

In terms of fire endurance, duration of tested walls (hourly-rating), 6" deep one and two-hour walls with metal framing have been tested directly, as have one-hour wood-frame walls. Given that metal frame test results are commonly accepted for use in wood framing systems of identical dimensions and fire endurance ratings, two-hour wood walls containing PVC, DWV, and DHCW piping should be acceptable. While no testing of PVC plumbing thru-penetrations with generic firestopping has been conducted for shaft walls, proprietary systems for such installations have been tested and are UL listed.

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[3]Examples of these efforts have resulted in recent CABO-NER [NER 370 issued 4-91] recognition for Model Building Code reference of the PPFA insulation manual "Plastic Pipe in Fire Resistive Construction" and publication of The Vinyl Institute sponsored research describing PVC-DWV fire performance in NFPA, BOCA and ICBO journals.

the Uniform Plumbing Code is used for buildings over three stories. However, from 1991 forward PVC pipe can be used in all types of construction (combustible and non-combustible) three stories or less.

The situation in the case of the IAPMO code creates a potentially serious impact to the expanded use of PVC-DWV and DHCW in the Western and mid-Western U.S.. Continuation of the present policies will limit growth of PVC product use in these areas.

4.3 Electrical Codes

The National Electrical Code, promulgated by the National Fire Protection Association (NFPA), allows for unlimited use of PVC-based conduit and tubing as long as it is not directly exposed to room areas. Specifically, these products must be protected (at minimum) by a 15-minute thermal barrier. In addition, they cannot be installed in areas where they will be exposed to return air flows for heating, ventilating, and air conditioning systems as in plenum spaces.

Few code-related bars to the use of PVC-based electrical products appear to exist at this time. However, further testing for both thermal barrier and fire endurance properties of assemblies incorporating these products is still needed. This will be discussed in the next section.

4.4 Major Cities

While few small to medium sized cities write their own building codes, several large cities do write codes impacting use of PVC (and other) plastic pipe, tube, and conduit products. Examples include Chicago, Seattle, San Francisco and Denver. In many of these situations, partial approvals and restrictions for these products exist through amendments made to a specific, adopted model code. Recent legal action in Pittsburgh has lifted many of these restrictions.

Extensive lobbying efforts, as well as presentation of appropriate technical data, will be needed before cities such as those listed above can be expected to allow expanded use of PVC products. In addition, because of the role unions, cost-plus contractors and contracting associations play in code adoption processes and enforcement in such cities, acceptance of the PVC products will require continued long term planning and work.

6.0 ECONOMIC/COST BENEFIT SUMMARY

Table and charts which follow summarize analyses conducted for the four classes of buildings studied. Numerical values are based on an average of dollar costs in the cities surveyed. Thus, they reflect the mid-range in cost of each product as installed.

Results show that use of PVC-based piping and electrical products present clear advantages overall in spite of the fact that they require additional fire-resistive installation detailing for certain applications.

Findings are sensitive to some extent to pipe diameter, but most of all to number of penetrations occurring in subject structures. For example, the data for the highrise residential and commercial structures both include substantially higher material and/or labor costs for particular pipe sizes such as 2" and 3" PVC-DWV or 1/2" CPVC-DHCW. The reason for this is not the cost of the pipe itself. Rather these are the sizes of pipe requiring firestop detailing which leads to substantially higher unit (i.e., price per foot installed) costs. When included in the overall price estimates however, the impact of such high unit costs are reduced. Such data support the need for an easily used thru-penetration firestop system (i.e., one with a low cost of installation).

5.2 Electrical In Walls

The situation with ENT and PVC-RNMC is similar to that with PVC-DWV, although few test results can be found justifying use of these products in other than two-hour walls and partitions.

Likewise, tests of the two-hour electrical assemblies were carried out with assemblies of 4" nominal depth. In the absence of data for thinner two-hour assemblies, a knowledgeable code official would be justified in refusing use of PVC electrical products in other than two-hour walls of nominal 4" or greater thickness. This lack of one-hour test results has already proved problematic in the field for ENT use in thinner walls containing ENT only or PVC boxes and ENT.

5.3 Floor/Ceiling Assemblies

With regard to floor/ceiling assemblies, no PVC plumbing products have been successfully tested in full-sized wood stud or metal-framed assemblies for the full duration intended in the tests.

NEMA's PVC conduit section has now conducted a successful fact-finding series with a non-combustible F/C assembly at Underwriter's Laboratories. This has led to a new three (3) hour CABO-NER recommendation. Earlier, testing with wood-framed F/C systems was conducted to assess the impact of the use of PVC boxes in particular on such assemblies.

Based on test results available, (with the exception of the National Electrical Code regulation requiring 15-minute finish rating protection with PVC-ENT use and building code prohibitions on their use in return-air plenums), use of PVC-ENT and conduit electrical products can be better justified in F/C assemblies than can use of PVC-DWV pipe.

7.0 CONCLUSION

Cost savings attainable through use of the PVC products studied are significant. This is the case even with the necessity to utilize firestop detailing which increases costs substantially, as is well demonstrated by data for pipe sizes commonly exiting from within fire-resistive assemblies such as shaft or other walls backing up on kitchens, lavatories, etc.

To realize the cost advantages the PVC products evaluated in this report and to achieve greater market penetration for such products, concerted focus on the code process in the Western U.S. will be needed along with continued work in major cities. In addition, the possible requirement of additional supportive fire-test data in selected plumbing and electrical product areas by local code officials will have to be addressed.

Cost/Benefit SummaryTables 1991

CSI Section No.	Description	Highrise Residential Average	PVC Product Cost as % of Metal Pipe	Highrise Commercial Average	PVC Product Cost as % of Metal Pipe	Wood-frame Townhouse Average	PVC Product Cost as % of Metal Pipe	Strip Shopping Average	PVC Product Cost as % of Metal Pipe
15.4100	Cast iron pipe hubless mech, joint	351,669		79,166		117,054		33,418	
15.4110	PVC, Sch 40, in building, w/ftgs, supports and proprietary fire stopping	207,619	59	56,549	71	72,546	62	20,546	61
15.4120	PVC, cellular core, Sch 40 in building w/ftgs, supports, and proprietary fire stopping	203,342	58	52,903	67	71,532	61	19,876	59
15.4130	PVC, solid core, Sch 40, in building w/ftgs, supports and generic fire stopping when possible	207,328	59	52,997	67	70,307	60	20,109	60
15.4140	PVC, cellular core, Sch 40, in building w/ftgs, supports and generic fire stopping when possible	202,976	58	52,054	66	69,423	59	19,474	58
15.4150	Copper pipe "l" in building, w/ftgs & supports	216,817		69,381		81,339		17,547	
15.4160	CPVC, supply pipe w/ftgs, supports a proprietary fire stopping	130,065	60	43,257	62	70,184	86	10,918	62
15.4170	CPVC, supply pipe w/ftgs, supports a generic proprietary fire stopping when possible	132,203	61	42,634	61	65,195	80	10,808	62
16.0510 16.0511	ENT Concealed-Lighting ENT with #12 CU Wire	79,828		32,451		38,227		16,805	
16.0510 16.0512	EMT Concealed-Lighting EMT with #12 CU Wire	114,898	69	46,696	69	54,999	69	24,177	70
16.0510 16.0513	ENT Concealed-Outlets ENT with #12 CU Wire	218,412		85,108		18,043		10,383	
16.0510 16.0514	EMT Concealed-Outlets EMT with #12 CU Wire	323,352	68	126,000	68	26,712	68	15,372	68

MATERIALS NOTES[4]

PIPE PRICING

Includes: Pipe, fittings, supports, man-hours for each component at local union rates, subcontractor overhead and profit, and tax.

FIRESTOPPING SYSTEMS CONSIDERED FOR ESTIMATE PREPARATION

Proset: Coupling, wye, plug. Installation is that of one/two fittings depending on system.

3M: Pipe wrapping, aluminum foil tape and caulking.

Thermafiber®: Batt insulation in walls but applied around pipe then sealed with smoke sealant.

DISTRIBUTORS CONTACTED FOR FIRESTOPPING

PVF Sales, Inc.
3M Electrical Product Division
U.S.G.
Gypsum Drywall Supply
R.V. Associates
Orion Industries
Weiss Russell & Co.
Scanlain & Associates Sales Co.
Proset System, Inc.

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[4] The total cost per lineal foot of pipe installed is affected by the number of penetrations per total pipe footage, e.g. for 200 penetrations/4000 lineal feet, the lineal foot cost is hardly affected. Whereas with 200 penetrations/800 lineal feet, the cost per lineal foot is greatly affected.

APPENDIX A*

MATERIALS NOTES

* In order to prepare the needed data, plans for each building were analyzed to determine (a) number of feet of product used (i.e., pipe, tube, or conduit), (b) number of fittings needed and (c) detailing needed to utilize the PVC products (i.e., firestop detailing, hangers, etc.). These materials were then totaled for a given size of pipe, tube, or conduit. Next, the unit cost was determined by dividing the total cost (of <u>all</u> materials) by the total number of feet used. This result is the "material cost" which is the average-per-foot cost. Next, labor costs associated with installing the number of feet of pipe, fittings, firestop and other detailing were totaled by pipe size. An average, again based on total feet of pipe of a particular size, was then taken representing an average labor cost. The sum of these two averages was used to determine the unit cost figure quoted. San Francisco was used as a base city, although calls were made to sources in the other five cities to develop local material, labor, and unit costs. This methodology is standard to the construction estimating industry for large projects.

APPENDIX B

ELECTRICAL NOTES

DISTRIBUTORS CONTACTED FOR PIPE/FITTINGS

San Francisco & Seattle:	Harrington Plastics P. E. O'Hair
Houston:	Harry Hope & Associates Hugh Cunningham Dan Roberts
Atlanta:	Clary Knovland Ferguson Rozzel Barks Sales
Cleveland:	Webbs Supply B. F. Goodrich Wolen Sales R. G. Sloane
Boston:	Boston Pipe & Fittings B. F. Goodrich Central Pipe & Supply Brahmen Dow & Co. Urellic Co. Total Plastic, Inc. Holbrook Plastic Pipe Supply, Inc.

CONTACTS FOR CELLULAR/FOAM CORE PVC PIPING

Plastics Pipe Institute
Plastic Pipe & Fittings Association
National Sanitation Foundation
Bristolpipe
L & H
Aaron Co.

APPENDIX C

3M FIRE BARRIER® NOTES

ELECTRICAL NOTES

In completing the calculations required for the electrical portion of the study, two basic criteria were used.

The lighting circuits conduit/wire and the device circuits conduit/wire were compared when using both electrical metallic tubing (EMT) and electrical non-metallic tubing (ENT). Both conduit and wire systems were figured with appropriate numbers of couplings and terminators and with #12 copper wire required for the circuits. In addition, both were shown at 3/4" and 1" sizes for each type of conduit.

Material costs were determined by phoning the Graybar distributors in the cities used for the study. The costs were discounted and marked up to reflect the retail value of the materials used. Labor rates were also calculated by using each individual city union labor rate and applying it to pre-determined unit man-hours.

APPENDIX D

RAW COST DATA FOR PROJECT ESTIMATES

3M FIRE BARRIER® NOTES						
ITEM #	DESCRIPTION	MAN HRS	MAT'L	INSTALL	TOTAL	UNIT
15.1607	Fire Barrier Penetration					
	System, Plastic Pipe					
15.1607011	FB, Water, Cplg, Ftg w / plg 1/2"-1"	0.0798	1.20	5.46	6.66	EA
15.1607021	FB, Water, Cplg, Ftg w / plg 2"	0.0903	3.02	6.18	9.20	EA
15.1607031	FB, Water, Cplg, Ftg w / plg 2 1/2"-3"	0.1103	3.59	7.55	11.14	EA
15.1607041	FB, Water, Cplg, Ftg w / plg 4"-5"	0.1247	5.18	8.52	13.70	EA
15.1607051	FB, Water, Cplg, Ftg w / plg 6"	0.1352	11.47	9.25	20.72	EA
15.1607061	FB, Water, Cplg, Ftg w / plg 8"	0.1488	17.52	10.17	27.69	EA
15.1607071	FB, Dwv, Cplg, Ftg w / plg 2"	0.0999	7.16	6.84	14.00	EA
15.1607081	FB, Dwv, Cplg, Ftg w / plg 3"	0.1299	10.35	8.89	19.24	EA
15.1607091	FB, Dwv, Cplg, Ftg w / plg 4"	0.1500	13.15	10.27	23.42	EA
15.1607111	FB, Dwv, Cplg, Ftg w / plg 6"	0.1786	19.92	12.22	32.14	EA
15.1607121	FB, Dwv, Cplg, Ftg w / plg 8"	0.2012	22.71	13.77	36.48	EA
15.1607131	FB, Caulk, Wrap / Strip 1/2"-1"	0.0999	1.06	6.84	7.90	EA
15.1607141	FB, Caulk, Wrap / Strip 2"	0.1200	1.56	8.21	9.77	EA
15.1607151	FB, Caulk, Wrap / Strip 3"	0.1398	3.01	9.57	12.58	EA
15.1607161	FB, Caulk, Wrap / Strip 4"	0.1499	3.81	10.26	14.07	EA
15.1607171	FB, Caulk, Wrap / Strip 5"	0.1700	4.05	11.63	15.68	EA
15.1607181	FB, Caulk, Wrap / Strip 6"	0.1899	6.86	13.00	19.86	EA
15.1607191	FB, Caulk, Wrap / Strip 8"	0.2099	12.26	14.36	26.62	EA
15.1607211	FB, Batt w / Smoke Seal 1/2"-1"	0.0931	0.04	6.37	6.41	EA
15.1607221	FB, Batt w / Smoke Seal 2"	0.1090	0.06	7.46	7.52	EA
15.1607231	FB, Batt w / Smoke Seal 3"	0.1233	0.17	8.44	8.61	EA
15.1607241	FB, Batt w / Smoke Seal 4"	0.1450	0.26	9.92	10.18	EA
15.1607251	FB, Batt w / Smoke Seal 5"	0.1607	0.36	11.00	11.36	EA
15.1607261	FB, Batt w / Smoke Seal 6"	0.1852	0.65	12.67	13.32	EA
15.1607271	FB, Batt w / Smoke Seal 8"	0.2028	1.12	13.88	15.00	EA

D.1.1

Highrise Residential In-Place Costs - DWV - Raw Data - 1991

CSI SECTION NO.	DESCRIPTION	MATERIAL COST	LABOR COST	SAN FRANCISCO	BOSTON *	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	UNIT COST AVERAGE
15.400	PLUMBING									
15.410	PLUMBING PIPING									
	C.I.P., SOIL NO HUB MECH. JOINT:									
15.4101	C.I.P., Soil, 1 1/2" No Hub	3.93	11.83	15.76	12.92	10 91	8.90	11.74	9.49	11.62
15.4102	C.I P., Soil, 2" No Hub	4.09	11.83	15.92	13.08	11.07	9.06	11.90	9.65	11.78
15.4103	C.I.P., Soil, 3" No Hub	5.36	12.94	18.30	15.19	12.99	10.79	13.90	11.44	13.77
15.4104	C.I.P., Soil, 4" No Hub	6 83	13.62	20.45	17.18	14 87	12 55	15.82	13.23	15.68
15.4105	C.I.P., Soil, 5" No Hub	8.85	15.62	24.47	20.72	18.07	15.41	19.16	16.19	19.00
15.4106	C.I.P., Soil, 6" No Hub	10.80	12.94	28.74	20.63	18.43	16.23	19.34	16.88	20.04
	PVC, SOLID CORE, SCH 40, IN BUILDING W/FTGS, SUPPORTS AND PROPRIETARY FIRE STOPPING:									
15.4111	Pipe, PVC, Sch 40, 1 1/2	1.60	10.56	12.16	9.63	7.83	6 04	8.57	6.56	8.46
15.4112	Pipe, PVC, Sch 40, 2"	1.41	6.78	8 19	6.56	5.41	4.26	5.88	4.60	5.82
15.4113	Pipe, PVC, Sch 40, 3"	2.58	8.82	11.40	9.28	7.78	6.28	8.40	6.73	8.31

CTL027066

APPENDIX D.1

HIGHRISE RESIDENTIAL

	PVC, CELLULAR CORE, SCH 40, IN BUILDING W/FTGS, SUPPORTS AND GENERIC FIRE STOPPING WHEN POSSIBLE									
15.4441	Pipe, PVC, Sch 40, 1 1/2	1.06	9.21	10.27	8.06	6.49	4.93	7.14	5.39	7.05
15.4442	Pipe, PVC, Sch 40, 2"	1.31	6.78	8.09	6.46	5.31	4.16	5.78	4.50	5.72
15.4443	Pipe, PVC, Sch 40, 3"	2.45	8.82	11.27	9.15	7.65	6.15	8.27	6.60	8.18
15.4444	Pipe, PVC, Sch 40, 4"	3.43	9.23	12.66	10.44	8.88	7.31	9.52	7.77	9.43
15.4445	Pipe, PVC, Sch 40, 5"	4.09	9.59	13.68	11.38	9.75	8.12	10.42	8.60	10.32
15.4446	Pipe, PVC, Sch 40, 6"	6.20	10.09	16.29	13.87	12.15	10.44	12.86	10.94	12.76
	UNIT COST REPRESENTS INSTALLED COST, PER FOOT, OF PIPE TUBING OR CONDUIT ESTIMATED.									
	• MANUFACTURER/SUPPLIER WOULD NOT REVEAL PVC PRICES WITHOUT AN ORDER. NUMBERS BASED ON ESTIMATE.									

CTL027068

15.4114	Pipe, PVC, Sch 40, 4"	3.61	9.23	12.84	10.62	9.06	7.49	9.70	7.95	9 61
15.4115	Pipe, PVC, Sch 40, 5"	4.34	9.59	13.93	11 63	10 00	8 37	10.67	8.85	10.57
15.4116	Pipe, PVC, Sch 40, 6"	6.55	10.09	16.64	14.22	12.50	10.79	13 21	11.29	13.11
	PVC, CELLULAR CORE, SCH. 40 IN BUILDING SUPPORT, AND PROPRIETARY FIRE STOPPING:									
15.4121	Pipe, PVC, Sch 40, 1 1/2	1.54	10.56	12.10	9.57	7 77	5.98	8 51	6.50	8 40
15 4122	Pipe, PVC, Sch 40, 2"	1.32	6.78	8.10	6.47	5.32	4.17	5.79	4.51	5.73
15.4123	Pipe, PVC, Sch 40, 3"	2.45	8.82	11.27	9.15	7.65	6.15	8.27	6.60	8 18
15.4124	Pipe, PVC, Sch 40, 4"	3.43	9.23	12.66	10.44	8 88	7.31	9.52	7.77	9 43
15.4125	Pipe, PVC, Sch 40, 5"	4.09	9.59	13.68	11.38	9 75	8.12	10.42	8.60	10.32
15.4126	Pipe, PVC, Sch 40, 6"	6.21	10.09	16.30	13.88	12.16	10.45	12.87	10.95	12.77
	PVC, SOLID CORE, SCH 40, IN BUILDING W/FTGS, SUPPORTS AND GENERIC FIRE STOPPING WHEN POSSIBLE:									
15.4131	Pipe, PVC, Sch 40, 1 1/2	1.11	10.30	11.41	8.94	7.19	5.44	7.91	5.95	7.81
15.4132	Pipe, PVC, Sch 40, 2"	1.41	6.78	8.19	6.56	5.41	4.26	5.88	4.60	5.82
15.4133	Pipe, PVC, Sch 40, 3"	2.58	8 82	11.40	9.28	7.78	6 28	8.40	6.73	8.31
15.4134	Pipe, PVC, Sch 40, 4"	3.62	9.23	12.85	10 63	9.07	7.50	9.71	7.96	9.62
15.4135	Pipe, PVC, Sch 40, 5"	4.31	9.59	13.90	11.60	9.97	8.34	10.64	8 82	10.54
15.4136	Pipe, PVC, Sch 40, 6"	6.53	10 09	16.62	14.20	12.48	10.77	13 19	11.27	13.09

	CPVC, W/FTGS, SUPPORTS, GENERIC FIRE STOPPING WHEN POSSIBLE:									
15.4171	Pipe, CPVC, 1/2"	1.16	6.18	7.34	5.86	4.81	3.76	5.24	4.06	5.18
15.4172	Pipe, CPVC, 3/4"	1.44	6.49	7.93	6.37	5.27	4.17	5.72	4.49	5.66
15.4173	Pipe, CPVC, 1"	1.79	6.17	7.96	6.48	5.43	4.38	5.86	4.69	5.80
15.4174	Pipe, CPVC, 1 1/4"	2.50	5.86	8.36	6.95	5.96	4.96	6.37	5.25	6.31
15.4175	Pipe, CPVC, 1 1/2"	2.48	6.43	8.91	7.37	6.27	5.18	6.72	5.50	6.66
15.4176	Pipe, CPVC, 2"	3.18	6.75	9.93	8.31	7.16	6.02	7.64	6.35	7.57

CTL027070

D.1.2

Highrise Residential In-Place Costs - DHCW - Raw Data - 1991

CSI SECTION NO.	DESCRIPTION	MATERIAL COST	LABOR COST	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	UNIT COST AVERAGE
	COPPER "L", W/FTGS & SUPPORTS:									
15.4151	Pipe, Copper "L", 1/2"	1.62	5.41	7.03	5.73	4.81	3.89	5.19	4.16	5.14
15.4152	Pipe, Copper "L", 3/4"	2.40	6.58	8.98	7.40	6.28	5.16	6.74	5.49	6.68
15.4153	Pipe, Copper "L", 1"	3.36	7.80	11.16	9.29	7.96	6.64	8.51	7.03	8.43
15.4154	Pipe, Copper "L", 1 1/4"	4.67	8.43	13.10	11.08	9.64	8.21	10.23	8.63	10.15
15.4155	Pipe, Copper "L", 1 1/2"	5.43	8.97	14.40	12.25	10.72	9.20	11.35	9.65	11.26
15.4156	Pipe, Copper "L", 2"	7.77	10.81	18.58	15.99	14.15	12.31	14.90	12.85	14.80
	CPVC, W/FTGS, SUPPORTS AND PROPRIETARY FIRE STOPPING:									
15.4161	Pipe, CPVC, 1/2"	1.21	6.25	7.46	5.96	4.90	3.84	5.34	4.15	5.27
15.4162	Pipe, CPVC, 3/4"	1.50	6.29	7.79	6.28	5.21	4.14	5.65	4.46	5.59
15.4163	Pipe, CPVC, 1"	2.13	5.60	7.73	6.39	5.43	4.48	5.83	4.76	5.77
15.4164	Pipe, CPVC, 1 1/4"	2.57	5.57	8.14	6.80	5.86	4.91	6.25	5.19	6.19
15.4165	Pipe, CPVC, 1 1/2"	2.59	5.94	8.53	7.10	6.09	5.08	6.51	5.38	6.45
15.4166	Pipe, CPVC, 2"	3.26	6.41	9.67	8.13	7.04	5.95	7.49	6.27	7.43

APPENDIX D.2

HIGHRISE BUSINESS/COMMERCIAL

D.1.3

Highrise Residential In-Place Costs - Electrical - Raw Data - 1991

CSI SECTION NO.	DESCRIPTION	MATERIAL COST	LABOR COST	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	UNIT COST AVERAGE
16000	ELECTRICAL									
16050.10	Conduit/Wire Assy - Lighting Circuits									
16050.11	3/4" ENT Conduit with CU Wire	1.81	1.39	3.20	3.11	2.77	2.50	2.72	2.59	2.82
16050.15	1" ENT Conduit with CU Wire	1.99	1.52	3.51	3.42	3.03	2.75	2.99	2.84	3.09
16050.12	3/4" EMT Conduit with CU Wire	2.22	2.49	4.71	4.58	3.97	3.52	3.85	3.67	4.05
16050.16	1" EMT Conduit with CU Wire	2.54	2.63	5.17	5.03	4.35	3.88	4.26	4.06	4.46
16050.10	Conduit/Wire Assy - Outlet Circuits									
16050.13	3/4" ENT Conduit with CU Wire	1.42	1.39	2.81	2.72	2.39	2.13	2.33	2.21	2.43
16050.17	1" ENT Conduit with CU Wire	1.60	1.52	3.12	3.03	2.65	2.38	2.60	2.46	2.71
16050.14	3/4" EMT Conduit with CU Wire	1.77	2.49	4.26	4.13	3.52	3.07	3.40	3.22	3.60
16050.18	1" EMT Conduit with CU Wire	1.89	2.63	4.52	4.38	3.70	3.23	3.61	3.41	3.81

15.4113	Pipe, PVC, Sch 40, 4"	4.64	9.89	14.53	12.16	10.48	8.79	11.17	9.29	11 07
15.4114	Pipe, PVC, Sch 40, 6"	7.47	12.31	19.78	16 83	14.73	12.64	15.59	13.26	15.47
15.4115	Pipe, PVC, Sch 40, 8"	11.48	13.08	24.57	21.42	19.20	16.97	20.11	17.63	19.98
	PVC, CELLULAR CORE, SCH. 40 IN BUILDING w/FTGS, SUPPORT, AND PROPRIETARY FIRE STOPPING:									
15.4121	Pipe, PVC, Sch 40, 1 1/2" - 2"	1.73	8 64	10.37	8.30	6.83	5 36	7.43	5.79	7.35
15.4122	Pipe, PVC, Sch 40, 2 1/2" - 3"	4.32	10.24	14.56	12.10	10.36	8 62	11.08	9.13	10.98
15.4123	Pipe, PVC, Sch 40, 4"	3 62	9 89	13.51	11.14	9.46	7.77	10.15	8 27	10.05
15.4124	Pipe, PVC, Sch 40, 6"	7.15	12.31	19.46	16.51	14.41	12.32	15.27	12.94	15.15
15.4125	Pipe, PVC, Sch 40, 8"	10.92	13.08	24.00	20.86	18.64	16.41	19.55	17.07	19.42
	PVC, SOLID CORE, SCH 40, IN BUILDING W/FTGS, SUPPORTS AND GENERIC FIRE STOPPING WHEN POSSIBLE:									
15.4131	Pipe, PVC, Sch 40, 1 1/2" - 2"	1.57	8.50	10 07	8.03	6.59	5.14	7.18	5.57	7.10
15.4132	Pipe, PVC, Sch 40, 2 1/2" - 3"	4.16	10.11	14.27	11.84	10.12	8.41	10.83	8.91	10.73
15.4133	Pipe, PVC, Sch 40, 4"	3.71	9.88	13.59	11.22	9.54	7.86	10.23	8.35	10 13
15.4134	Pipe, PVC, Sch 40, 6"	7.16	12.30	19.46	16.51	14.42	12.33	15.28	12.94	15.16
15.4135	Pipe, PVC, Sch 40, 8"	11 24	13.07	24 31	21.17	18.95	16.73	19.87	17.38	19 74

D.2.1

Highrise Commercial In-Place Costs - DWV - Raw Data - 1991

CSI SECTION NO.	DESCRIPTION	MATERIAL COST	LABOR COST	SAN FRANCISCO	BOSTON *	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	UNIT COST AVERAGE
15.4000	PLUMBING									
15.4100	PLUMBING PIPING									
	C.I.P., SOIL NO HUB MECH, JOINT:									
15.4101	C.I.P., Soil, 1 1/2" - 2" No Hub	3.93	11.83	15.76	12.92	10.91	8.90	11.74	9.49	11.62
15.4102	C.I.P., Soil, 2 1/2" - 3" No Hub	5.36	12.94	18.30	15.19	12.99	10.79	13.90	11.44	13.77
15.4103	C.I.P., Soil, 4" No Hub	6 83	13 62	20.45	17.18	14.87	12.55	15.82	13.23	15.68
15.4104	C.I.P., Soil, 6" No Hub	10.80	17.94	28.74	24.43	21.38	18.33	22.64	19.23	22.46
15.4105	C.I.P., Soil, 8" No Hub	12.18	20.26	32.44	27.58	24.13	20 69	25.55	21.70	25.35
	PVC, SOLID CORE, SCH 40, IN BUILDING W/FTGS, SUPPORTS AND PROPRIETARY FIRE STOPPING:									
15.4111	Pipe, PVC, Sch 40, 1 1/2" - 2"	1.80	8 64	10.44	8.37	6.90	5.43	7.50	5.86	7.42
15.4112	Pipe, PVC, Sch 40, 2 1/2" - 3"	4.43	10.24	14.67	12 21	10.47	8.73	11.19	9.24	11.09

CTL027075

D.2.2

Highrise Commercial In-Place Costs - DHCW - Raw Data - 1991

CSI SECTION NO.	DESCRIPTION	MATERIAL COST	LABOR COST	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	UNIT COST AVERAGE
	COPPER "L", W/FTGS & SUPPORTS:									
15.4151	Pipe, Copper "L", 1/2" - 3/4"	2.40	6.69	9.09	7.48	6.35	5.21	6.82	5.54	6.75
15.4152	Pipe, Copper "L", 1" - 1 1/2"	5.43	9.12	14.55	12.36	10.81	9.26	11.45	9.72	11.36
15.4153	Pipe, Copper "L", 2"	7.77	11.00	18.77	16.13	14.26	12.39	15.03	12.94	14.92
15.4154	Pipe, Copper "L", 3"	14.55	14.00	28.55	25.19	22.81	20.43	23.79	21.13	23.65
15.4155	Pipe, Copper "L", 4"	24.70	17.06	41.76	37.67	34.77	31.87	35.96	32.72	35.79
15.4156	Pipe, Black Steel, 6"	19.21	29.34	48.55	41.51	36.52	31.53	38.57	33.00	38.28
	CPVC, W/FTGS, SUPPORTS AND PROPRIETARY FIRE STOPPING:									
15.4161	Pipe, CPVC, 1/2" - 3/4"	1.68	7.68	9.36	7.52	6.21	4.91	6.75	5.29	6.67
15.4162	Pipe, CPVC, 1" - 1 1/2"	3.56	11.13	14.69	12.02	10.13	8.23	10.91	8.79	10.79
15.4163	Pipe, CPVC, 2"	3.38	6.57	9.95	8.37	7.26	6.14	7.72	6.47	7.65
15.4164	Pipe, CPVC, 3"	6.67	11.10	17.77	15.11	13.22	11.33	14.00	11.89	13.89
15.4165	Pipe, CPVC, 4"	8.98	9.86	18.84	16.47	14.80	13.12	15.49	13.61	15.39
15.4166	Pipe, CPVC, 6"	16.17	10.64	26.81	24.26	22.45	20.64	23.19	21.17	23.09

	PVC, CELLULAR CORE, SCH 40, IN BUILDING W/FTGS, SUPPORTS AND GENERIC FIRE STOPPING WHEN POSSIBLE:									
15.4141	Pipe, PVC, Sch 40, 1 1/2" - 2"	1.51	8.50	10.01	7.97	6.53	5.08	7.12	5.51	7.04
15.4142	Pipe, PVC, Sch 40, 2 1/2" - 3"	4.06	10.11	14.17	11.74	10.02	8.31	10.73	8.81	10.63
15.4143	Pipe, PVC, Sch 40, 4"	3.53	9.88	13.41	11.04	9.36	7.68	10.05	8.17	9.95
15.4144	Pipe, PVC, Sch 40, 6"	6.82	12.30	19.12	16.17	14.08	11.99	14.94	12.60	14.82
15.4145	Pipe, PVC, Sch 40, 8"	10.68	13.07	23.75	20.61	18.39	16.17	19.31	16.82	19.18
	* MANUFACTURER/SUPPLIER WOULD NOT REVEAL PRICES WITHOUT AN ORDER. NUMBERS BASED ON ESTIMATE.									

D.2.3

Highrise Commercial In-Place Costs - Electrical - Raw Data - 1991

CSI SECTION NO.	DESCRIPTION	MATERIAL COST	LABOR COST	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	UNIT COST AVERAGE
16000	ELECTRICAL									
16050.10	Conduit/Wire Assy - Lighting Circuits									
16050.11	3/4" ENT Conduit with CU Wire	1.81	1.39	3.20	3.11	2.77	2.50	2.72	2.59	2.82
16050.15	1" ENT Conduit with CU Wire	1.99	1.52	3.51	3.42	3.03	2.75	2.99	2.84	3.09
16050.12	3/4" EMT Conduit with CU Wire	2.22	2.49	4.71	4.58	3.97	2.52	3.85	3.67	3.88
16050.16	1" EMT Conduit with CU Wire	2.54	2.63	5.17	5.03	4.35	3.88	4.26	4.06	4.46
16050.10	Conduit/Wire Assy - Outlet Circuits									
16050.13	3/4" ENT Conduit with CU Wire	1.42	1.39	2.81	2.72	2.39	2.13	2.33	2.21	2.43
16050.17	1" ENT Conduit with CU Wire	1.60	1.52	3.12	3.03	2.65	2.38	2.60	2.46	2.71
16050.14	3/4" EMT Conduit with CU Wire	1.77	2.49	4.26	4.13	3.52	3.07	3.40	3.22	3.60
16050.18	1" EMT Conduit with CU Wire	1.89	2.63	4.52	4.38	3.70	3.23	3.61	3.41	3.81

	CPVC, W/FTGS, SUPPORTS, GENERIC FIRE STOPPING WHEN POSSIBLE:									
15.4171	Pipe, CPVC, 1/2" - 3/4"	1.48	7.56	9.04	7.23	5.94	4.66	6.47	5.03	6.39
15.4172	Pipe, CPVC, 1" - 1 1/2"	2.58	10.76	13.34	10.76	8.93	7.10	9.68	7.64	9 57
15.4173	Pipe, CPVC, 2"	3.00	6.55	9.55	7.98	6.86	5.75	7.32	6.08	7.26
15.4174	Pipe, CPVC, 3"	6.35	10.94	17.29	14.66	12 80	10.94	13.57	11.49	13.46
15.4175	Pipe, CPVC, 4"	8.94	9.86	18.80	16.43	14.76	13.08	15.45	13 57	15.35
15.4176	Pipe, CPVC, 6"	16.10	10.64	26.74	24.19	22.38	20.57	23.12	21.10	23.02

D.3.1

Wood-frame Townhouse In-Place Costs - DWV - Raw Data - 1991

CSI SECTION NO.	DESCRIPTION	MATERIAL COST	LABOR COST	SAN FRANCISCO	BOSTON •	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	UNIT COST AVERAGE
15.4000	PLUMBING									
15.4100	PLUMBING PIPING									
	C.I.P., SOIL NO HUB MECH, JOINT:									
15.4101	Copper "M" Pipe 3/4"	1.95	6.69	8 64	7.03	5.90	4.76	6.37	5.09	6.30
15.4102	C.I.P., Soil, 1 1/2" No Hub	3.93	11.83	15.76	12.92	10.91	8 90	11.74	9.49	11.62
15.4103	C.I.P., Soil, 2" No Hub	4 09	11.83	15.92	13 08	11.07	9.06	11.90	9.65	11.78
15.4104	C.I.P., Soil, 2 1/2 - 3" No Hub	5.36	12.94	18.30	15.19	12.99	10.79	13 90	11.44	13.77
15 4105	C.I.P., Soil, 4" No Hub	6 83	13.62	20.45	17.18	14.87	12.55	15 82	13.23	15.68
15.4106	C.I.P., Soil, 5" No Hub	8 85	15 62	24.47	20.72	18.07	15.41	19.16	16 19	19.00
15.4107	C.I.P., Soil, 6" No Hub	10.80	17.91	28.74	24.43	21.38	18 33	22.64	19 23	22.46
15.4108	C.I.P., Soil, 8" No Hub	12.18	20.26	32.44	27.58	24.13	20.69	25.55	21.70	25.35
	PVC, SOLID CORE, SCH 40, IN BUILDING W/FTGS, SUPPORTS AND PROPRIETARY FIRE STOPPING:									
15.4111	Pipe, PVC, Sch 40, 3/4"	0.90	6.65	7.55	5.95	4.82	3.69	5.29	4.03	5 22

APPENDIX D.3

WOOD-FRAME TOWNHOUSE

CTL027081

15.4132	Pipe, PVC, Sch 40, 1 1/2"	1.21	7.46	8.67	6.88	5.61	4.34	6.13	4.72	6.06
15.4133	Pipe, PVC, Sch 40, 2"	1.57	7.83	9.40	7.52	6.19	4.86	6.74	5.25	6.66
15.4134	Pipe, PVC, Sch 40, 2 1/2 - 3"	2.98	10.42	13.40	10.90	9.13	7.36	9.86	7.88	9.75
15.4135	Pipe, PVC, Sch 40, 4"	3.62	9.28	12.90	10.67	9.10	7.52	9.74	7.98	9.65
15.4136	Pipe, PVC, Sch 40, 5"	4.31	9.49	13.80	11.52	9.91	8.30	10.57	8.77	10.48
15.4137	Pipe, PVC, Sch 40, 6"	6.53	10.06	16.59	14.18	12.47	10.76	13.17	11.26	13.07
15.4138	Pipe, PVC, Sch 40, 8"	11.05	12.45	23.50	20.51	18.40	16.28	19.27	16.90	19.14
	PVC, CELLULAR CORE, SCH 40, IN BUILDING W/FTGS, SUPPORTS AND GENERIC FIRE STOPPING WHEN POSSIBLE:									
15.4141	Pipe, PVC, Sch 40, 3/4"	0.78	6.47	7.25	5.70	4.60	3.50	5.05	3.82	4.99
15.4142	Pipe, PVC, Sch 40, 1 1/2"	1.16	7.46	8.62	6.83	5.56	4.29	6.08	4.67	6.01
15.4143	Pipe, PVC, Sch 40, 2"	1.48	7.83	9.31	7.43	6.10	4.77	6.65	5.16	6.57
15.4144	Pipe, PVC, Sch 40, 2 1/2 - 3"	2.85	10.42	13.22	10.77	9.00	7.23	9.73	7.75	9.61
15.4145	Pipe, PVC, Sch 40, 4"	3.45	9.28	12.73	10.50	8.93	7.35	9.57	7.81	9.48
15.4146	Pipe, PVC, Sch 40, 5"	4.09	9.49	13.58	11.30	9.69	8.08	10.35	8.55	10.26
15.4147	Pipe, PVC, Sch 40, 6"	6.20	10.06	16.26	13.85	12.14	10.43	12.84	10.93	12.74
15.4148	Pipe, PVC, Sch 40, 8"	10.50	12.45	22.95	19.96	17.85	15.73	18.72	16.35	18.59
	• MANUFACTURER/SUPPLIER WOULD NOT REVEAL PRICES FOR FOAM CORE PVC-DWV WITHOUT AN ORDER. NUMBERS BASED ON ESTIMATE.									

15.4112	Pipe, PVC, Sch 40, 1 1/2"	1.26	7.84	9.10	7.22	5.89	4.55	6.43	4.94	6.36
15.4113	Pipe, PVC, Sch 40, 2"	1.63	8 23	9 86	7.88	6 49	5.09	7 06	5.50	6 98
15.4114	Pipe, PVC, Sch 40, 2 1/2 - 3"	2.98	10.42	13.40	10.90	9.13	7.36	9 86	7.88	9.75
15.4115	Pipe, PVC, Sch 40, 4"	3.62	9.28	12.90	10 67	9.10	7.52	9.74	7.98	9.65
15.4116	Pipe, PVC, Sch 40, 5"	4.31	9.49	13.80	11.52	9.91	8.30	10.57	8.77	10.48
15.4117	Pipe, PVC, Sch 40, 6"	6 53	10.06	16.59	14.18	12.47	10.76	13.17	11.26	13 07
15.4118	Pipe, PVC, Sch 40, 8"	11.05	12.45	23.50	20.51	18.40	16.28	19.27	16.90	19.14
	PVC, CELLULAR CORE, SCH 40, IN BUILDING W/FTGS, SUPPORTS AND PROPRIETARY FIRE STOPPING:									
15.4121	Pipe, PVC, Sch 40, 3/4"	0 80	6 65	7.45	5 85	4 72	3 59	5.19	3.93	5.12
15.4122	Pipe, PVC, Sch 40, 1 1/2"	1.20	7.84	9.04	7.16	5.83	4.49	6.37	4.88	6 30
15.4123	Pipe, PVC, Sch 40, 2"	1 54	8.23	9.77	7.79	6.40	5 00	6 97	5 41	6.89
15.4124	Pipe, PVC, Sch 40, 2 1/2 - 3"	2 85	10 42	13.27	10.77	9.00	7.23	9.73	7.75	9.62
15.4125	Pipe, PVC, Sch 40, 4"	3.45	9.28	12.73	10.50	8.93	7.35	9.57	7 81	9.48
15.4126	Pipe, PVC, Sch 40, 5"	4.09	9.49	13.58	11.30	9.69	8.08	10.35	8.55	10 26
15.4127	Pipe, PVC, Sch 40, 6"	6.20	10 06	16.26	13.85	12 14	10.43	12.84	10.93	12 74
15.4128	Pipe, PVC, Sch 40, 8"	10.54	12.45	22.99	20.00	17.89	15.77	18.76	16.39	18.63
	PVC, SOLID CORE, SCH. 40 IN BUILDING W/FTGS, SUPPORT, AND GENERIC FIRE STOPPING WHEN POSSIBLE:									
15.4131	Pipe, PVC, Sch 40, 3/4"	0.81	6.47	7.28	5.73	4.63	3.53	5.08	3.85	5.02

15.4165	Pipe, CPVC, 1 1/2"	2.49	5.34	7 83	6.55	5.64	4.73	6.01	5.00	5.96
15.4166	Pipe, CPVC, 2"	3.18	5.90	9.08	7.66	6 66	5.66	7.07	5.95	7 02
15.4167	Pipe, CPVC, 2 1/2"	5.07	6.91	11.98	10 32	9.15	7.97	9.63	8.32	9.56
15.4168	Pipe, CPVC, 3"	5.97	8 82	14.79	12 67	11.17	9.67	11.79	10.12	11.70
	CPVC, W/FTGS, SUPPORTS, GENERIC FIRE STOPPING WHEN POSSIBLE:									
15.4171	Pipe, CPVC, 1/2"	1.19	6.10	7 29	5 83	4.79	3.75	5.22	4 06	5.16
15.4172	Pipe, CPVC, 3/4"	1.51	6 45	7.96	6.41	5.32	4 22	5.77	4.54	5.70
15.4173	Pipe, CPVC, 1"	1.81	5.64	7.45	6.10	5.14	4.18	5.53	4.46	5 48
15.4174	Pipe, CPVC, 1 1/4"	2 61	5.91	8.52	7.10	6.10	5.09	6.51	5.39	6 45
15.4175	Pipe, CPVC, 1 1/2"	2.49	5.34	7.83	6 55	5.64	4.73	6 01	5 00	5.96
15.4176	Pipe, CPVC, 2"	3.18	5.90	9.08	7.66	6.66	5.66	7.07	5.95	7.02
15.4177	Pipe, CPVC, 2 1/2"	5.07	6.91	11.98	10.32	9.15	7.97	9.63	8.32	9.56
15 4178	Pipe, CPVC, 3"	5.97	8 82	14.79	12.67	11 17	9 67	11.79	10.12	11.70

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D.3.2

Wood-frame Townhouse In-Place Costs - DHCW - Raw Data - 1991

CSI SECTION NO.	DESCRIPTION	MATERIAL COST	LABOR COST	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	UNIT COST AVERAGE
	COPPER "M", W/FTGS & SUPPORTS:									
15.4151	Pipe, Copper "M", 1/2"	1.33	5.50	6.83	5.51	4.58	3.64	4.96	3.92	4.91
15.4152	Pipe, Copper "M", 3/4"	1.95	6.69	8.64	7.03	5.90	4.76	6.37	5.09	6.30
15.4153	Pipe, Copper "M", 1"	2.74	7.94	10.68	8.77	7.42	6.07	7.98	6.47	7.90
15.4154	Pipe, Copper "M", 1 1/4"	3.80	8.15	11.95	9.99	8.61	7.22	9.18	7.63	9.10
15.4155	Pipe, Copper "M", 1 1/2"	4.48	9.12	13.60	11.41	9.86	8.31	10.50	8.77	10.41
15.4156	Pipe, Copper "M", 2"	6.37	11.00	17.37	14.73	12.86	10.99	13.63	11.54	13.52
15.4157	Pipe, Copper "M", 2 1/2"	9.14	12.50	21.64	18.64	16.52	14.39	17.39	15.02	17.27
15.4158	Pipe, Copper "M", 3"	11.91	14.00	25.91	22.55	20.17	17.79	21.15	18.49	21.01
	CPVC, W/FTGS, SUPPORTS AND PROPRIETARY FIRE STOPPING:									
15.4161	Pipe, CPVC, 1/2"	1.33	7.30	8.63	6.88	5.64	4.40	6.15	4.76	6.08
15.4162	Pipe, CPVC, 3/4"	1.51	6.45	7.96	6.41	5.32	4.22	5.77	4.54	5.70
15.4163	Pipe, CPVC, 1"	1.81	5.64	7.45	6.10	5.14	4.18	5.53	4.46	5.48
15.4164	Pipe, CPVC, 1 1/4"	2.69	6.51	9.20	7.64	6.53	5.42	6.99	5.75	6.92

APPENDIX D.4

STRIP SHOPPING CENTER

D.3.3

Wood-frame Townhouse In-Place Costs - Electrical - Raw Data - 1991

CSI SECTION NO.	DESCRIPTION	MATERIAL COST	LABOR COST	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	UNIT COST AVERAGE
16000	ELECTRICAL									
16050.10	Conduit/Wire Assy - Lighting Circuits									
16050.11	3/4" ENT Conduit with CU Wire	1.81	1.39	3.20	3.11	2.77	2.50	2.72	2.59	2.82
16050.15	1" ENT Conduit with CU Wire	1.99	1.52	3.51	3.42	3.03	2.75	2.99	2.84	3.09
16050.12	3/4" EMT Conduit with CU Wire	2.22	2.49	4.71	4.58	3.97	3.52	3.85	3.67	4.05
16050.16	1" EMT Conduit with CU Wire	2.54	2.63	5.17	5.03	4.35	3.88	4.26	4.06	4.46
16050.10	Conduit/Wire Assy - Outlet Circuits									
16050.13	3/4" ENT Conduit with CU Wire	1.42	1.39	2.81	2.72	2.39	2.13	2.33	2.21	2.43
16050.17	1" ENT Conduit with CU Wire	1.60	1.52	3.12	3.03	2.65	2.38	2.60	2.46	2.71
16050.14	3/4" EMT Conduit with CU Wire	1.77	2.49	4.26	4.13	3.52	3.07	3.40	3.22	3.60
16050.18	1" EMT Conduit with CU Wire	1.89	2.63	4.52	4.38	3.70	3.23	3.61	3.41	3.81

	PVC, CELLULAR CORE, SCH 40, IN BUILDING W/FTGS, SUPPORTS AND PROPRIETARY FIRE STOPPING:									
15.4121	Pipe, PVC, Sch 40, 3/4"	0.75	6.26	7.01	5.51	4.44	3.38	4.88	3.69	4.82
15.4122	Pipe, PVC, Sch 40, 1 1/2"	1.12	7.07	8.19	6.49	5.29	4.09	5.79	4.44	5.72
15.4123	Pipe, PVC, Sch 40, 2"	1.31	6.70	8.01	6.40	5.26	4.12	5.73	4.46	5.67
15.4124	Pipe, PVC, Sch 40, 6"	6.20	10.06	16.26	13.85	12.14	10.43	12.84	10.93	12.74
	PVC, SOLID CORE, SCH. 40 IN BUILDING W/FTGS, SUPPORT, AND GENERIC FIRE STOPPING WHEN POSSIBLE:									
15.4131	Pipe, PVC, Sch 40, 3/4"	0.74	6.22	6.96	5.47	4.41	3.35	4.85	3.66	4.78
15.4132	Pipe, PVC, Sch 40, 1 1/2"	1.10	7.03	8.13	6.44	5.25	4.05	5.74	4.40	5.67
15.4133	Pipe, PVC, Sch 40, 2"	1.41	6.70	8.11	6.50	5.36	4.22	5.83	4.56	5.77
15.4134	Pipe, PVC, Sch 40, 6"	6.53	10.06	16.59	14.18	12.47	10.76	13.17	11.26	13.07
	PVC, CELLULAR CORE, SCH 40, IN BUILDING W/FTGS, SUPPORTS AND GENERIC FIRE STOPPING WHEN POSSIBLE:									
15.4141	Pipe, PVC, Sch 40, 3/4"	0.70	6.22	6.92	5.43	4.37	3.31	4.81	3.62	4.74
15.4142	Pipe, PVC, Sch 40, 1 1/2"	1.05	7.03	8.08	6.39	5.20	4.00	5.69	4.35	5.62
15.4143	Pipe, PVC, Sch 40, 2"	1.31	6.70	8.01	6.40	5.26	4.12	5.73	4.46	5.67
15.4144	Pipe, PVC, Sch 40, 6"	6.20	10.06	16.26	13.85	12.14	10.43	12.84	10.93	12.74
	* MANUFACTURER/SUPPLIER WOULD NOT REVEAL PRICES WITHOUT AN ORDER. NUMBERS BASED ON ESTIMATE.									

D.4.1

Strip Shopping Center In-Place Costs - DWV - Raw Data - 1991

CSI SECTION NO.	DESCRIPTION	MATERIAL COST	LABOR COST	SAN FRANCISCO	BOSTON *	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	UNIT COST AVERAGE
15.4000	PLUMBING									
15.4100	PLUMBING PIPING									
	C.I.P., SOIL NO HUB MECH. JOINT:									
15.4101	Copper "M" Pipe 3/4"	1.95	6.69	8.64	7.03	5.90	4.76	6 37	5.09	6 30
15.4102	C.I.P., Soil, 1 1/2" No Hub	3.93	11.83	15.76	12.92	10.91	8.90	11.74	9.49	11.62
15.4103	C.I.P., Soil, 2" No Hub	4.09	11.83	15.91	13.08	11.07	9.06	11.90	9.65	11.78
15.4104	C.I.P., Soil, 6" No Hub	10.80	17.94	28.74	24.43	21.38	18.33	22.64	19.23	22.46
	PVC, SOLID CORE, SCH 40, IN BUILDING W/FTGS, SUPPORTS AND PROPRIETARY FIRE STOPPING:									
15.4111	Pipe, PVC, Sch 40, 3/4"	1.04	6.26	7.30	5.80	4.73	3.67	5.17	3.98	5.11
15.4112	Pipe, PVC, Sch 40, 1 1/2"	1.18	7.07	8.25	6.55	5.35	4.15	5.85	4.50	5.78
15.4113	Pipe, PVC, Sch 40, 2"	1.41	6.70	8.11	6 50	5.36	4 22	5 83	4.56	5 77
15.4114	Pipe, PVC, Sch 40, 6"	6.53	10.06	16.59	14.18	12.47	10.76	13.17	11.26	13.07

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D.4.3

Strip Shopping Center In-Place Costs - Electrical - Raw Data - 1991

CSI SECTION NO.	DESCRIPTION	MATERIAL COST	LABOR COST	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	UNIT COST AVERAGE
16000	ELECTRICAL									
16050.10	Conduit/Wire Assy - Lighting Circuits									
16050.11	3/4" ENT Conduit with CU Wire	1.81	1.39	3.20	3.11	2.77	2.50	2.72	2.59	2.82
16050.15	1" ENT Conduit with CU Wire	1.99	1.52	3.51	3.42	3.03	2.75	2.99	2.84	3.09
16050.12	3/4" EMT Conduit with CU Wire	2.22	2.49	4.71	4.58	3.97	3.52	3.85	3.67	4.05
16050.16	1" EMT Conduit with CU Wire	2.54	2.63	5.17	5.03	4.35	3.88	4.26	4.06	4.46
16050.10	Conduit/Wire Assy - Outlet Circuits									
16050.13	3/4" ENT Conduit with CU Wire	1.42	1.39	2.81	2.72	2.39	2.13	2.33	2.21	2.43
16050.17	1" ENT Conduit with CU Wire	1.60	1.52	3.12	3.03	2.65	2.38	2.60	2.46	2.71
16050.14	3/4" EMT Conduit with CU Wire	1.77	2.49	4.26	4.13	3.52	3.07	3.40	3.22	3.60
16050.18	1" EMT Conduit with CU Wire	1.89	2.63	4.52	4.38	3.70	3.23	3.61	3.41	3.81

D.4.2

Strip Shopping Center In-Place Costs - DHCW - Raw Data - 1991

CSI SECTION NO.	DESCRIPTION	MATERIAL COST	LABOR COST	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	UNIT COST AVERAGE
	COPPER "L", W/FTGS & SUPPORTS:									
15.4151	Pipe, Copper "L", 1/2"	1.62	5.50	7.12	5.80	4.87	3.93	5.25	4.21	5 20
15.4152	Pipe, Copper "L", 3/4"	2.40	6 69	9.09	7.48	6.35	5.21	6 82	5.54	6 75
15.4153	Pipe, Copper "L", 1"	3.36	7.94	11.30	9.39	8 04	6.69	8.60	7 09	8 52
15.4154	Pipe, Copper "L", 2"	7.77	11.00	18.77	16.13	14 26	12 39	15.03	12.94	14 92
	CPVC, W/FTGS, SUPPORTS AND PROPRIETARY FIRE STOPPING:									
15 4161	Pipe, CPVC, 1/2"	1.26	6 60	7.86	6.28	5.15	4.03	5 62	4 36	5 55
15.4162	Pipe, CPVC, 3/4"	1.50	6.21	7.71	6.22	5 16	4.11	5.60	4 42	5 54
15.4163	Pipe, CPVC, 1"	1.79	5.92	7.71	6.29	5.28	4.28	5.70	4.57	5.64
15.4164	Pipe, CPVC, 2"	3 22	5.97	9.19	7.76	6.74	5.73	7.16	6.03	7 10
	CPVC, W/FTGS, SUPPORTS, GENERIC FIRE STOPPING WHEN POSSIBLE:									
15.4171	Pipe, CPVC, 1/2"	1.16	6 69	7.85	6 24	5.11	3.97	5.58	4.30	5.51
15.4172	Pipe, CPVC, 3/4"	1.44	6.19	7.63	6.14	5.09	4.04	5.53	4.35	5.46
15.4173	Pipe, CPVC, 1"	1.79	5.92	7.71	6 29	5.28	4.28	5.70	4 57	5.64
15.4174	Pipe, CPVC, 2"	3.18	5.93	9.11	7.69	6.68	5.67	7.09	5.97	7.03

A COST/BENEFIT STUDY:
In-Place Costs and Technical and Regulatory Constraints To Use of PVC Based Pipe, Tube and Conduit In Construction

A Report To:

The Vinyl Institute
155 Route 46 West
Wayne, NJ 07470

Attn: Mr. Al Reventas
Dr. Roy Gottesman

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Berkeley, CA 94710

Attn: Joseph B. Zicherman, Ph.D.

June 1991

Table of Contents

List of Tables

EXECUTIVE SUMMARY

It has long been assumed that PVC-based (polyvinyl chloride) plumbing pipe, tube, and conduit products offer cost savings in construction as compared to their metal counterparts. In this study, this assumption has been tested by developing comparative cost data for these two competing classes of products.

Specifically, the following competitive cost estimates were prepared:

- Cast iron versus PVC drain, waste and vent (DWV) pipe
- Copper tubing versus CPVC for domestic hot and cold water (DHCW)
- Electrical metallic tubing (EMT) versus electrical non-metallic tubing (ENT) products used as raceways for lighting and local electrical circuits

Four different building types ranging from highrise, non-combustible construction through lowrise, fire-rated wood frame were used for costs analyses. **The specific buildings upon which the estimates are based have actually been constructed; they are not hypothetical.** Estimates were prepared by a nationally recognized cost estimating firm and are organized according to CSI (Construction Specifications Institute) format. Results are based on current survey data of supplier and installer costs and rates in six cities across the USA to determine geographical influences on comparative costs of the competing materials.

A survey was also conducted to determine technical and regulatory constraints regarding usage of PVC-based products. This survey addressed technical justification for product use based on adequate fire performance data. Finally, building codes were examined to determine if product was use acceptable based on model code provisions.

In terms of regulatory bars, few exist to unlimited use of most of the PVC products included in this study.[1] In terms of technical bars, there has been extensive fire testing of the PVC products considered here. However, additional fire test data for one-hour applications of ENT products in walls would be of value in assuring increasing product acceptance. Likewise, although theoretical justifications can be developed obviating their need, additional fire test data for PVC piping installed in fire rated floor/ceiling assemblies and walls less than 6" thick could be required by local code officials before sanctioning use in their jurisdictions.

Finally, results showed the PVC-based products to be between 20 and 30+% less as installed, even when costs of firestop detailing to insure maintenance of fire resistive integrity with their use are included.

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[1]The West Coast IAPMO-based Uniform Plumbing Code is a glaring exception to this.

1.0 INTRODUCTION

PVC-based (polyvinyl chloride) construction products are becoming increasingly available as replacements for conventional products. Typically, they provide both direct advantages in performance and cost/benefit advantages to the construction industry.

With this in mind, preparation of an in-depth assessment of the cost effectiveness of PVC based products versus their conventional, metal counterparts for pipe, tube, and conduit were the subject of this study.

Specific study objectives were:

- to compare direct, in-place costs of these products with competing metal products,
- to consider technical ramifications related to fire safety associated with such replacement,
- to evaluate current fire-related, regulatory (i.e., model code) barriers to use of these products.

Specific data developed include:

- Direct Cost Comparisons For In-place:
  - PVC drain, waste, and vent (DWV) piping versus cast iron soil pipe.
  - CPVC (chlorinated PVC) as a replacement for copper hot and cold water (DHCW) supply piping.[2]
  - PVC-ENT (electrical non-metallic tubing) as a replacement for EMT (electrical metallic tubing).
- Assessment of existing model building regulations affecting use of PVC products.
- Discussion of technical barriers to use of the PVC products.

Technical barriers were identified by evaluations of testing and research records and literature related to fire performance of the products under study.

[2] Attempts were also made to develop data on CPVC based fire sprinkler systems. Due to the lack of field data on the use of these products, as well as the nature of the cost estimating process, the estimating approaches available did not appear of sufficient reliability to be included after an in-depth analysis was conducted.

2.0 METHODOLOGY

Study results were obtained by utilizing actual plans, specifications, and materials take-offs for buildings of differing construction types, all of which have actually been completed. Results are not based on hypothetical structures.

For a specific description of the cost estimating process used, see Appendix A.

2.1 Materials and Installation Estimating

Types of materials required for construction of the original buildings were modified to take into account installation-detailing unique to use of PVC products. In order to do this, IFT personnel identified installation detailing for PVC products which differed from conventional products. The estimators then modified conventional detailing as needed for safe use of the PVC products. Thus, additional detailing costs have been factored into estimates for each PVC product cost estimate.

PVC based products were estimated with specific firestop-detailing for both DWV and DHCW as is consistent with their safe use in the field. The cast iron DWV and copper DHCW on the other hand were estimated with no application of firestopping beyond grout which may be routinely applied with wallboard installation. While this may seem a conservative estimating method for the study, it reflects current estimating practice. More importantly, it expresses true economic comparisons for current construction practices used.

Material take-offs were prepared in Spring, 1991 and reflect pricing of materials and labor at that time. The analysis took into account geographic variability in both raw materials and installation pricing for a total of six cities. Bases for pricing of products were obtained from sources in the field and are listed in Construction Specifications Institute (CSI) format. Analyses were conducted by a major nationwide cost estimating firm for IFT TECHNICAL SERVICES.

2.2 Item Pricing

Specific items of interest related to pipe pricing, firestopping costs, and basis for foam core PVC pricing can be found in Appendix A.

Appendix B includes comments on electrical product pricing bases used.

Appendix C includes pricing bases for use of 3M FIRE BARRIER® cost estimates. This product was determined to be the more cost effective when compared to other products considered. USG THERMAFIBER® was the "generic" thermal insulation used for price quotes. Common fiberglass types could be used in certain applications. This would result in further net savings for specific jobs.

2.3 PVC Cost/Benefit Ratios

In addition to cost estimates for each project expressed in dollars-per-unit for the products studied (i.e., cost/foot including labor, detailing, accessories, etc.) ratios have been developed which express direct comparisons between competing classes of products as installed.

These ratios are reflective of relative costs of installed metal versus PVC systems regardless of whether union or non-union installation is considered, since the ratio of productivity between these installer classes should remain constant. They also reflect the substantial differences in construction costs in different areas of the U.S.

2.4 Code Analysis

An analysis has been prepared as part of the study (Section 3) of applicable model codes provisions which regulate use of PVC products. The examples developed do not represent every possible installation situation, but do cover a broad group of installation possibilities. The analysis includes references to prescriptive code provisions which bar use of particular products where technical feasibility for their use exists. Thus, code changes will have to be effected before such technically feasible uses of PVC products are permitted in jurisdictions covered by the codes in question. Examples include removal of the three story restriction found in the 1991 Uniform Plumbing Code and development of acceptable code language to permit use of PVC-based pipe in appropriate plenum spaces. The latter is especially true for plenums in buildings constructed with combustible materials.

2.5 Technical Analysis

Bars to PVC product use from a technical standpoint are identified in Section 4. Such bars exist because particular types of construction assemblies identified have not been demonstrated to show necessary fire endurance.

3.0 COST ESTIMATE ANALYSIS RESULTS

3.1 Non-Combustible, Highrise Residential Case

In this case a Type-1 non-combustible highrise project has been analyzed. The building analyzed was a 30+ story, high quality (non-"spec" and non-fast-track) residential project.

Plastic products for which analyses were conducted include:

- replacement of cast-iron DWV piping with PVC-DWV,
- DHCW supply piping replacement with CPVC supply piping,
- EMT for electrical power distribution and signaling replacement by PVC electrical non-metallic tubing (ENT) where appropriate.

The tables which follow summarize comparative in-place costs for plumbing pipe (DWV and DHCW) and electrical systems estimated. Because this is a residential project, substantially more pipe is used than in the commercial highrise (Case 3.2). Consequently, more plumbing thru-penetrations occur as well, which impacts unit cost (cost per foot).

The tables also include ratios of the two competing products classes showing the fractional in-place cost for PVC replacement of metallic materials.

Appendix D.1 contains the raw data from which the following tables were derived. The reader may want to evaluate the appendices to discern trends in in-place costs versus pipe size, etc.

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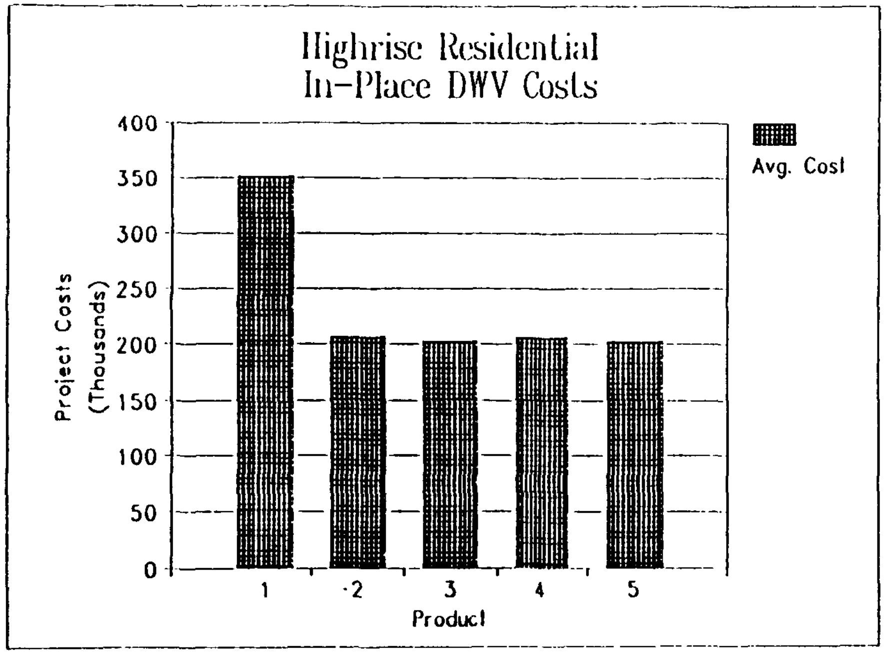

Legend

1 – Cast Iron

2 – PVC, Solid Core, Proprietary Fire

3 – PVC, Cellular Core, Proprietary Fire

4 – PVC, Solid Core, Generic Fire

5 – PVC, Cellular Core, Generic Fire

Table 3.1.1 Highrise Residential In-Place DWV Costs (in Dollars) - 1991

CSI SECTION NO.	DESCRIPTION	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	PROJECT COST AVERAGE
15.4100	CAST IRON PIPE HUBLESS MECH, JOINT	462,102	383,109	332,556	282,003	353,372	296,871	351,669
15.4110	PVC, SOLID CORE SCH 40, IN BUILDING, W/FTGS, SUPPORTS AND PROPRIETARY FIRE STOPPING	276,129	229,150	195,874	162,598	209,576	172,385	207,619
15.4120	PVC, CELLULAR CORE, SCH. 40 IN BUILDING W/FTGS, SUPPORTS, AND PROPRIETARY FIRE STOPPING	271,851	224,873 *	191,597	158,321	205,299	168,108	203,342
15.4130	PVC, SOLID CORE, SCH 40, IN BUILDING W/FTGS, SUPPORTS AND GENERIC FIRE STOPPING WHEN POSSIBLE	275,815	228,852	195,587	162,322	209,284	172,105	207,328
15.4140	PVC, CELLULAR CORE, SCH 40, IN BUILDING W/FTGS, SUPPORTS AND GENERIC FIRE STOPPING WHEN POSSIBLE	271,370	224,471 *	191,252	158,032	204,930	167,802	202,976

* Manufacturer/Supplier would not reveal prices without an order. Numbers based on estimate.

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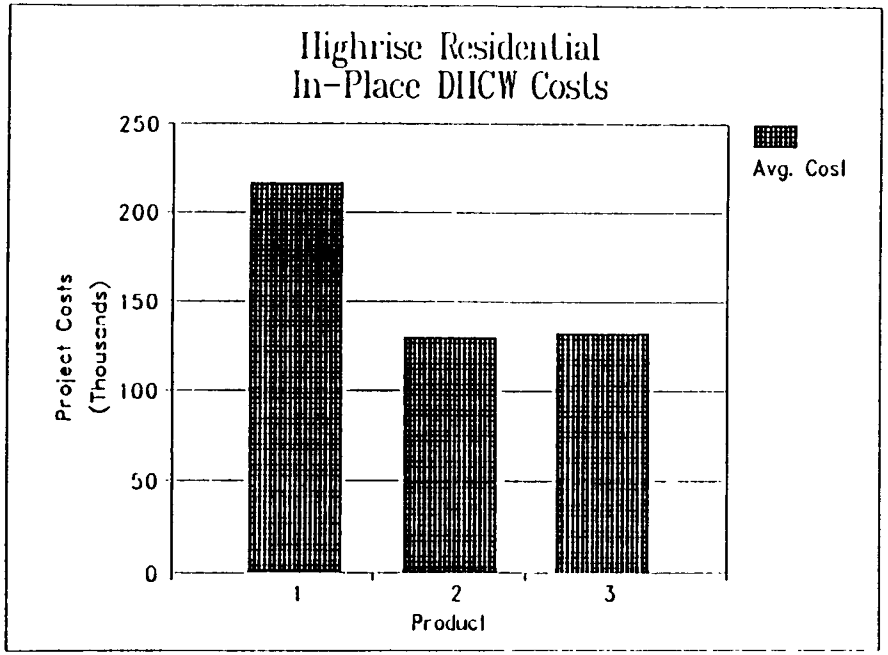
3.1.2 Highrise Residential
Ratio of In-Place Costs
PVC/Cast Iron DWV - 1991

CSI SECTION NO.	DESCRIPTION	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	PROJECT RATIO AVERAGE
15.4110/15.4100	PVC SOLID CORE DWV, PROPRIETARY FIRE STOPPING/CAST IRON	0.5975	0.5981	0.5890	0.5766	0.5931	0.5807	0.5892
15.4120/15.4100	PVC CELLULAR CORE DWV, PROPRIETARY FIRE STOPPING/CAST IRON	0.5883	0.5870 *	0.5761	0.5614	0.5810	0.5663	0.5767
15.4130/15.4100	PVC SOLID CORE DWV, GENERIC FIRE STOPPING/CAST IRON	0.5969	0.5974	0.5881	0.5756	0.5922	0.5797	0.5883
15.4140/15.4100	PVC CELLULAR CORE DWV, GENERIC FIRE STOPPING/CAST IRON	0.5873	0.5859 *	0.5751	0.5604	0.5799	0.5652	0.5756

* Manufacturer/supplier would not reveal prices without an order. Numbers based on estimate.



Legend

1 – Copper

2 – CPVC, Proprietary Fire

3 – CPVC, Generic Fire

3.1.3 Highrise Residential In-Place DHCW Costs (in Dollars) - 1991

CSI SECTION NO.	DESCRIPTION	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	PROJECT COST AVERAGE
15.4150	COPPER PIPE "L" IN BUILDING, W/FTGS & SUPPORTS	278,694	236,264	206,210	176,156	218,585	184,995	216,817
15.4160	CPVC, SUPPLY PIPE W/FTGS, SUPPORTS AND PROPRIETARY FIRE STOPPING	172,853	143,513	122,730	101,947	131,288	108,060	130,065
15.4170	CPVC, SUPPLY PIPE W/FTGS, SUPPORTS AND GENERIC FIRE STOPPING WHEN POSSIBLE	177,536	146,451	124,432	102,413	133,499	108,889	132,203

3.1.4 Highrise Residential
Ratio of In-Place Costs
CPVC/Copper DHCW - 1991

CSI SECTION NO.	DESCRIPTION	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	PROJECT RATIO AVERAGE
15.4160/15.4150	CPVC - DHCW - PROPRIETARY FIRE STOPPING/COPPER TYPE "M"	0.6202	0.6074	0.5952	0.5787	0.6006	0.5841	0.5977
15.4170/15.4150	CPVC - DHCW - GENERIC FIRE STOPPING/COPPER TYPE "M"	0.6370	0.6199	0.6034	0.5814	0.6107	0.5886	0.6068

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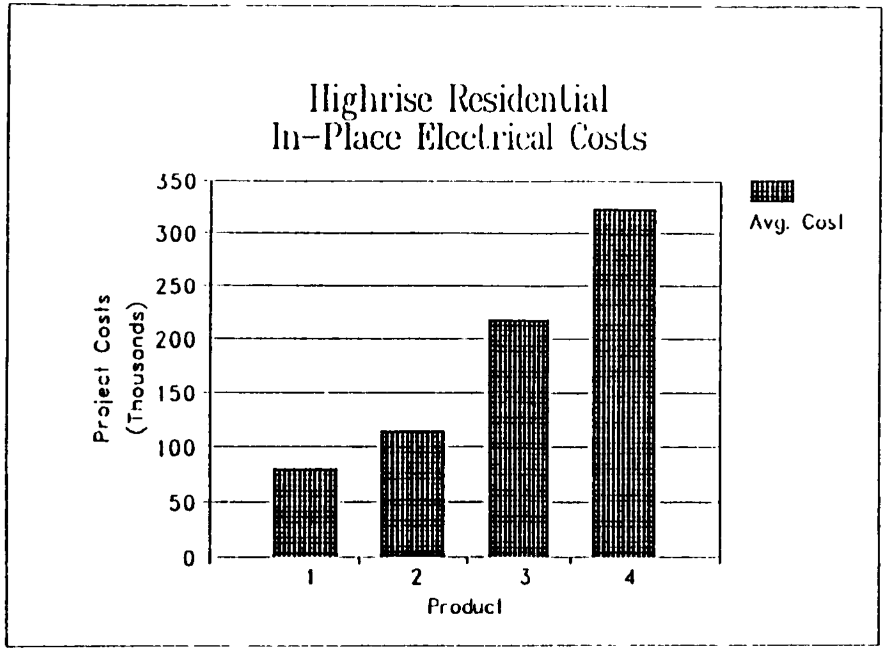


Legend

1 – ENT Concealed – Lighting

2 – EMT Concealed – Lighting

3 – ENT Concealed – Outlets

4 – EMT Concealed – Outlets

3.1.5 Highrise Residential In-Place Electrical Costs (in Dollars) - 1991

CSI SECTION NO.	DESCRIPTION	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	PROJECT COST AVERAGE
16.0510 16.0511	ENT Concealed-Lighting ENT with #12 CU Wire	90,784	88,230	78,384	70,925	77,166	73,478	79,828
16.0510 16.0512	EMT Concealed-Lighting EMT with #12 CU Wire	133,622	129,934	112,628	99,862	109,224	104,117	114,898
16.0510 16.0513	ENT Concealed-Outlets ENT with #12 CU Wire	252,394	244,310	214,669	191,316	209,280	198,502	218,412
16.0510 16.0514	EMT Concealed-Outlets EMT with #12 CU Wire	382,633	370,956	316,166	275,747	305,388	289,220	323,352

3.1.6 Highrise Residential
Ratio of In-Place Costs
ENT/EMT - 1991

CSI SECTION NO.	DESCRIPTION	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	PROJECT RATIO AVERAGE
16.0510 16.0511/16.0512	ENT/EMT Concealed-Lighting with #12 CU Wire	0.6794	0.6790	0.6960	0.7102	0.7065	0.7057	0.6961
16.0510 16.0513/16.0514	ENT/EMT Concealed-Outlets with #12 CU Wire	0.6596	0.6586	0.6790	0.6938	0.6853	0.6863	0.6771

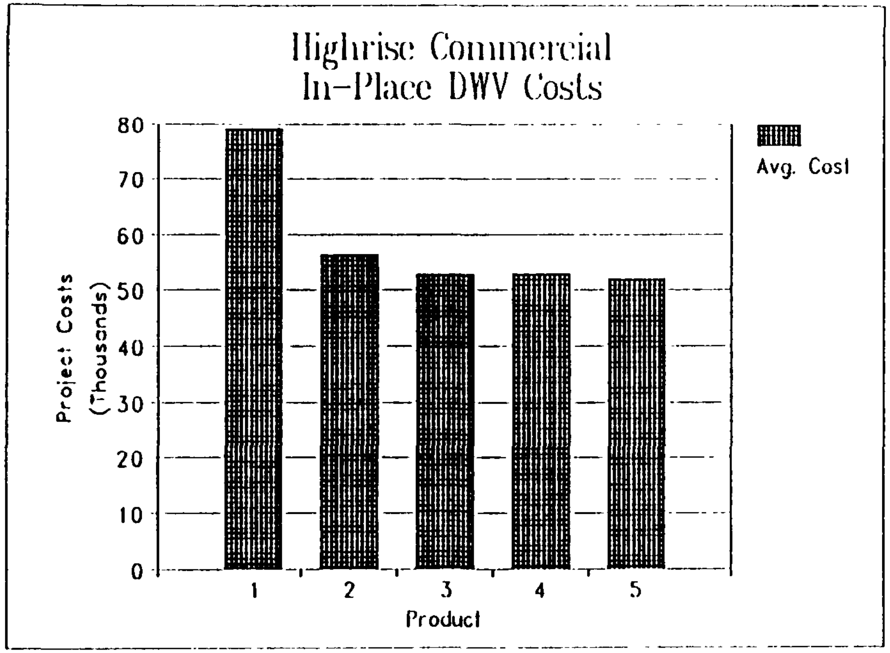
3.2 Highrise (Non-Combustible) Business/Commercial Case

This case study is for a highrise, non-combustible sprinklered building, including upper-story office occupancies and lower-story commercial spaces. Because of the typical high-rise core design used, distribution of utilities is, in general, restricted to the central building area.

Replacement estimates have been prepared for PVC-DWV (replacing cast-iron) and CPVC hot and cold water supply piping (replacing copper). Electrical conduit (EMT) is replaced by ENT and RNMC (rigid non-metallic conduit) as appropriate.

The tables and Appendix D.2 are arranged as per the preceding Section 3.1 .

CTL027108



Legend

1 – Cast Iron

2 – PVC, Solid Core, Proprietary Fire

3 – PVC, Cellular Core, Proprietary Fire

4 – PVC, Solid Core, Generic Fire

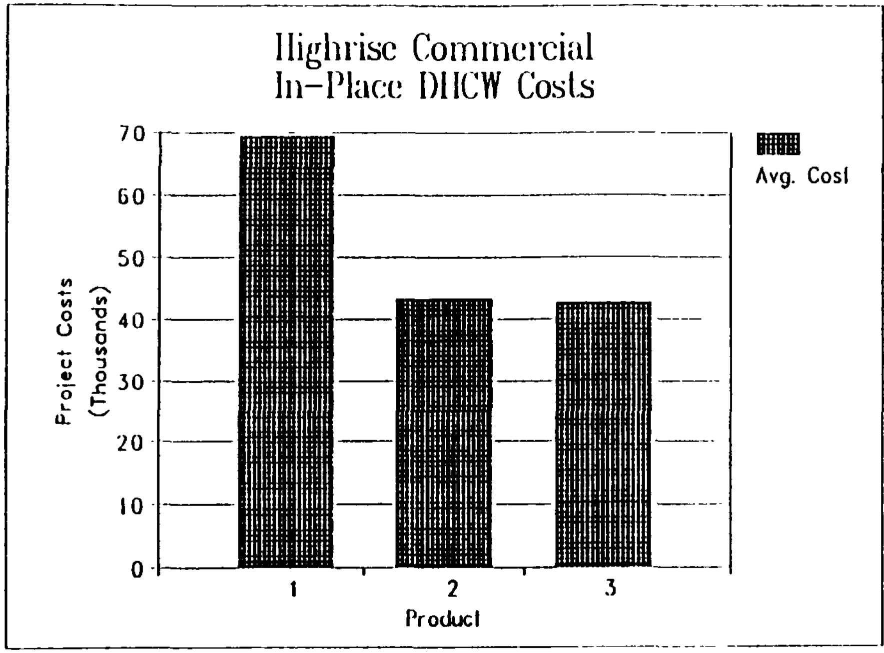
5 – PVC, Cellular Core, Generic Fire

3.2.1 Highrise Commercial In-Place DWV Costs (in Dollars) - 1991

CSI SECTION NO.	DESCRIPTION	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	PROJECT COST AVERAGE
15.4100	CAST IRON PIPE HUBLESS MECH, JOINT	103,337	86,763	75,023	63,282	79,857	66,735	79,166
15.4110	PVC, SOLID CORE SCH 40, IN BUILDING W/FTGS, SUPPORTS AND PROPRIETARY FIRE STOPPING	74,018	62,038	53,554	45,070	57,047	47,565	56,549
15.4120	PVC, CELLULAR CORE, SCH. 40 IN BUILDING W/FTGS, SUPPORTS, AND PROPRIETARY FIRE STOPPING	70,370	58,393	49,909	41,425	53,402	43,920	52,903
15.4130	PVC, SOLID CORE, SCH 40, IN BUILDING W/FTGS, SUPPORTS AND GENERIC FIRE STOPPING WHEN POSSIBLE	70,401	58,467	50,013	41,559	53,494	44,045	52,997
15.4140	PVC, CELLULAR CORE, SCH 40, IN BUILDING W/FTGS, SUPPORTS AND GENERIC FIRE STOPPING WHEN POSSIBLE	69,459	57,524	49,070	40,616	52,551	43,103	52,054

3.2.2 Highrise Commercial
Ratio of In-Place Costs
PVC/Cast Iron DWV - 1991

CSI SECTION NO.	DESCRIPTION	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	PROJECT RATIO AVERAGE
15.4110/15.4100	PVC SOLID CORE DWV, PROPRIETARY FIRE STOPPING/CAST IRON	0.7163	0.7150	0.7138	0.7122	0.7144	0.7127	0.7141
15.4120/15.4100	PVC, CELLULAR CORE DWV, PROPRIETARY FIRE STOPPING/CAST IRON	0.6810	0.6730	0.6652	0.6546	0.6687	0.6581	0.6668
15.4130/15.4100	PVC, SOLID CORE DWV, GENERIC FIRE STOPPING/CAST IRON	0.6813	0.6739	0.6666	0.6567	0.6699	0.6600	0.6681
15.4140/15.4100	PVC, CELLULAR CORE DWV, GENERIC FIRE STOPPING/CAST IRON	0.6722	0.6630	0.6541	0.6418	0.6581	0.6459	0.6558



Legend

1 – Copper

2 – CPVC, Proprietary Fire

3 – CPVC, Generic Fire

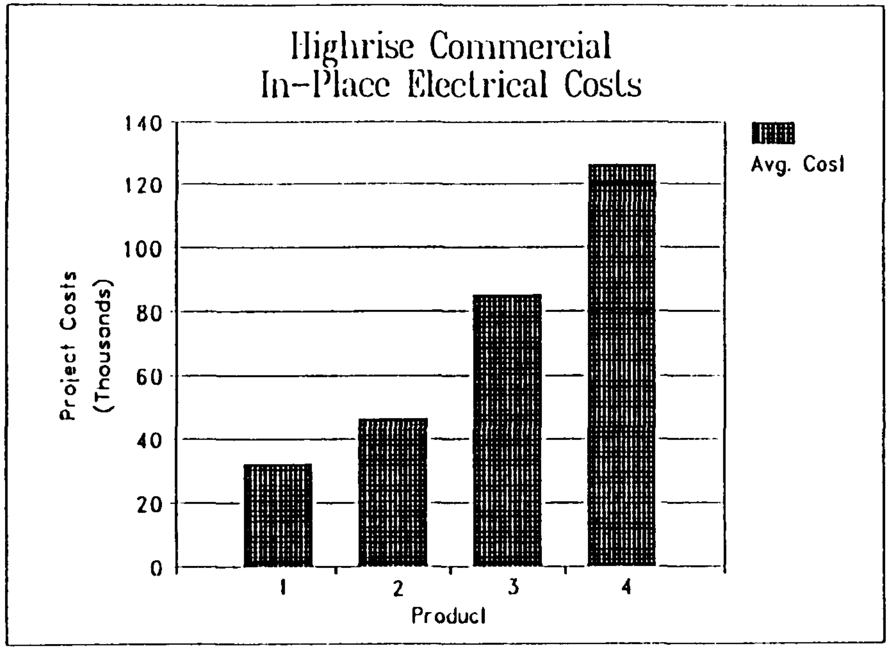
3.2.3 Highrise Commercial In-Place DHCW Costs (in Dollars) - 1991

CSI SECTION NO.	DESCRIPTION	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	PROJECT COST AVERAGE
15.4150	COPPER PIPE "L" IN BUILDING, W/FTGS & SUPPORTS	87,519	75,082	66,272	57,462	69,900	60,053	69,381
15.4160	CPVC, SUPPLY PIPE W/FTGS, SUPPORTS AND PROPRIETARY FIRE STOPPING	52,621	46,200	41,652	37,104	43,525	38,441	43,257
15.4170	CPVC, SUPPLY PIPE W/FTGS, SUPPORTS AND GENERIC FIRE STOPPING WHEN POSSIBLE	51,933	45,556	41,040	36,523	42,900	37,851	42,634

CTL027111

3.2.4 Highrise Commercial
Ratio of In-Place Costs
CPVC/Copper DHCW - 1991

CSI SECTION NO.	DESCRIPTION	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	PROJECT RATIO AVERAGE
15.4160/15.4150	CPVC - DHCW - PROPRIETARY FIRE STOPPING/COPPER TYPE "M"	0.6013	0.6153	0.6285	0.6457	0.6227	0.6401	0.6256
15.4170/15.4150	CPVC - DHCW - GENERIC FIRE STOPPING/COPPER TYPE "M"	0.5934	0.6067	0.6193	0.6356	0.6137	0.6303	0.6165



Legend

1 – ENT Concealed – Lighting

2 – EMT Concealed – Lighting

3 – ENT Concealed – Outlets

4 – EMT Concealed – Outlets

3.2.5 Highrise Commercial In-Place Electrical Costs (in Dollars) - 1991

CSI SECTION NO.	DESCRIPTION	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	PROJECT COST AVERAGE
16.0510 16.0511	ENT Concealed-Lighting ENT with #12 CU Wire	36,896	35,858	31,938	28,825	31,361	29,826	32,451
16.0510 16.0512	EMT Concealed-Lighting EMT with #12 CU Wire	54,306	52,807	45,774	40,585	44,390	42,315	46,696
16.0510 16.0513	ENT Concealed-Outlets ENT with #12 CU Wire	98,350	95,200	83,650	74,550	81,550	77,350	85,108
16.0510 16.0514	EMT Concealed-Outlets EMT with #12 CU Wire	149,100	144,550	123,200	107,450	119,000	112,700	126,000

CTL027113

3.2.6 Highrise Commercial
Ratio of In-Place Costs
ENT/EMT - 1991

CSI SECTION NO.	DESCRIPTION	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	PROJECT RATIO AVERAGE
16.0510 16.0511/16.0512	ENT/EMT Concealed-Lighting with #12 CU Wire	0.6794	0.6790	0.6977	0.7102	0.7065	0.7049	0.6963
16.0510 16.0513/16.0514	ENT/EMT Concealed-Outlets with #12 CU Wire	0.6596	0.6586	0.6790	0.6938	0.6853	0.6863	0.6771

3.3 Wood-Frame Townhouse Case

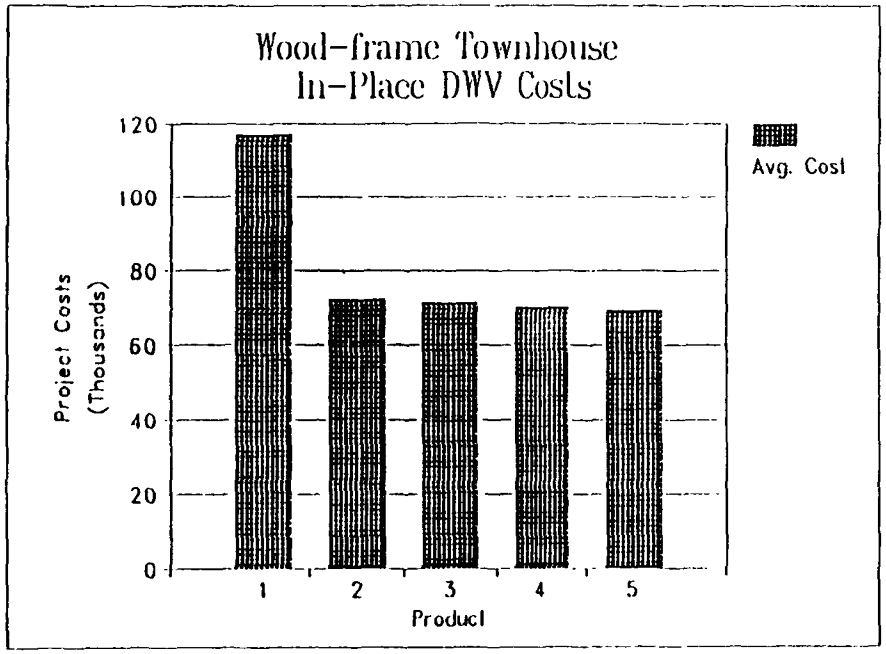
This project is a residential townhouse development which also includes common areas and limited commercial spaces. Estimates were for typical residential units only.

Specific replacement estimates were prepared for PVC in place of cast iron DWV piping and CPVC for copper DHCW.

In this case, PVC-ENT was directly compared to EMT, although in many jurisdictions for a project of this type Romex non-metallic sheathed cable would be the economic material of choice. In the jurisdiction where the project was actually built, however, electrical wiring needed to be installed within a raceway. Thus, EMT was originally used.

Summary results of the analyses follow and raw data can be found in Appendix D.3.

CTL027115



Legend

1 – Cast Iron

2 – PVC, Solid Core, Proprietary Fire

3 – PVC, Cellular Core, Proprietary Fire

4 – PVC, Solid Core, Generic Fire

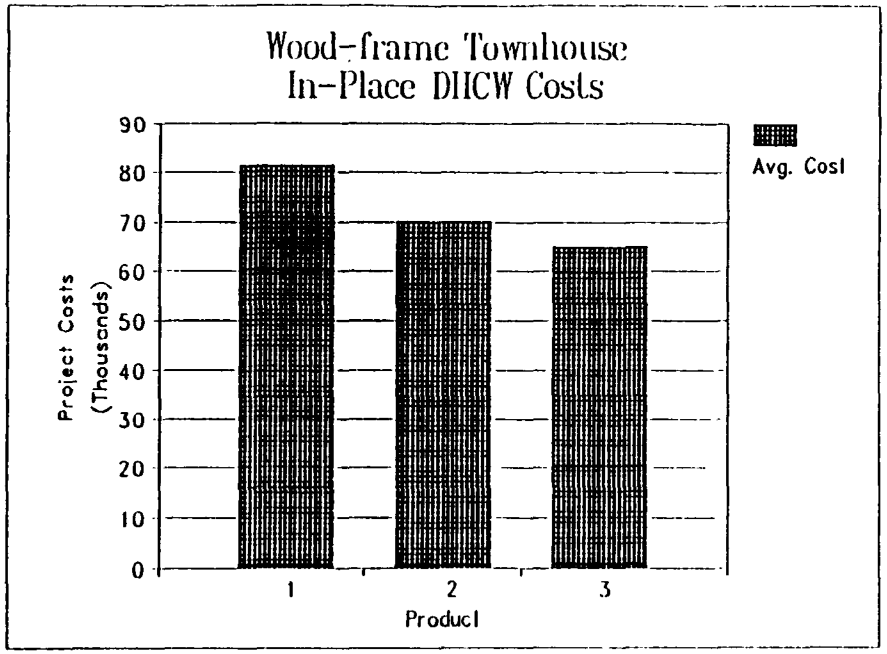
5 – PVC, Cellular Core, Generic Fire

3.3.1 Wood-frame Townhouse In-Place DWV Costs (in Dollars) - 1991

CSI SECTION NO.	DESCRIPTION	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	PROJECT COST AVERAGE
15.4100	CAST IRON PIPE HUBLESS, MECH JOINT (W/COPPER "M")	157,161	129,659	110,178	90,698	118,200	96,428	117,054
15.4110	PVC, SOLID CORE, SCH 40, IN BUILDING, W/FTGS, SUPPORTS AND PROPRIETARY FIRE STOPPING	101,531	81,656	67,577	53,499	73,374	57,640	72,546
15.4120	PVC, CELLULAR CORE, SCH 40, IN BUILDING W/FTGS, SUPPORTS AND PROPRIETARY FIRE STOPPING	100,517	80,641	66,563	52,485	72,360	56,625	71,532
15.4130	PVC, SOLID CORE, SCH 40, IN BUILDING W/FTGS, SUPPORTS AND GENERIC PROPRIETARY FIRE STOPPING WHEN POSSIBLE	98,349	79,120	65,500	51,879	71,108	55,885	70,307
15.4140	PVC, CELLULAR CORE, SCH 40, IN BUILDING W/FTGS, SUPPORTS AND GENERIC FIRE STOPPING WHEN POSSIBLE	97,411	78,247	64,627	51,007	70,235	55,013	69,423

3.3.2 Wood-frame Townhouse
Ratio of In-Place Costs
PVC/Cast Iron DWV - 1991

CSI SECTION NO.	DESCRIPTION	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	PROJECT RATIO AVERAGE
15.4110/15.4100	PVC SOLID CORE DWV, PROPRIETARY FIRE STOPPING/CAST IRON	0.6460	0.6298	0.6133	0.5899	0.6208	0.5978	0.6163
15.4120/15.4100	PVC, CELLULAR CORE DWV, PROPRIETARY FIRE STOPPING/CAST IRON	0.6396	0.6219	0.6041	0.5787	0.6122	0.5872	0.6073
15.4130/15.4100	PVC, SOLID CORE DWV, GENERIC FIRE STOPPING/CAST IRON	0.6258	0.6102	0.5945	0.5720	0.6016	0.5796	0.5973
15.4140/15.4100	PVC, CELLULAR CORE DWV, GENERIC FIRE STOPPING/CAST IRON	0.6198	0.6035	0.5866	0.5624	0.5942	0.5705	0.5895



Legend

1 – Copper

2 – CPVC, Proprietary Fire

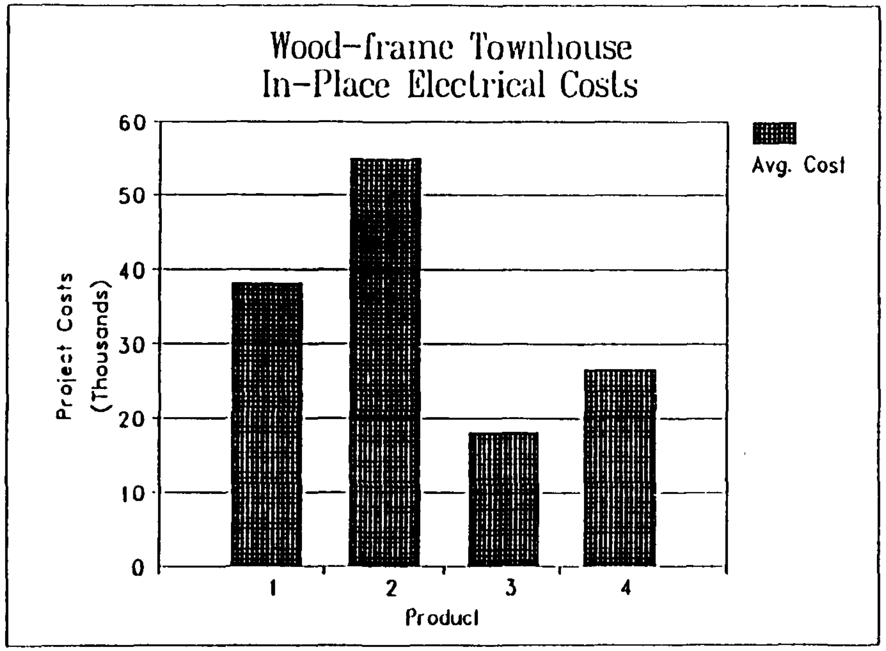
3 – CPVC, Generic Fire

3.3.3 Wood-frame Townhouse In-Place DHCW Costs (in Dollars) - 1991

CSI SECTION NO.	DESCRIPTION	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	PROJECT COST AVERAGE
15.4150	COPPER PIPE "M" IN BUILDING, W/FTGS & SUPPORTS	109,509	90,193	76,510	62,828	82,144	66,852	81,339
15.4160	CPVC, SUPPLY PIPE W/FTGS, SUPPORTS AND PROPRIETARY FIRE STOPPING	96,838	78,561	65,614	52,668	70,945	56,476	70,184
15.4170	CPVC, SUPPLY PIPE W/FTGS, SUPPORTS AND GENERIC FIRE STOPPING WHEN POSSIBLE	89,572	72,856	61,016	49,175	65,891	52,658	65,195

3.3.4 Wood-frame Townhouse
Ratio of In-Place Costs
CPVC/Copper DHCW - 1991

CSI SECTION NO.	DESCRIPTION	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	PROJECT RATIO AVERAGE
15.4160/15.4150	CPVC - DHCW - PROPRIETARY FIRE STOPPING/COPPER TYPE "M"	0.8843	0.8710	0.8576	0.8383	0.8637	0.8448	0.8599
15.4170/15.4150	CPVC - DHCW - GENERIC FIRE STOPPING/COPPER TYPE "M"	0.8179	0.8179	0.7975	0.7827	0.8021	0.7877	0.7993



Legend

1 – ENT Concealed – Lighting

2 – EMT Concealed – Lighting

3 – ENT Concealed – Outlets

4 – EMT Concealed – Outlets

3.3.5 Wood-frame Townhouse In-Place Electrical Costs (in Dollars) - 1991

CSI SECTION NO.	DESCRIPTION	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	PROJECT COST AVERAGE
16.0510 16.0511	ENT Concealed-Lighting ENT with #12 CU Wire	43,456	42,233	37,616	33,950	36,937	35,172	38,227
16.0510 16.0512	EMT Concealed-Lighting EMT with #12 CU Wire	63,961	62,196	53,912	47,801	52,283	49,838	54,999
16.0510 16.0513	ENT Concealed-Outlets ENT with #12 CU Wire	20,850	20,182	17,733	15,804	17,288	16,398	18,043
16.0510 16.0514	EMT Concealed-Outlets EMT with #12 CU Wire	31,609	30,644	26,118	22,779	25,228	23,892	26,712

3.3.6 Wood-frame Townhouse
Ratio of In-Place Costs
ENT/EMT - 1991

CSI SECTION NO.	DESCRIPTION	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	PROJECT RATIO AVERAGE
16.0510 16.0511/16.0512	ENT/EMT Concealed-Lighting with #12 CU Wire	0.6794	0.6790	0.6977	0.7102	0.7065	0.7057	0.6964
16.0510 16.0513/16.0514	ENT/EMT Concealed-Outlets with #12 CU Wire	0.6596	0.6586	0.6790	0.6938	0.6853	0.6863	0.6771

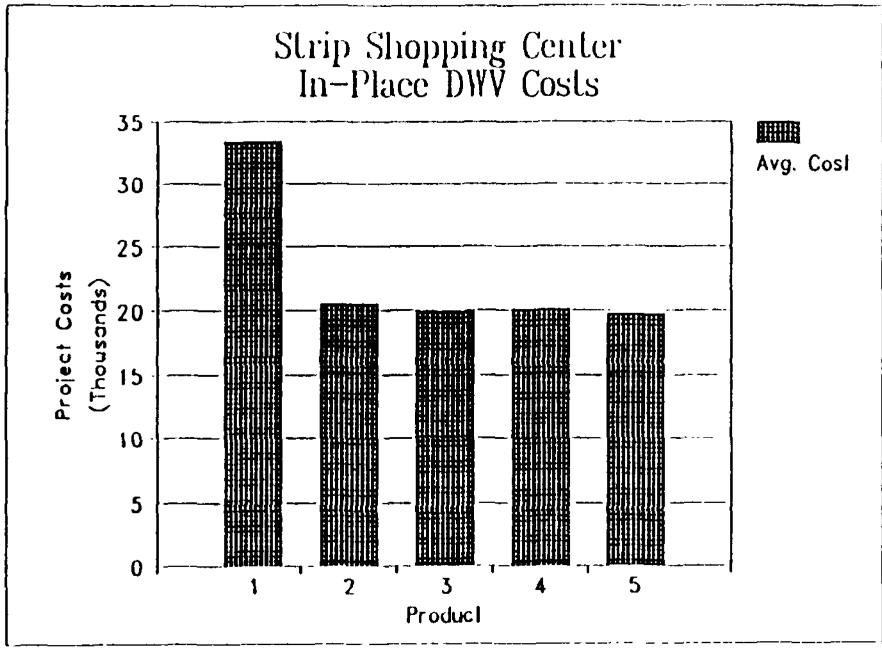
CTL027121

3.4 Strip Shopping Center Case

Of the four projects analyzed, this case represents the lowest ratio of penetrations of fire-rated assemblies requiring firestop detailing to quantity of pipe, tube, or conduit. This is because the buildings are single-story and typically are separated by occupancy separation walls which are unpenetrated for utility distribution. Services enter each unit separately.

In addition, the areas of the individual units are sufficiently small that they are undivided internally by fire resistive partitions.

Summary results of the analyses follow. Raw data can be found in Appendix D.4.



Legend

1 – Cast Iron

2 – PVC, Solid Core, Proprietary Fire

3 – PVC, Cellular Core, Proprietary Fire

4 – PVC, Solid Core, Generic Fire

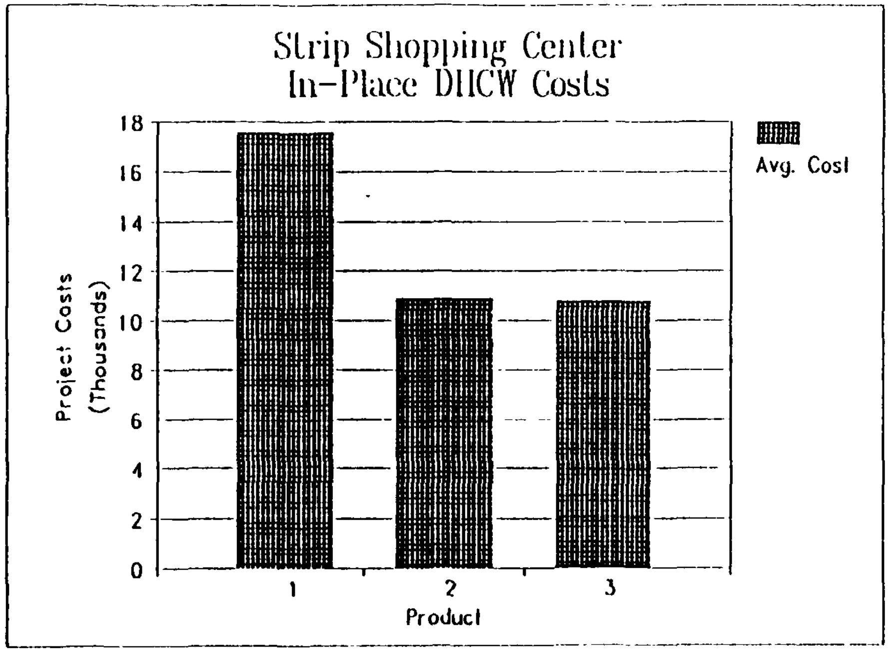
5 – PVC, Cellular Core, Generic Fire

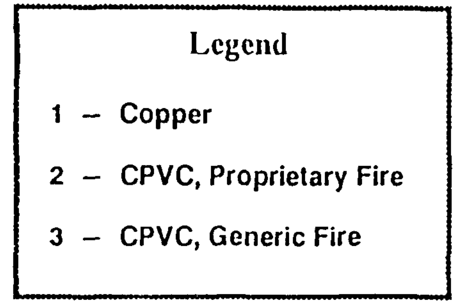
3.4.1 Strip Shopping Center In-Place DWV Costs (in Dollars) - 1991

CSI SECTION NO.	DESCRIPTION	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	PROJECT COST AVERAGE
15.4100	CAST IRON PIPE HUBLESS, MECH JOINT	44,022	36,752	31,600	26,448	33,721	27,964	33,418
15.4110	PVC, SOLID CORE, SCH 40, IN BUILDING, W/FTGS, SUPPORTS AND PROPRIETARY FIRE STOPPING	27,626	22,771	19,332	15,893	20,748	16,905	20,546
15.4120	PVC, CELLULAR CORE, SCH 40, IN BUILDING W/FTGS, SUPPORTS AND PROPRIETARY FIRE STOPPING	26,956	22,101	18,662	15,223	20,078	16,235	19,876
15.4130	PVC, SOLID CORE, SCH 40, IN BUILDING W/FTGS, SUPPORTS AND GENERIC FIRE STOPPING WHEN POSSIBLE	27,166	22,327	18,899	15,471	20,310	16,479	20,109
15.4140	PVC, CELLULAR CORE, SCH 40, IN BUILDING W/FTGS, SUPPORTS AND GENERIC FIRE STOPPING WHEN POSSIBLE	26,804	21,965	18,537	15,109	19,948	16,117	19,747

3.4.2 Strip Shopping Center
Ratio of In-Place Costs
PVC/Cast Iron DWV - 1991

CSI SECTION NO.	DESCRIPTION	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	PROJECT RATIO AVERAGE
15.4110/15.4100	PVC SOLID CORE DWV, PROPRIETARY FIRE STOPPING/CAST IRON	0.6275	0.6196	0.6118	0.6009	0.6153	0.6045	0.6133
15.4120/15.4100	PVC, CELLULAR CORE DWV, PROPRIETARY FIRE STOPPING/CAST IRON	0.6123	0.6014	0.5906	0.5756	0.5954	0.5806	0.5926
15.4130/15.4100	PVC, SOLID CORE DWV, GENERIC FIRE STOPPING/CAST IRON	0.6171	0.6075	0.5981	0.5850	0.6023	0.5893	0.5999
15.4140/15.4100	PVC, CELLULAR CORE DWV, GENERIC FIRE STOPPING/CAST IRON	0.6089	0.5977	0.5866	0.5713	0.5916	0.5763	0.5887





3.4.3 Strip Shopping Center In-Place DHCW Costs (in Dollars) - 1991

CSI SECTION NO.	DESCRIPTION	SAN FRANCISCO	BOSTON	CLEVELAND	HOUSTON	SEATTLE	ATLANTA	PROJECT COST AVERAGE
15.4150	COPPER PIPE "M" IN BUILDING, W/FTGS & SUPPORTS	22,722	19,173	16,660	14,146	17,695	14,886	17,547
15.4160	CPVC, SUPPLY PIPE W/FTGS, SUPPORTS AND PROPRIETARY FIRE STOPPING	14,730	12,116	10,265	8,414	11,027	8,958	10,918
15.4170	CPVC, SUPPLY PIPE W/FTGS, SUPPORTS AND GENERIC FIRE STOPPING WHEN POSSIBLE	14,610	12,003	10,156	8,310	10,917	8,853	10,808

CTL027125