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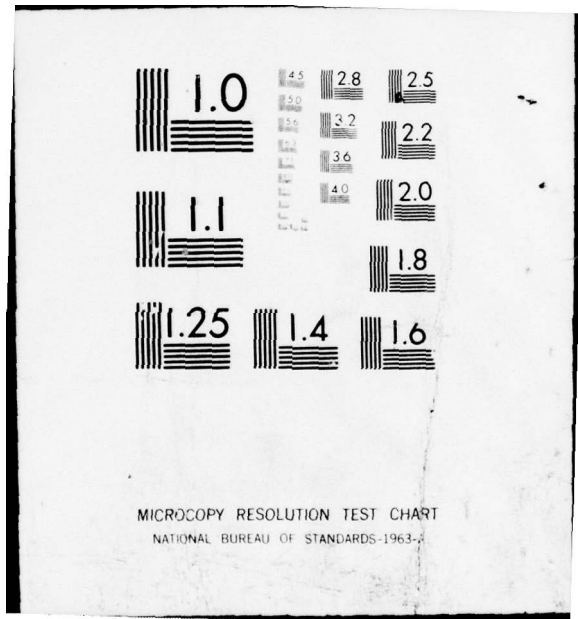
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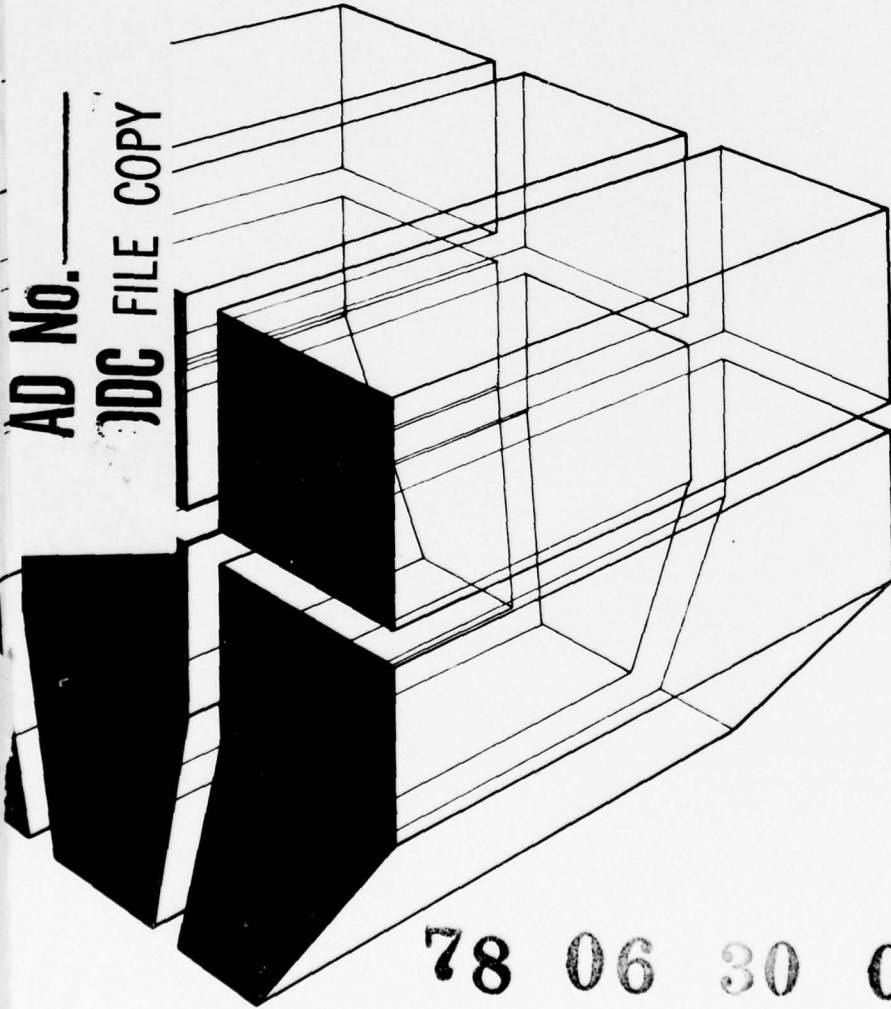
Plastics in Theater of Operations Construction

SCHEDULE 40 POLYVINYL CHLORIDE PIPE FOR ARMY
THEATER OF OPERATIONS CONSTRUCTION

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report presents the results of a study conducted to evaluate the potential of plastic pipe for use in Army Theater of Operations construction. The study compared the cost, weight, and labor requirements of the metallic and bituminous fiber piping systems specified in Technical Manual 5-303 with those of a plastic piping system. Schedule 40 polyvinyl chloride (PVC) pipe, which was found adequate for all cold water distribution and plumbing as well as drain-waste-vent and sewer systems, was selected for the comparison.		

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It was determined that substitution of PVC for metallic piping would result in cost, weight, and labor reductions of approximately 43, 76, and 57 percent, respectively. Although PVC does not offer such advantages over the bituminous fiber piping, the latter has demonstrated poor performance and is no longer readily available. Compared to the total conventional AFCS piping system (metallic and bituminous fiber), the PVC system offers estimated weight savings of 33 percent and labor savings of 5 percent, with a cost increase of 15 percent. An additional advantage to the PVC system is that specification of a single type and wall thickness of pipe simplifies procurement and inventory procedures.

It is recommended that TM 5-303 be revised to allow substitution of Schedule 40 PVC piping for metallic piping in cold water distribution and plumbing, drain-waste-vent, and sewer applications. If the unavailability of bituminous fiber pipe is verified, it is recommended that PVC be substituted as the specified material in TM 5-303.

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FOREWORD

This investigation was conducted for the Directorate of Military Construction, Office of the Chief of Engineers (OCE), under Project 4A763734DT08, "Military Construction Engineering Development"; Task T6, "Base Development"; Work Unit 003, "Plastics in Theater of Operations Construction." The OCE Technical Monitor is Mr. G. E. McWhite.

The work was performed by the Engineering and Materials Division (EM), U.S. Army Construction Engineering Research Laboratory (CERL), Champaign, IL.

Dr. G. R. Williamson is Chief of EM. COL J. E. Hays is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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SCHEDULE 40 POLYVINYL CHLORIDE PIPE FOR ARMY THEATER OF OPERATIONS CONSTRUCTION

1 INTRODUCTION

Background

Military construction in the theater of operations (T/O) must be expedient, efficient, and dependable. The extent to which these needs are met depends in part on the construction material technology available. It is Army policy to maintain current knowledge and, if necessary, develop new construction materials and practices that will enable T/O construction to satisfy the aforementioned criteria. A continuous effort is being exerted to improve the logistic aspects of construction materials as well as the ease with which they are assembled or installed. This study to determine the use of thermoplastic pipe in T/O construction is part of the Army's effort to achieve these goals.

An earlier study by Mikucki¹ suggested the potential for manufacture and use of plastic pipe in the T/O, and showed the logistical and installation savings that could be realized. A wide variety of thermoplastic pipe is commercially available, including polyvinyl chloride (PVC), chlorinated polyvinyl chloride (CPVC), acrylonitrile-butadiene styrene (ABS), polyethylene (PE), polypropylene (PP), and others. Of these, Schedule 40 PVC pipe appears to be the best suited for T/O construction for the following reasons.

1. PVC pipe is versatile and can be used for cold water supply, drain-waste-vent systems, and sewers. Thus, one type of pipe could be used for all T/O piping applications except steam or hot water; this would reduce the complexity of procurement, on-site inventory, and stockpiling.

2. PVC is the most widely applied thermoplastic pipe, accounting for two-thirds of all such pipe used.²

¹W. J. Mikucki, *Theater of Operations Water Supply—Feasibility of Manufacturing and Using Plastic Pipe in the Theater of Operations*, Technical Report E-16/AD769600 (Construction Engineering Research Laboratory [CERL], October 1973).

²Alvin Smith, *Investigation of Plastic Pipe for Use by the Corps of Engineers*, Technical Report M-219/ADA042313 (CERL, June 1977).

It is readily available from many Continental United States (CONUS) sources, which is a necessity for construction materials specified for T/O use. Although sources of PVC pipe of the sizes and strengths suggested for use also exist outside CONUS, particularly in principal European cities, the availability in sufficient quantities is not always assured.

3. In typical T/O construction, hot water distribution is not usually required and water pressures are seldom expected to exceed the 100 psi (689.5 kPa) pressure rating of Schedule 40 PVC pipe.

Objective

The objective of this investigation is to define the advantages and disadvantages of substituting Schedule 40 PVC piping materials for the metallic and bituminous fiber piping systems specified by TM 5-303.³ The criteria to be studied are cost, weight, and labor.

Approach

A typical 3000-man troop camp Army Facilities Components System (AFCS) installation was chosen to represent a broad spectrum of piping applications in T/O construction, including cold water distribution and plumbing, as well as drain-waste-vent and sewer systems. Optional facilities as defined in AFCS were chosen to insure adequate comparison since they are relatively small and are less complex than large facilities. The AFCS facility material lists were studied to determine piping supplies required to construct such installations, and a substitute Schedule 40 PVC plumbing system was designed. Cost, weight, and labor data for the existing and proposed piping systems were obtained from a variety of 1977 sources. The systems were compared in terms of these data in order to develop recommendations concerning the adoption of the proposed PVC piping materials in the AFCS manuals.

Mode of Technology Transfer

The information supplied by this investigation can be used as the basis for altering TM 5-303, *Army Facilities Components System—Planning Logistic Data and Bills of Material*, to include use of Schedule 40 PVC piping materials.

³Army Facilities Components Systems—Planning Logistic Data and Bills of Material, TM 5-303 (Department of the Army, 1977).

2 DEVELOPMENT OF COST, WEIGHT, AND LABOR DATA

Installation Selection

The military installation which displays all types of piping applications under consideration is the 3000-man troop camp which has a self-contained water supply and sewage disposal plant. The AFCS installation numbers are as follows:

Installation Description	AFCS Number
3000-man troop camp, temperate climate	NT 5621
120,000 gal/day (454 200 l/day) water supply	WS 2521
30,000 gal/day (113 550 l/day) sewage disposal plant	PS 2171

Determination of Required Piping Materials

The installation lists were consulted to determine the facilities required to construct each installation. The facilities lists were then used to determine the types, sizes, and amounts of piping materials required. These materials are given in Appendices A and B for metallic and bituminous fiber piping systems, respectively. It was assumed that the materials required for the Schedule 40 PVC piping system could be substituted for those of the conventional systems on a one-for-one basis.

Compilation of Data

The material cost data for the conventional piping systems were obtained from 1977 market prices in McMaster-Carr,⁴ Means Cost Data,⁵ and the National Construction Estimator.⁶ AFCS data reviewed did not reflect current market prices and were not used. Material cost data for the PVC piping system were obtained from Celanese Piping Systems, Inc.,⁷ a large supplier of PVC pipe fittings.

⁴Catalog No. 83 (McMaster-Carr Supply Co., 1977).

⁵Building Construction Cost Data, 35th Annual Edition (Robert Snow Means Co., Inc., 1977).

⁶National Construction Estimator, 25th ed. (Craftsman Book Co. of America, 1977).

⁷Chemtrol Industrial Thermoplastic Pipe Fittings and Valves Composite Catalog (Celanese Piping Systems, Inc., 1977).

Weight data for the conventional piping system were obtained from TM 5-303; weight data for the PVC system were obtained from Celanese Piping Systems, Inc.⁸

Labor man-hours for both the conventional and PVC piping systems were obtained by back calculating from labor costs, which were obtained from the National Construction Estimator on the basis of the size and lengths of the various pipes required in each system. The cost was then divided by the hourly cost of a pipe fitter (\$16.04) that was used in the determination of the labor cost by the National Construction Estimator.

The material cost and weight data are given in Appendices A and B, while the labor data are in Appendix C.

3 RESULTS

Bituminous Fiber Pipe

When attempting to obtain pricing, weight, and labor data for bituminous fiber pipe, it was found that this type of pipe is no longer readily available. Regardless of which piping supply company was consulted, there was unanimous agreement that the bituminous fiber pipe was obsolete or not available. Thermoplastic pipe was being used instead. Further investigation indicated that bituminous fiber pipe which had been in service for several years had often collapsed under hydrostatic or soil pressures. Thus, although the fiber pipe was inexpensive and easy to install, its use was discontinued because of poor performance.

Comparison of Piping System Cost, Weight, and Labor Requirements

Table 1 compares the conventional metallic piping system with a substitute Schedule 40 PVC system. This comparison showed that use of the PVC system would result in a 43 percent total cost savings, a 76 percent weight reduction, and a 57 percent reduction in installation time.

Table 2 compares the AFCS bituminous fiber pipe system with a substitute Schedule 40 PVC pressure

⁸Chemtrol Plastic Piping Handbook (Celanese Piping Systems, Inc., 1973).

Table 1
Metallic Pipe System Vs. PVC Pipe System

System	Material Cost, \$	Weight, lb (kg)	Installation Time, Man-Hours	Labor Cost (in CONUS)	Total Cost, \$
Metallic	28,310.08	34,027.19 (15467)	1,208.08	19,377.50	47,687.58
PVC (Sched. 40)	16,278.20	8,043.83 (3656.3)	524.44	8,412.40	24,690.60
PVC-Advantage, %	+43	+76	+57	+57	+48

Table 2
Bituminous Fiber Pipe System Vs. PVC Pipe System

System	Material Cost, \$	Weight, lb (kg)	Installation Time, Man-Hours	Labor Cost (in CONUS)	Total Cost, \$
Fiber Pipe	14,606.24	27,439.23 (12472.4)	1,243.24	19,941.60	34,547.84
PVC (Sched. 40)	41,340.59	33,143.58 (15065.3)	1,797.91	28,838.40	70,178.99
PVC-Advantage, %	-183	-21	-45	-45	-103

pipng system. Use of the PVC system would result in a cost increase of 103 percent, a system weight increase of 21 percent, and a 45 percent increase in installation time.

Table 3 compares the total conventional piping system (metallic and bituminous fiber) with a substitute Schedule 40 PVC system. Results show that for only a 15 percent increase in cost, the overall system weight could be reduced by 5 percent.

Since both the availability and performance of bituminous fiber pipe are highly questionable, comparison with only metallic pipe shows a significant advantage (43 percent savings in material cost, 76 percent decrease in shipping weight, 57 percent decrease in labor man-hours) for the PVC system. An overall savings of 48 percent could therefore be realized. It was also found that the conventional piping system used four different piping materials while the PVC system requires only one piping material, thereby reducing the procurement and inventory effort.

4 CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. The use of Schedule 40 PVC pipe is a viable method of improving AFCS T/O construction with respect to cost, weight, and labor reductions as well as the simplification of piping material procurement and inventory procedures.

2. The maximum benefit of Schedule 40 PVC pipe is observed when it is substituted for metallic piping materials. In this case, the cost, weight, and labor reductions were estimated to be 43, 76, and 57 percent, respectively.

3. Compared to the bituminous fiber pipe specified by AFCS, Schedule 40 PVC pressure pipe does not appear to offer any cost, weight, or labor advantages. However, the performance of bituminous fiber pipe has been poor and it is no longer readily available in the United States or overseas.

Table 3
Total Conventional AFCS Piping System Vs. PVC System

System	Material Cost \$	Weight lb, (kg)	Installation Time, Man-Hours	Labor Cost (in CONUS)	Total Cost \$
Conventional	42,916.32	61,466.42 (27938.3)	2,451.32	39,319.10	82,235.42
PVC (Sched. 40)	57,618.79	41,143.58 (18701.6)	2,322.36	37,250.80	94,869.59
PVC-Advantage, %	-32	+33	+5	+5	-15

4. Compared to the total conventional AFCS piping system (metallic and bituminous fiber), the estimated weight and labor savings for PVC pipe were 33 and 5 percent, respectively. The corresponding cost increase was estimated at 15 percent.

Recommendations

It is recommended that TM 5-303 be revised to allow Schedule 40 PVC piping to be substituted for metallic piping in cold water distribution and plumbing, drain-waste-vent systems, and sewer applications.

It is also recommended that the unavailability of bituminous fiber pipe be verified. If bituminous fiber pipe is unavailable commercially, PVC should be substituted wherever it is specified in TM 5-303.

REFERENCES

Army Facilities Component Systems-Planning Logistic Data and Bills of Material, TM 5-303 (Department of Army, 1977).

Building Construction Cost Data, 35th Annual Edition (Robert Snow Means Co., Inc., 1977).

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Chemtrol Industrial Thermoplastic Pipe Fittings and Valves Composite Catalog (Celanese Piping Systems, Inc., 1973).

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Smith, Alvin, *Investigation of Plastic Pipe for Use by the Corps of Engineers*, Technical Report M-219/ADA042313 (CERL, June 1977).

APPENDIX A: COMPARISON OF METALLIC AND PVC PIPING SYSTEMS

AFCS Piping Element	Unit	Amount Reqd.	Conventional Metallic System		Schedule 40 PVC System	
			Total Cost, \$	Total Weight, lb*	Total Cost, \$	Total Weight, lb*
Valve, 6 x 20	ea.	1	664.98	961	328.20	18.35
Pipe, 3/4 in.*	ft*	50	66.00	56.5	15.75	11.0
Pipe, 2 in.	ft	600	2136.00	2208	489.60	420.0
Tube, 6-5/8 in.	lg.	7	665.00	1239	288.40	252.70
Tube, 4-1/2 in.	lg.	227	11350.00	15892	5379.90	4630.60
Coupling, 4 in.	ea.	299	1225.50	2018.25	1518.92	367.77
Bushing, 2 in. x 1/4 in.	ea.	15	18.30	16.35	24.75	2.85
Elbow, 1-1/4 in., 90°	ea.	15	19.50	15.30	19.80	4.20
Elbow, 3/4 in., 90°	ea.	2	.78	.8	1.04	.22
Pipe, 1-1/4 in.	ft	1150	2484.00	2622	583.05	494.5
Tee, 2 in. x 1-1/4 in.	ea.	2	12.50	.56	5.78	1.48
Tee, 4 in.	ea.	2	36.90	23.82	29.98	5.42
Elbow, 4 in., 90°	ea.	10	117.00	80.0	114.60	19.50
Bushing, 2 in. x 3/4 in.	ea.	2	2.44	.40	2.48	.38
Elbow, 2 in., 90°, 1/4 in.	ea.	9	23.23	19.71	22.50	4.68
Reducer, 4 x 2 in.	ea.	5	24.00	17.50	31.50	6.75
Reducer, 6 x 4 in.	ea.	8	59.20	51.04	121.36	27.44
Coupling, 6 in.	ea.	25	167.50	325.0	469.50	69
Tee, 6 in.	ea.	4	200.00	104.0	201.60	44
Tee, 4 x 4 x 2 in.	ea.	15	276.75	120.0	244.85	57.75
Pipe, 6 in.	ft	120	1557.60	2301.6	494.40	433.2
Pipe, 4 in.	ft.	120	741.60	1306.8	284.40	244.8
Nipple, 4 x 6 in.	ea.	8	25.20	34.0	59.60	7.92
Nipple, 6 x 6 in.	ea.	4	20.00	26.0	54.04	6.92
Elbow, 4 x 45 in.	ea.	4	56.16	47.0	45.84	6.12
Elbow, 6 x 45 in.	ea.	4	158.40	76.0	144.04	21.76
Elbow, 6 x 90 in.	ea.	4	132.00	126.0	144.04	30.52
Elbow, 4 in., 90°	ea.	8	93.60	109.36	91.68	15.60
Coupling, 6 in.	ea.	2	13.40	97.50	37.56	5.52
Coupling, 4 in.	ea.	2	8.20	60.0	10.16	2.46
Valve, 4 in. gate	ea.	2	370.00	329.8	491.62	29.10
Valve, 6 in. gate	ea.	2	590.00	300.0	980.00	68.0
Valve, 4 in. float	ea.	2	1200.00	205.0	1391.62	97.10
Pipe, 2 in.	ft	400	1424.00	1472	328.00	280
Coupling, 4 in.	ea.	1	4.10	6.75	5.08	1.23
Nipple, 1.5 x 2.5 in.	ea.	4	2.04	2.28	7.84	.52
Nipple, 2 x 2.5 in.	ea.	6	4.14	3.72	13.74	.84
Nipple, 2 x 6 in.	ea.	2	2.46	3.38	6.14	.68
Reducer, 2 x 1.5 in.	ea.	6	12.12	7.62	7.38	.84
Union, 2 in.	ea.	4	26.80	9.68	71.04	2.0
Elbow, 2 in., 45°	ea.	4	10.52	14.80	12.84	1.76
Tee, 2 in.	ea.	2	7.10	11.20	5.78	1.44
Elbow, 2 in., 90°	ea.	16	39.52	65.60	40.00	8.32
Reducer, 4 x 2 in.	ea.	1	4.10	5.10	6.30	1.35
Reducer, 2 x 4 in.	ea.	1	4.10	5.10	6.30	1.35
Coupling, 6 in.	ea.	1	4.10	5.10	18.78	2.76
Valve, 2 in. gate	ea.	1	68.00	8.4	52.75	4.70
Valve, 2 in. float	ea.	1	336.80	14.60	348.40	17.93
Valve, 4 in. float	ea.	1	600.00	102.50	556.60	27.50
Valve, 2 in. gate	ea.	1	68.00	8.4	52.75	4.70
Pipe, 6 in.	ft	46	597.08	882.28	189.52	166.06
Flange, 6 in.	ea.	4	74.80	72.0	109.00	17.40
Nipple, 6 x 6 in.	ea.	2	10.00	13.0	19.00	3.62
Elbow, 6 in., 45°	ea.	4	158.40	76.0	144.00	11.80
Drain, 6 in., 45°	ea.	2	74.96	56.0	72.00	7.22
Pipe, 6 in.	ft	20	259.60	383.60	82.40	72.2
TOTALS			28,310.08	34,027.19	16,278.20	8,043.83

*Metric conversion factors: 1 in. = 25.4 mm; 1 ft = 0.3048 m; 1 lb = 0.4536 kg.

APPENDIX B: COMPARISON OF BITUMINOUS FIBER AND PVC PIPING SYSTEMS

AFCS Piping Element	Unit	Amount Reqd.	Conventional Metallic System		Schedule 40 PVC System	
			Total Cost, \$	Total Weight, lb*	Total Cost, \$	Total Weight, lb*
Coupling, 4 in.*	ea.	15	6.00	30.75	76.20	18.45
Coupling, 6 in.	ea.	42	43.68	147.0	788.76	115.92
Adapter, 4 in.	ea.	25	30.25	46.75	150.50	33.50
Adapter, 6 in.	ea.	4	9.96	105.48	84.40	25.60
Bend, 4 in., 45°	ea.	20	80.40	294.8	229.20	30.60
Bend, 6 in., 45°	ea.	6	74.16	132.0	216.06	17.70
Bend, 6 in., 90°	ea.	1	12.36	64.25	36.01	4.10
Bend, 4 in., 90°	ea.	25	81.75	500.0	286.50	48.75
Pipe, 4 in.	ft*	2224	1779.20	3475.0	5270.88	4536.96
Pipe, 6 in.	ft	6592	10,481.28	18787.20	27,159.04	23797.12
Coupling, 6 in.	ea.	40	66.40	190.00	751.20	110.40
Pipe, 6 in.	ft	320	508.80	912.0	1318.40	1155.20
Coupling, 6 in.	ea.	80	132.80	380.0	1502.40	220.80
Pipe, 4 in.	ft	192	153.60	300.0	455.04	391.68
Pipe, 6 in.	ft	640	1017.60	1824.0	2636.80	2310.40
Pipe, 4 in.	ft	160	128.00	250.0	379.20	326.40
TOTALS			14,606.24	27,439.23	41,240.59	33,143.58

*Metric conversion factors: 1 in. = 25.4 mm; 1 ft = 0.3048 m; 1 lb = 0.4536 kg.

APPENDIX C: COMPARISON OF LABOR REQUIREMENTS

Metallic Pipe Vs. PVC Pipe

Pipe Size, in. †	Metallic System			PVC System		
	Amount Reqd., ft†	Labor Cost,* \$	Man-Hours** Reqd.	Amount Reqd., ft†	Labor Cost,* \$	Man-Hours** Reqd.
3/4	50	99.00	6.17	50	39.50	2.46
1-1/4	1150	2967.00	184.98	1150	1069.50	66.68
2	1000	3520.00	219.45	1000	1300.00	81.05
6	186	1320.00	82.29	186	632.00	39.40
4	120	570.00	35.54	120	276.00	17.21
6-1/2	70	119.00	7.42	70	238.00	14.84
4-1/2	2270	10,782.50	672.23	2270	4857.00	302.81
TOTALS		\$19,337.50	1208.08	TOTALS	\$8,412.40	524.44

Fiber Pipe Vs. PVC Pipe

Pipe Size, in. †	Bituminous Fiber Pipe			PVC System		
	Amount Reqd., ft†	Labor Cost,* \$	Man-Hours** Reqd.	Amount Reqd., ft†	Labor Cost,* \$	Man-Hours** Reqd.
4	2576	4611.04	287.47	4	6182.40	385.44
6	7552	15,330.56	955.77	6	22,656.00	1412.47
TOTALS		\$19,941.60	1243.24	TOTALS	\$28,838.40	1797.91

*Based on a total hourly cost of \$16.04 for plumbers in CONUS, taken from National Construction Estimator, 1977.

**Data obtained from National Construction Estimator, 1977.

†Metric conversion factors: 1 in. = 25.4 mm; 1 ft. = 0.3048 m.

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