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## THE DESIGN AND COST OF A TWELVE-INCH UNDERGROUND STEAM MAIN

By O. E. Eckert

The accompanying steam main design is similar to a design which has been in use in the City of Lansing for about ten (10) years for lines 8 inches and larger. A similar design which is the same, except that wood forms are used, has been in use for a considerably longer period and is still used for smaller mains. The type of design submitted has proven entirely satisfactory. General features such as location of the main and location of alignment guides and anchors are shown on Figure 1.

The duct formation (Fig. 2) makes use of an arched top to carry the load and so reduce the thickness of concrete required.

After placing the drainage tile and crushed stone, a single ply of tarred felt paper is laid over the stone. This paper serves the double purpose of preventing the concrete from running into the stone and also waterproofs the underside of the duct to some extent. Beveled keyway strips are next set flush with the top of the base slab and so located as to form a recess for the edge of the sheet metal form. Wooden inserts are also spaced according to the roller support spacing.

The sides and top of the duct are formed by using U-shaped corrugated black steel form. The edges of the form are placed in the recess provided and firmly wedged in place. After this the reinforcing steel is placed and the concrete cast. The top of the duct is waterproofed with a layer of tarred felt paper placed while the concrete is still wet.

Expansion in the concrete duct is provided for by projecting the duct through the manhole walls and preventing bond with the wall by using a paper separator between the duct and manhole wall. Suitable reinforcing is provided in the duct with  $\frac{3}{8}$ -in. deformed bars.

Seepage of water into the duct is allowed to drain to the nearest manhole which is drained to the sewer.

The pipe is purchased with  $37\frac{1}{2}^\circ$  machine beveled ends, and is fabricated by the electric arc process of welding. The pipe is aligned and welded in the trench. The use of welding rollers permits the rotation of the pipe during welding.

All line welds are of the open throat double vee design with throats reinforced to not less than the thickness of the thinnest parts joined plus 25 per cent. Butt welds are built up in three sections. The first section is made  $\frac{1}{8}$  inch thick using  $\frac{1}{4}$ -in. rod with 230 amps. at 37 volts, and not less than 5 minutes welding time. The second section is  $\frac{5}{16}$  inch thick, using  $\frac{3}{8}$ -in. rod with 285 amps. at 40 volts and a welding time of at least 7 minutes. The third section is  $\frac{1}{4}$  inch thick using  $\frac{3}{8}$ -in. rod at 285 amps. and 40 volts and a welding time of not less than 10 minutes.

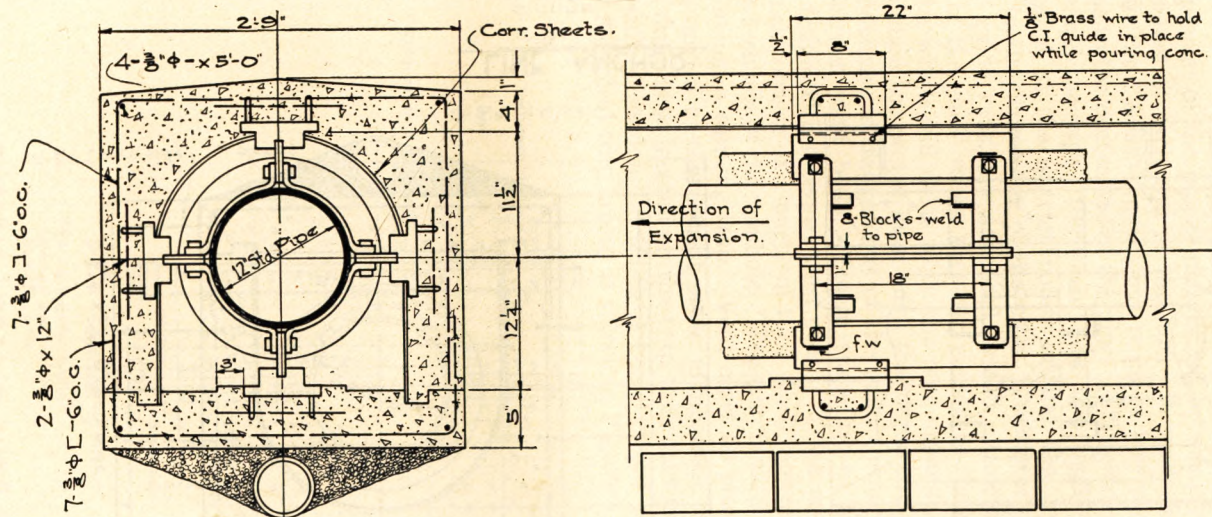










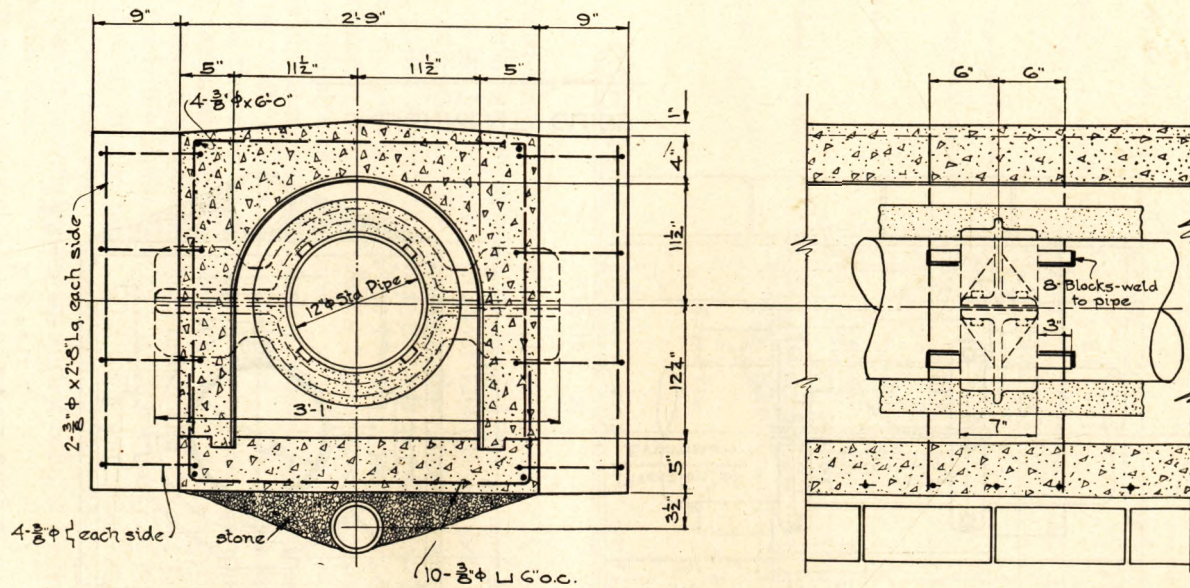


# ALIGNMENT GUIDE

1 1/2" = 12"

FIGURE -4.





# LINE ANCHOR

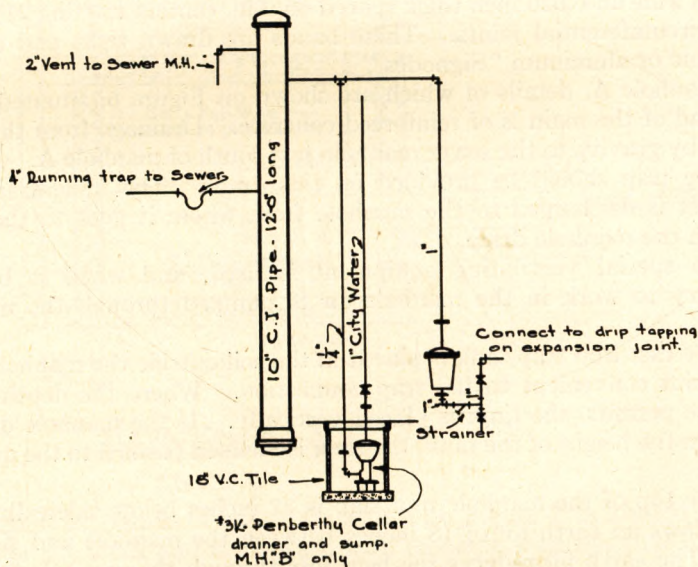
1 1/2" = 12"

FIGURE - 5



Alignment of the pipe is maintained by using two guides (Fig. 4) on 12-ft. centers at each end of the line. A guide is used which is quite similar to the "Adsko" guide but requires less vertical height from the duct base to the center line of the pipe. This guide consists of two clamp rings around the pipe. Between these two rings are carried four guide rails located at the quarter points around the pipe circumference and parallel to the center line of the pipe. Cast iron guide shoes, slotted to suit the guide rails, are anchored in the concrete duct. To facilitate placing of the guide shoes, they are pinned to the guide rails with  $\frac{1}{8}$ -in. brass wire which will shear when the pipe expands. Lugs welded to the pipe maintain the proper location of the alignment guide on the pipe.

Condensate is trapped out of the main through drip pockets cast in the expansion joint body. Steam traps are of the Anderson inverted bucket design with a forged steel body. Traps are discharged to a trap tank which consists of a length of 10-in. C. I. pipe set in a vertical position in the soil outside of the manhole. The trap tank discharges to the nearest sewer through a running trap. Vent must be provided on the tank and is to be carried to the nearest sewer manhole or catch basin. The condensate drain is so located on the trap tank that the tank is about three-fourths full of condensate which is being cooled before discharge to the sewer. A typical trap layout is shown in Figure 3.



**TYPICAL TRAP & SUMP PUMP  
CONNECTIONS**  
FIGURE 3



Thermal expansion of the pipe is provided for by means internally guided slip type expansion joints having the slip end beveled for welding.

The body of the expansion joints are of cast steel with anchor bases welded to the body. The sliding sleeves are of nickel-chromium plated steel tubing.

The packing used in the expansion joints should be "John Crane No. 1151" or equal.

Insulation for the proposed main consists of a single layer of 85 per cent magnesia 3 inches thick. The covering is to be held in place with galvanized iron bands  $\frac{3}{8}$  inch wide and .015 inch thick spaced on 18-in. centers, 9 inches from each end of the insulation sections. These bands are drawn tight and crimped together with galvanized iron seals as manufactured by the Signode Steel Strapping Company. Any part of the seal projecting above the surface of the insulation should be hammered flush.

A waterproof jacket of 60-lb. asphaltic impregnated asbestos felt is placed around the insulation. Horizontal joints are lapped 4 inches and sealed with asphaltic compound. The outside lap of the joint extends to the horizontal center line to form a water shed. All circumferential joints are covered with an independent strip of 35-lb. asbestos felt 8 inches wide wrapped twice around the pipe, cemented and secured with two bands. The waterproof jacket is fastened with zinc or aluminum band  $\frac{1}{2}$  inch wide and .020 inch thick spaced on 9-in. centers starting  $2\frac{1}{2}$  inches from circumferential joints. These bands are drawn tight and crimped with zinc or aluminum "Signodes."

Manhole A, details of which are shown on Figure 6, situated at the west end of the main is of reinforced concrete. Drainage from this manhole is by gravity to the sewer manhole just south of manhole A. A back-pressure trap should be provided on this drain. The underdrain from the duct is discharged to the manhole from where it goes to the sewer through the manhole drain.

No special ventilating equipment is used, and when it becomes necessary to work in the manhole air is pumped through the manhole cover.

The cast iron trap tank is placed in the soil outside the manhole vault at a point convenient to the trap connection. Where the depth of the manhole permits, the tank is placed vertically. If the manhole depth is less than the height of the tank, the tank is inclined parallel to the manhole wall.

The top of the manhole roof slab is 22 inches below sidewalk grade. This allows an earth fill of 18 inches between the manhole and sidewalk slab. The earth fill reduces the heat loss through the manhole roof and also helps prevent cracking of the sidewalk due to uneven settlement between manhole and surrounding ground. The manhole frame consists



of a cast iron frame and lid having 30-in. diameter clear opening. An inner flange is also provided on the manhole frame to take an inner cover of wood 2 inches thick to reduce loss through the cover. The frame and cover is set flush with the sidewalk on top of a square neck on the manhole proper.

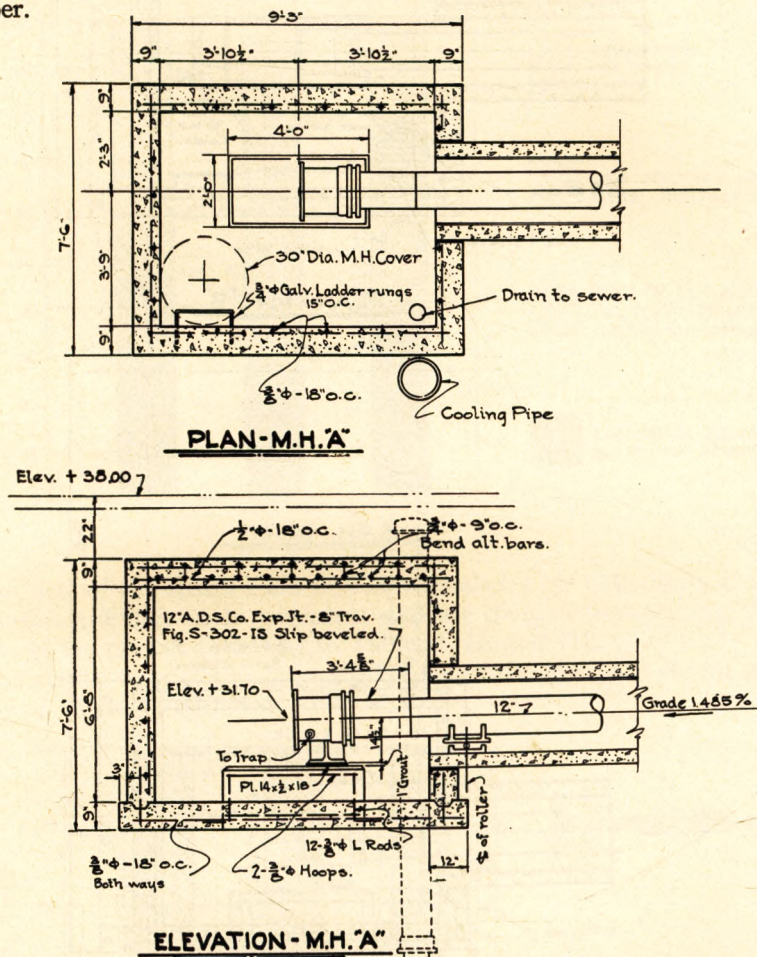


FIGURE- 6

Manhole B, details of which are shown on Figure 7, is located at the east end of the block and is identical with manhole A except that it is set deeper in the ground and due to being below the sewers a sump pump is provided to drain the manhole. A No. 3K Penberthy cellar drainer is



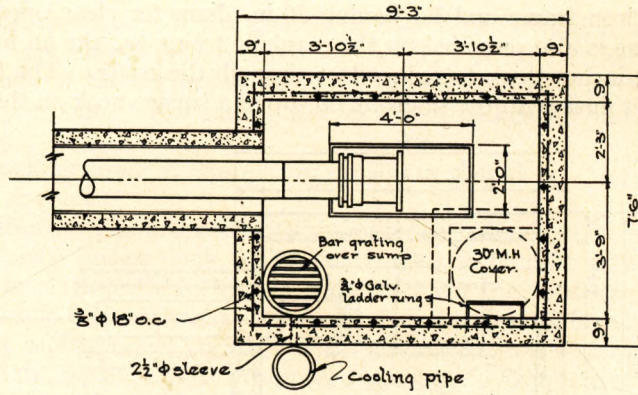
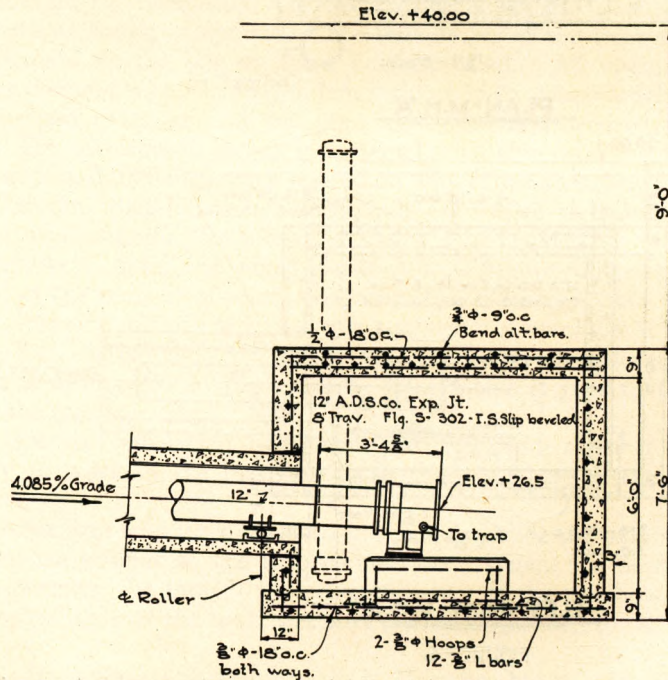
**PLAN - M.H. "B"****ELEVATION - M.H. "B"**

FIGURE - 7.



used for this purpose and discharges through the trap cooling tank to the sewer. This drainer has a capacity of 3,200 gallons per hour against a 5-ft. head. Sewer connection from this manhole is made to the 36-in. sewer running north and south on the street west of the manhole.

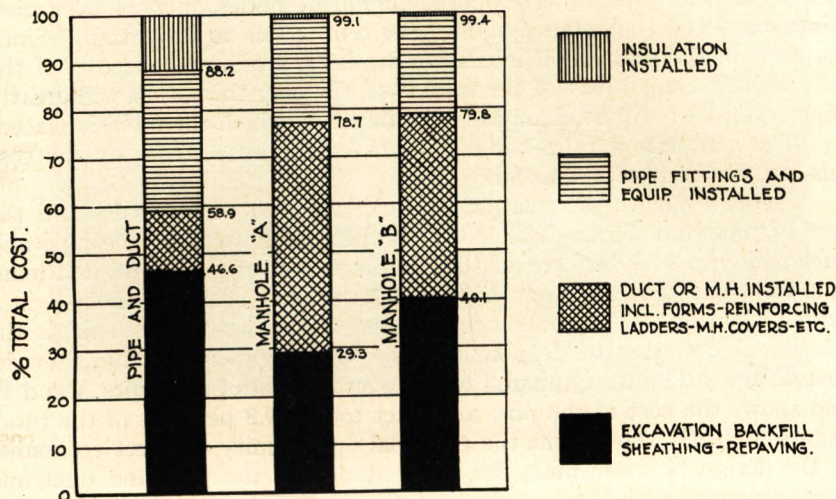


FIGURE No. 8

Costs of the steam main and two manholes are submitted, based on the standard unit costs provided, and are divided between the various parts of the project according to Tables I, II, and III.

Relative costs of the various divisions of the work are shown graphically on Figures 8 and 9.

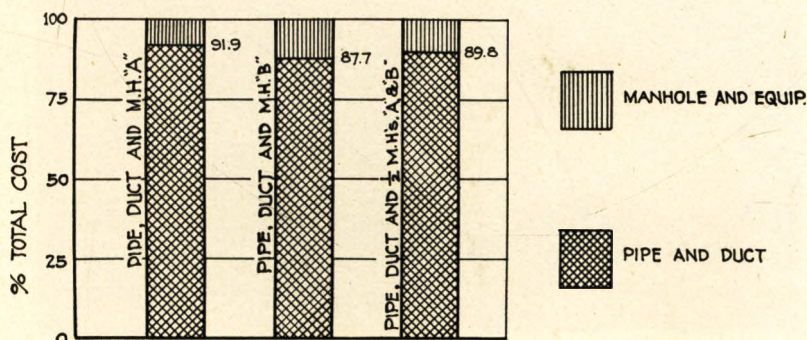


FIGURE No. 9



In the left-hand column of Figure 8 are shown the proportionate costs of the four classes of work going into the pipe and duct. The total cost is taken as 100 per cent. Of this amount 46.6 per cent is for excavation, backfill, sheathing, paving, etc.; 12.3 per cent installation of conduit; 29.2 per cent for pipe, roller supports, alignment guides, anchors, expansion joints, etc., and the balance of 11.9 per cent is due to insulation. Since the costs of the piping and insulation are fairly fixed, and the cost of the duct is only a small part of the total cost, the only thing that will greatly affect total cost will be changes in the depth at which the main is placed.

The center and right-hand columns of Figure 8 show similar cost relations for manholes A and B.

Figure 9 shows the relation between the cost of manholes and the cost of pipe and duct. The left-hand column shows that the pipe and duct make up 91.9 per cent of the combined cost of pipe, duct and manhole A. The center column shows 87.7 per cent using manhole B in a similar relation. The difference between these two figures reflects the additional cost due to deep manholes. The right-hand column is the cost of pipe and duct compared to the average cost of manholes A and B, and shows the cost of the pipe and duct to be 89.8 per cent of the total. Figure 9 clearly shows that the principal opportunity to effect economies in the design of steam main lies in the design of the pipe and duct and when reviewed with Figure 8 in mind, the depth at which a main is placed controls to a great extent that proportion of the cost that is subject to any great variation.





FIG. 1—Typical butt weld.

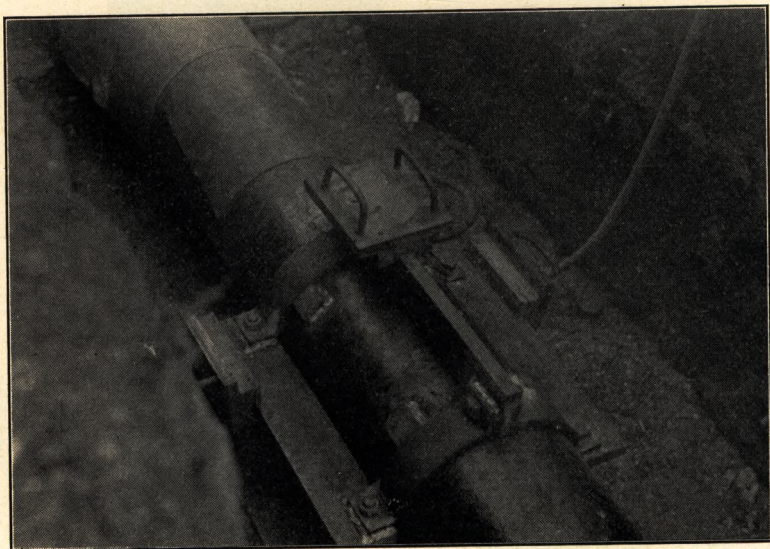


FIG. 2—Typical alignment guide ready for duct forms.





FIG. 3—Pipe aligned and welded ready for covering.



FIG. 4—Pipe insulated and waterproofed.  
Sheet metal conduit partially placed.



**TABLE I (Eckert, Lansing, Mich.)**  
**MATERIAL, LABOR AND COST—TRENCH PIPE AND CONDUIT**

| Description<br><br>Column 1                    | Quantities           |                       | Costs                |                   |                   | Remarks<br><br>Column 7 |
|------------------------------------------------|----------------------|-----------------------|----------------------|-------------------|-------------------|-------------------------|
|                                                | Material<br>Column 2 | Lab.-Hrs.<br>Column 3 | Material<br>Column 4 | Labor<br>Column 5 | Total<br>Column 6 |                         |
| Remove paving, sidewalk.....                   | 1,411 sq. ft.        | .....                 | .....                | \$141.10          | \$141.10          |                         |
| Replace paving, sidewalk.....                  | 1,411 sq. ft.        | .....                 | \$141.10             | 197.54            | 338.64            |                         |
| Excavation, open trench, 0 to 6 ft. depth...   | 262.0 cu. yd.        | .....                 | .....                | 720.50            | 720.50            |                         |
| Excavation, open trench, 6 to 11 ft. depth...  | 70.5 cu. yd.         | .....                 | .....                | 246.75            | 246.75            |                         |
| Excavation, open trench, 11 to 16 ft. depth... | 4.1 cu. yd.          | .....                 | .....                | 17.43             | 17.43             |                         |
| Excavation, tunnel.....                        | 31 cu. yd.           | .....                 | .....                | 139.50            | 139.50            |                         |
| Hauling excavation, truck and driver.....      | 385 cu. yd.          | .....                 | .....                | 481.25            | 481.25            |                         |
| Backfill, open trench.....                     | 193.6 cu. yd.        | .....                 | .....                | 242.00            | 242.00            |                         |
| Backfill, tunnel.....                          | 18.1 cu. yd.         | .....                 | .....                | 45.25             | 45.25             |                         |
| Hauling backfill, truck and driver.....        | 211.7 cu. yd.        | .....                 | .....                | 264.63            | 264.63            |                         |
| Shoring open trench, material.....             | 16.0 M.B.F.          | .....                 | 560.00               | .....             | 560.00            |                         |
| Shoring open trench, placing.....              | 16.0 M.B.F.          | .....                 | .....                | 320.00            | 320.00            |                         |
| Shoring open trench, removing.....             | 16.0 M.B.F.          | .....                 | .....                | 160.00            | 160.00            |                         |
| Guard rails.....                               | 700 L.F.             | .....                 | .....                | 52.50             | 70.00             |                         |
| Shoring tunnel, material.....                  | 2.4 M.B.F.           | .....                 | .....                | 84.00             | 84.00             |                         |
| Shoring tunnel, placing.....                   | 2.4 M.B.F.           | .....                 | .....                | 96.00             | 96.00             |                         |
| Shoring tunnel, removing.....                  | 2.4 M.B.F.           | .....                 | .....                | 48.00             | 48.00             |                         |
| Stone underdrain.....                          | 534 cu. yd.          | .....                 | .....                | 5.75              | 21.56             |                         |
| Tile underdrain.....                           | 391 L.F.             | .....                 | .....                | 7.82              | 27.37             |                         |
| Tar paper.....                                 | 2.5 rolls            | .....                 | .....                | 2.00              | 8.00              |                         |
| Hot sand, backfill.....                        | 43 ton               | .....                 | 129.00               | 53.75             | 182.75            |                         |
| Conduit forms (inside of conduit).....         | 390 L.F.             | .....                 | 195.00               | 20.00             | 215.00            |                         |
| Key check.....                                 | 784 L.F.             | .....                 | 39.20                | 15.68             | 54.88             |                         |
| Reinforcing bars.....                          | 2,300 lb.            | .....                 | 69.00                | 57.50             | 126.50            |                         |
| Tar paper.....                                 | 2.5 rolls            | .....                 | 6.00                 | 2.00              | 8.00              |                         |
| Concrete.....                                  | 76.3 cu. yd.         | .....                 | 572.25               | 152.60            | 724.85            |                         |
| Pipe.....                                      | 393'-3"              | .....                 | 845.49               | 550.55            | 1,396.04          |                         |
| Pipe welds.....                                | 11 pcs.              | .....                 | .....                | 165.00            | 165.00            |                         |
| Annealing welds.....                           | 11 pcs.              | .....                 | .....                | 44.00             | 44.00             |                         |
| Saddles and roller supports.....               | 32 pcs.              | .....                 | 288.00               | .....             | 288.00            |                         |
| Welding on saddles.....                        | 32 in.               | .....                 | .....                | 27.20             | 27.20             |                         |
| Pipe supports.....                             | 32 pcs.              | .....                 | .....                | 30.40             | 30.40             |                         |
| Alignment guides.....                          | 4 pcs.               | .....                 | 158.00               | 15.20             | 173.20            |                         |
| Anchors—pipe.....                              | 1 pc.                | .....                 | 40.00                | .....             | 40.00             |                         |
| Welding on anchors.....                        | 1 pc.                | .....                 | .....                | 24.20             | 24.20             |                         |
| Expansion joints for pipe.....                 | 2 pcs.               | .....                 | 474.00               | 19.00             | 493.00            |                         |
| Test piping.....                               | .....                | .....                 | .....                | 110.00            | 110.00            |                         |
| Insulation—pipe.....                           | 391 L.F.             | .....                 | 893.00               | 182.00            | 1,075.00          |                         |
| Insulation (expansion joints).....             | 2 pcs.               | .....                 | 8.00                 | 4.00              | 12.00             |                         |
| Totals.....                                    | .....                | .....                 | \$4,560.90           | \$4,661.10        | \$9,222.00        |                         |



TABLE II (Eckert, Lansing, Mich.)  
MATERIAL, LABOR AND COST—MANHOLE A

| Description<br>Column 1               | Quantities    |           | Costs    |          |          | Remarks<br>Column 7 |
|---------------------------------------|---------------|-----------|----------|----------|----------|---------------------|
|                                       | Material      | Lab.-Hrs. | Material | Labor    | Total    |                     |
|                                       | Column 2      | Column 3  | Column 4 | Column 5 | Column 6 |                     |
| Removing paving, sidewalk.....        | 107 sq. ft.   | ....      | .....    | \$10.70  | \$10.70  |                     |
| Replacing paving, sidewalk.....       | 107 sq. ft.   | ....      | \$10.70  | 14.98    | 25.68    |                     |
| Excavation, 0 to 6 ft. depth.....     | 16.65 cu. yd. | ....      | .....    | 45.79    | 45.79    |                     |
| Excavation, 6 to 11 ft. depth.....    | 8.35 cu. yd.  | ....      | .....    | 29.23    | 29.23    |                     |
| Hauling.....                          | 26.35 cu. yd. | ....      | .....    | 32.94    | 32.94    |                     |
| Backfill.....                         | 6 cu. yd.     | ....      | .....    | 7.50     | 7.50     |                     |
| Hauling (truck and driver).....       | 6 cu. yd.     | ....      | .....    | 7.50     | 7.50     |                     |
| Shoring material.....                 | .94 M.B.F.    | ....      | 37.60    | .....    | 37.60    |                     |
| Shoring placing.....                  | .94 M.B.F.    | ....      | .....    | 29.14    | 29.14    |                     |
| Shoring removal.....                  | .94 M.B.F.    | ....      | .....    | 18.80    | 18.80    |                     |
| Form work material.....               | 268 sq. ft.   | ....      | 26.80    | .....    | 26.80    |                     |
| Form work placing.....                | 268 sq. ft.   | ....      | .....    | 80.40    | 80.40    |                     |
| Form work stripping.....              | 268 sq. ft.   | ....      | .....    | 5.36     | 5.36     |                     |
| Guard rail.....                       | 50 L.F.       | ....      | 1.25     | 3.75     | 5.00     |                     |
| Reinforcing.....                      | 440 lb.       | ....      | 8.80     | 11.00    | 19.80    |                     |
| Concrete.....                         | 10 cu. yd.    | ....      | 75.00    | 20.00    | 95.00    |                     |
| Hot sand backfill.....                | 2.47 ton      | ....      | 7.41     | 3.09     | 10.50    |                     |
| Ladder rungs.....                     | 8 pcs.        | ....      | 2.64     | .40      | 3.04     |                     |
| Manhole frame and grating.....        | 1 pc.         | ....      | 25.00    | .....    | 25.00    |                     |
| Sewer line.....                       | 1 pc.         | ....      | .....    | .....    | 125.00   |                     |
| Anchor bolts.....                     | 4 pcs.        | ....      | 2.80     | .....    | 2.80     |                     |
| Steam trap.....                       | 1 pc.         | ....      | 50.00    | .....    | 50.00    |                     |
| Trap inlet piping.....                | 7 L.F.        | ....      | .....    | 3.00     | 3.00     |                     |
| Trap inlet valves.....                | 2 pcs.        | ....      | 16.00    | .....    | 16.00    |                     |
| Trap inlet fittings.....              | 1 pc.         | ....      | 8.00     | .....    | 8.00     |                     |
| Trap discharge piping.....            | 10 L.F.       | ....      | .75      | 4.00     | 4.75     |                     |
| Trap discharge valves.....            | 1 pc.         | ....      | 2.00     | .....    | 2.00     |                     |
| Trap discharge fittings.....          | 1 pc.         | ....      | .50      | .....    | .50      |                     |
| Trap discharge tank and brackets..... | 1 pc.         | ....      | 75.00    | 5.00     | 80.00    |                     |
| Insulation, trap inlet piping.....    | 7 L.F.        | ....      | 3.00     | 1.20     | 4.20     |                     |
| Insulation, trap discharge.....       | 10 L.F.       | ....      | 2.20     | 1.00     | 3.20     |                     |
| Totals.....                           | .....         | ....      | \$355.45 | \$334.78 | \$815.23 |                     |



**TABLE III (Eckert, Lansing, Mich.)**  
**MATERIAL, LABOR AND COST—MANHOLE B**

| Description                           | Quantities    |           | Costs    |          |            | Remarks  |
|---------------------------------------|---------------|-----------|----------|----------|------------|----------|
|                                       | Material      | Lab.-Hrs. | Material | Labor    | Total      |          |
|                                       | Column 2      | Column 3  | Column 4 | Column 5 | Column 6   |          |
| Column 1                              |               |           |          |          |            | Column 7 |
| Removing paving, sidewalk.....        | 107 sq. ft.   | ....      | .....    | \$10.70  | \$10.70    |          |
| Replacing paving, sidewalk.....       | 107 sq. ft.   | ....      | \$10.70  | 14.98    | 25.68      |          |
| Excavation, 0 to 6 ft. depth.....     | 17.35 cu. yd. | ....      | .....    | 47.71    | 47.71      |          |
| Excavation, 6 to 11 ft. depth.....    | 14.45 cu. yd. | ....      | .....    | 50.58    | 50.58      |          |
| Excavation, 11 to 16 ft. depth.....   | 15.20 cu. yd. | ....      | .....    | 64.60    | 64.60      |          |
| Hauling.....                          | 48.35 cu. yd. | ....      | .....    | 60.44    | 60.44      |          |
| Backfill.....                         | 20 cu. yd.    | ....      | .....    | 25.00    | 25.00      |          |
| Hauling (truck and driver).....       | 20 cu. yd.    | ....      | .....    | 25.00    | 25.00      |          |
| Shoring material.....                 | 2.25 M.B.F.   | ....      | 90.00    | .....    | 90.00      |          |
| Shoring placing.....                  | 2.25 M.B.F.   | ....      | .....    | 69.75    | 69.75      |          |
| Shoring removing.....                 | 2.25 M.B.F.   | ....      | .....    | 45.00    | 45.00      |          |
| Form work material.....               | 440 sq. ft.   | ....      | 44.00    | .....    | 44.00      |          |
| Form work placing.....                | 440 sq. ft.   | ....      | .....    | 132.00   | 132.00     |          |
| Form work stripping.....              | 440 sq. ft.   | ....      | .....    | 5.28     | 5.28       |          |
| Guard rail.....                       | 50 L.F.       | ....      | 1.25     | 3.75     | 5.00       |          |
| Reinforcing.....                      | 450 lb.       | ....      | 9.00     | 11.25    | 20.25      |          |
| Concrete.....                         | 11½ cu. yd.   | ....      | 86.25    | 23.00    | 109.25     |          |
| Hot sand backfill.....                | 6.8 tons      | ....      | 20.40    | 8.50     | 28.90      |          |
| Ladder rungs.....                     | 14 pcs.       | ....      | 4.62     | .70      | 5.32       |          |
| Manhole frame and grating.....        | 1 pc.         | ....      | 25.00    | .....    | 25.00      |          |
| Sump pit, frame and grating.....      | 1 pc.         | ....      | 5.00     | 1.00     | 6.00       |          |
| Sewer line.....                       | 1 pc.         | ....      | .....    | .....    | 125.00     |          |
| Anchor bolts.....                     | 4 pcs.        | ....      | 2.80     | .....    | 2.80       |          |
| Steam trap.....                       | 1 pc.         | ....      | 50.00    | .....    | 50.00      |          |
| Trap inlet piping.....                | 7 L.F.        | ....      | .....    | 3.00     | 3.00       |          |
| Trap inlet valves.....                | 2 pcs.        | ....      | 16.00    | .....    | 16.00      |          |
| Trap inlet fittings.....              | 2 pcs.        | ....      | 8.00     | .....    | 8.00       |          |
| Trap discharge piping.....            | 10 L.F.       | ....      | .75      | 4.00     | 4.75       |          |
| Trap discharge valves.....            | 1 pc.         | ....      | 2.00     | .....    | 2.00       |          |
| Trap discharge fittings.....          | 1 pc.         | ....      | .50      | .....    | .50        |          |
| Trap discharge tank and brackets..... | 1 pc.         | ....      | 75.00    | 5.00     | 80.00      |          |
| Insulation—trap inlet.....            | 7 L.F.        | ....      | 3.00     | 1.20     | 4.20       |          |
| Insulation—trap discharge.....        | 10 L.F.       | ....      | 2.20     | 1.00     | 3.20       |          |
| Pump—material and labor.....          | 1 pc.         | ....      | 40.00    | .....    | 40.00      |          |
| Suction and discharge piping.....     | 1 pc.         | ....      | 5.00     | 10.00    | 15.00      |          |
| Water service.....                    | 1 pc.         | ....      | .....    | .....    | 32.00      |          |
| Totals.....                           | .....         | ....      | \$501.47 | \$623.44 | \$1,281.91 |          |