The tools used are slightly wider than those used for caulking with lead.

In spite of the strength of the joint, its removal is surprisingly easy. At different times, 20-in. plugs have been taken out, and there has not been the slightest difficulty where the method described in the paper was used. To caulk a joint of this size the writer allows about one hour's time of one man.

Edward R. Bowen: The writer has read this paper with keen interest. It gives in admirable detail the results of an extended experience in handling the cement joint in cast-iron pipe construction. The advantages of this type of joint have not been generally realized among water-works engineers. It is not only less expensive than the lead joint, but, in some ways, distinctly better.

As protection against electrolysis it is almost a perfect insulator. Tests made at the Long Beach Water Department yards showed the resistance of cement joints on an 8-in. line to be nearly 19 ohms, or more than three times the resistance of the ordinary lead joint. Because of the high resistance, under ordinary electrolytic conditions, extremely small currents could travel along the pipe line. Tests were made in Long Beach in the vicinity of an electric railway sub-station to determine the quantity of current carried by the water-pipe lines. In this particular location there were cast-iron lines with both lead and cement joints. The position of the pipe lines with respect to their susceptibility to electrolytic action was practically the same. An appreciable flow of current was discovered in the pipe lines with the lead joints, and a very much smaller flow was noted in the line with the cement joints. In the latter instance, however, the same drop in potential could be obtained by inserting the connections in the soil at the same distance apart as they were applied to the pipe lines.

In the writer's opinion, the success or failure of the cement joint depends solely on the method used in its construction. It is extremely important to have as little moisture in the cement as possible. The mixture described in the paper has proved to be entirely satisfactory, and care should be taken to avoid using more moisture than is there recommended. If more water is used the cement in setting shrinks away from the pipe, resulting in a leaky connection.

**Table 6.—Cost of Cement Joints**

| Diameter of pipe, in inches. | Jute. | | Cement. | | Labor. | | Total cost of joint. |
|---|---|---|---|---|---|---|---|
| | Pounds per joint. | Cost at 6 cents per pound. | No. of joints per sack. | Cost at $1.00 per sack. | No. of joints per 8-hour day. | Cost at $2.75 per day. | |
| 4 | 0.14 | $0,008 | 24 | $0 042 | 50 | $0.055 | $0.105 |
| 6 | 0.19 | 0.011 | 18 | 0.056 | 42 | 0.065 | 0 132 |
| 8 | 0.24 | 0.014 | 14 | 0.071 | 34 | 0.081 | 0 167 |
| 10 | 0.43 | 0 026 | 11 | 0.091 | 28 | 0 098 | 0.215 |
| 12 | 0.51 | 0.031 | 8 | 0.125 | 24 | 0.115 | 0.270 |
| 14 | 0.58 | 0.035 | 7 | 0.143 | 20 | 0.138 | 0.315 |
| 16 | 0.66 | 0.040 | 6 | 0.167 | 17 | 0 162 | 0.368 |
| 18 | 0.73 | 0.044 | 5 | 0.200 | 14 | 0.196 | 0.440 |
| 20 | 0.80 | 0.048 | 4 | 0 250 | 11 | 0.250 | 0.548 |
| 24 | 0 95 | 0.057 | 3 | 0 333 | 7 | 0.393 | 0 783 |

Tables 6 and 7 have been prepared to illustrate the relative costs of the two types of joints. Table 6 is based on the data in the paper. Table 7 is based on the cost data assembled by the Los Angeles City Water Department.

George W. Pracy: Several months ago the Spring Valley Water Company laid 4,730 ft. of 4-in., 900 ft. of 6-in., and 827 ft. of 8-in. cast-iron bell-and-spigot pipe, with cement joints.

**Table 7.—Cost of Lead Joints**

| Diameter of pipe in inches. | Lead. | | Yarn. | | Fuel at 0 6 per pound of lead. | Labor cost, based on $2.75 per man per day. | Total cost of joint. |
|---|---|---|---|---|---|---|---|
| | Pounds per joint. | Cost at 6 cents per pound. | Pounds per joint. | Cost at 6 cents per pound. | | | |
| 4 | 7 | $0.420 | 0.2 | $0.012 | $0.042 | $0.110 | $0.584 |
| 6 | 9 | 0.540 | 0.4 | 0.024 | 0.054 | 0 168 | 0.786 |
| 8 | 14 | 0.840 | 0.5 | 0.030 | 0.084 | 0.216 | 1.170 |
| 10 | 16 | 0.960 | 0.6 | 0,036 | 0 096 | 0.230 | 1.322 |
| 12 | 20 | 1.200 | 0.8 | 0.048 | 0.120 | 0.264 | 1.632 |
| 14 | 24 | 1.440 | 0.85 | 0.051 | 0.144 | 0.310 | 1.945 |
| 16 | 29 | 1.740 | 1.0 | 0.060 | 0.174 | 0.324 | 2.298 |
| 18 | 31 | 1.860 | 1.1 | 0.066 | 0.186 | 0.360 | 2.472 |
| 20 | 35 | 2.100 | 1 3 | 0.078 | 0.210 | 0.432 | 2.820 |
| 24 | 40 | 2.400 | 1.5 | 0.090 | 0.240 | 0.492 | 3.222 |

The cement was mixed by one man who handed it around to the two or three men making the joints. No caulking was done on the joints, the cement being tamped by hand with a caulking iron. After the joint was full, a bead was put on around the face of the bell. Neat cement was used. Just as little water as possible was added in mixing. When ready for use, the wet cement was still dry enough to crumble when handled. The first few joints were filled with a wet mix, with the result that, in these joints, the cement shrunk away from the iron, and all the joints had to be remade. As an experiment, one of the 8-in. joints was caulked hard, using an extra dry cement. This gave a good joint, but not better than the others. and it took twice as long to make.

Water was turned into the pipes 48 hours after the last joint was made. For the first day nearly every joint leaked. After that, they took up rapidly and, at the end of one week, all were tight.

The pipe was laid in five sections of about 1,300 ft. each. All but one section was tested by measuring the quantity pumped into the section during a given period. Tests were made after the pipe had been under ordinary working pressure for about 1 week to 10 days. For the first section laid, this leakage was ⅓ gallon per lineal foot of pipe joint per 24 hours. The second leaked so slowly that the leakage could not be measured. The last two sections laid were absolutely tight. The lines were pumped to pressure and left standing, in one case, for ½ hour and in the other case for 2½ hours, without any drop in pressure. The 6-in. pipe section could not be tested, as it was necessary to put it into use immediately.

The quantity of cement used was as follows:—

| No. of joints. | Size. | Quantity of cement, in pounds. |
|---|---|---|
| 187 | 4-in. | |
| 2 | 5-in. | 750 |
| 12 | 8-in. | |
| 78 | 6-in. | 360 |
| 168 | 4-in. | |
| 86 | 8-in. | 1,715 |

These figures include all waste. On an average the 4-in. joints took about 4 lbs., the 6-in. joints 5 lbs., and 8-in. joints from 7 to 9 lbs. These figures are rough approximations, based on the theoretical quantity necessary for a joint of each size.

The fire hydrants on the line were set with lead joints, as it was feared that the vibration of the hydrants, when in use, would break the cement joints.

The lines have given entire satisfaction.