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was a little better on that job and that you got more cooperation and more speed than on other jobs?

John C. Haroldson: No, I would say that the over all cost of work would have been lower if the welding contractor's work had been better coordinated with the excavating contractor's work. There is no doubt but what the work would have progressed more rapidly and at less cost if the welding contractor's crew had been sufficient to complete the pipe work as quickly as the trench was graded and ready for pipe. The total cost of the job probably suffered some from the fact that the ditching was done on a cost plus basis, while the pipe laying and welding was done on a flat price contract for the job. The excavating contractor's original estimate on Item 1 was about half of the actual cost. Some of the increased cost was due to the abnormal conditions encountered, but when we first figured costs and secured the contractor's estimate, it looked like the line would be built for $16.00 a foot. I still believe that this type of line could be put in at a cost of $2.00 per foot per inch of pipe diameter.

Chairman Saurwein: Thank you, Mr. Haroldson and gentlemen.

In the absence of Robert F. Throne of the Public Service Company of Colorado, John L. McKinley of the same company will present his prepared paper on construction in Denver. Mr. McKinley.

. . . Mr. McKinley then presented the prepared paper . . .

HEATING-SYSTEM EXPANSION AT DENVER AND USE OF PRECAST-CONCRETE MANHOLES

Robert F. Throne

(In this paper the author reports upon the merits of precast manholes in connection with installation of a 7832-foot steam-transmission line as a part of the load-expansion program of the Denver Steam Heating System with some references to the conditioning and metering of the turbine-bled steam at the plant and the overall cost of the project.)

The business district of Denver has been served district steam during the 9-month heating season since 1889 by the Public Service Company of Colorado and its predecessors. The distribution system has been periodically extended as the business area expanded and in 1910 was entirely rebuilt to its present service area.

The greatest sendouts of about 125,000 lb per hour were attained in 1920 and 1921, since which period the replacement of district steam continuously increased due to a combination of many factors, such as competitive fuels and the small capitalized value of basement area.

For a number of years, district-heating service was rendered at a loss with the resultant recurring consideration of abandonment. However, in very recent years the general interest in district steam has materially increased. The influencing factors are many and are made up of the increased cost and irregular availability of firm fuel; the increased cost of attendant labor, both hourly and due to the 40-hour week influence; the increased value of commercial building space; and the modernization of commercial establishments incorporating modern lighting improvements. Factors also having a bearing to some extent have been the increased traffic and alley congestion as affecting solid fuel deliveries and, in the case of coal, the removal of ashes.

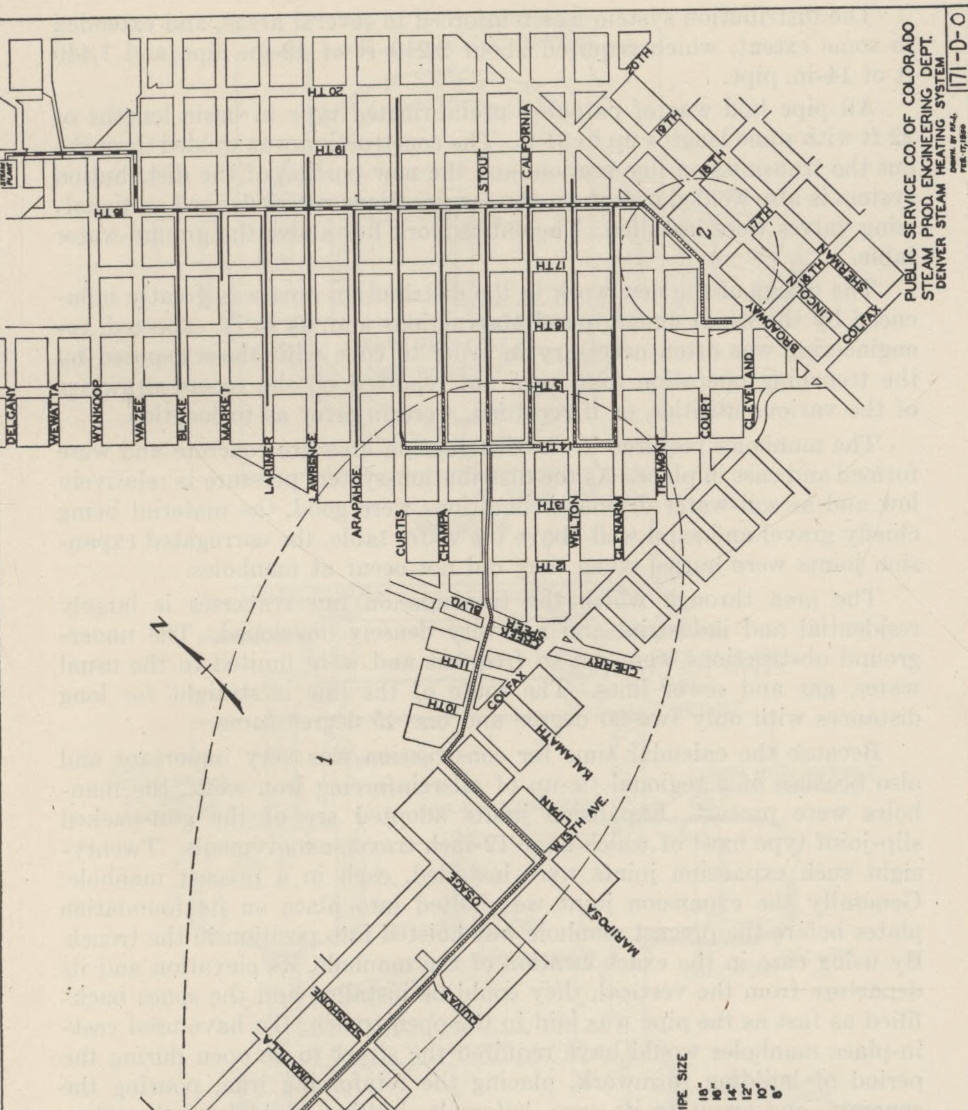
District steam was primary steam from low-pressure boilers using coal as fuel until 1932, was residual fuel oil until December 1947 and since 1947, has been natural gas with fuel-oil backup.

Live steam was sent out from the heating plant at 19th and New Haven Streets at a pressure varying up to 25 psi, dependent on the demand, in order to maintain 4 to 5-psi main pressure at the assumed low point.

Coincident with the renewed interest in district heating, in 1947 a 35,000-kw turbogenerator was installed at the Lacombe Station, operating at 850 psi and 900F and provision was made for uncontrolled bleeding of first-stage steam and ninth-stage steam to serve the district-heating system. The reduction in production cost by using bled steam warranted the necessary expenditures to construct a steam-transmission line 7,832 ft long to connect to the present distribution system, as well as the installation of a 300,000 lb per hr hot-process water-treating plant to furnish the needed make-up water as the condensate is not returned to the plant. Other plant improvements consisted of automatic-type pressure-reducing valves, desuperheating equipment of the spray type and steam-metering equipment with built-in pressure- and temperature-correction feature.

In order to attain the minimum investment, the line was designed as a pressure-reducing valve; that is, while the pressure at the discharge end varies from about 5 to 25 psi, the inlet pressure varies from 10 to 250 psi, as the send-out rate varies from the minimum to over 250,000 lb per hr. This line contains 6,657 ft of 14-in. and 1,175 ft of 16-in. O.D. Schedule 30 pipe. At its terminal it discharges into 700 ft of new 16-in. O.D. and 990 ft of new 14-in. O.D. pipe, constituting a header that connects 6 of the existing parallel streets and through these 6 streets serves the present rectangular grid-type distribution system through pipe sizes of 8-in. and 12-in. diameter.

The transmission line has handled to-date up to 190,000 lb per hr with actual pressure drops as expected.



PUBLIC SERVICE CO. OF COLORADO
STEAM PROD. ENGINEERING DEPT.
DENVER STEAM HEATING SYSTEM
171-D-0
STEAM PLANT
DELGANY
WEWATTA
WYNKOOP
WAZEE
BLAKE
MARKET
LARIMER
LAWRENCE
ARAPAHOE
CURTIS
CHAMPA
STOUT
CALIFORNIA
WELTON
GLENARM
TREMONT
COURT
CLEVELAND
BROADWAY
LINCOLN
SHERMAN
COLFAX
CHERRY CREEK
SPEER BLVD
KALAMATH
LIPAN
W. 13TH AVE.
MARIPOSA
OSAGE
QUIVAS
SHOSHONE
UMATILLA
YUMA
ZUNI
LACOMBE
LEGEND
PIPE SIZE
18"
16"
14"
12"
10"
8"
SCALE

FIG. 1

The distribution system was reinforced in several areas, and extended to some extent, which required about 2,210 ft of 12-in. pipe and 1,440 ft of 14-in. pipe.

All pipe laid was of patented prefabricated type in basic lengths of 22 ft with some lengths up to 31 ft. The construction was welded throughout the transmission line section, and the new portion of the distribution system is also welded except for the few locations where flanged sectionalizing valves were installed. The entire work lies above the ground-water table.

The design of the new work in the distribution area was greatly influenced by the usual underground obstructions and, as to be expected, re-engineering was often necessary in order to cope with those exposed by the trenching operation that were not reported on the record drawings of the various utilities, or if recorded, were in error as to location.

The manholes required in the distribution area are concrete and were formed and cast in place. As the distribution-system pressure is relatively low and as soil-water drainage conditions were good, the material being chiefly gravel and sand well above the water table, the corrugated expansion joints were buried when they did not occur at manholes.

The area through which the transmission line traverses is largely residential and industrial and not very densely developed. The underground obstructions were not so frequent and were limited to the usual water, gas and sewer lines. The route of the line is straight for long distances with only two 90 degree and one 45 degree turns.

Because the calendar time for construction was very important and also because of a regional tie-up of all reinforcing iron work, the manholes were precast. Expansion joints adopted are of the gun-packed slip-joint type most of which have 12-inch traverse movements. Twenty-eight such expansion joints were installed, each in a precast manhole. Generally the expansion joint was bolted into place on its foundation plates before the precast manhole was hoisted into position in the trench. By using care in the exact location of the manhole, its elevation and its departure from the vertical, they could be installed and the space backfilled as fast as the pipe was laid in the open trench. To have used cast-in-place manholes would have required the street to be open during the period of building formwork, placing the reinforcing iron, pouring the concrete, and awaiting its cure, before backfilling could be done. Carpenters and other craftsmen would also be needed and their availability during this period was often critical.

Fig. 2 portrays the chief features of the precast manhole provided in the present design. The expansion joint can be removed through the

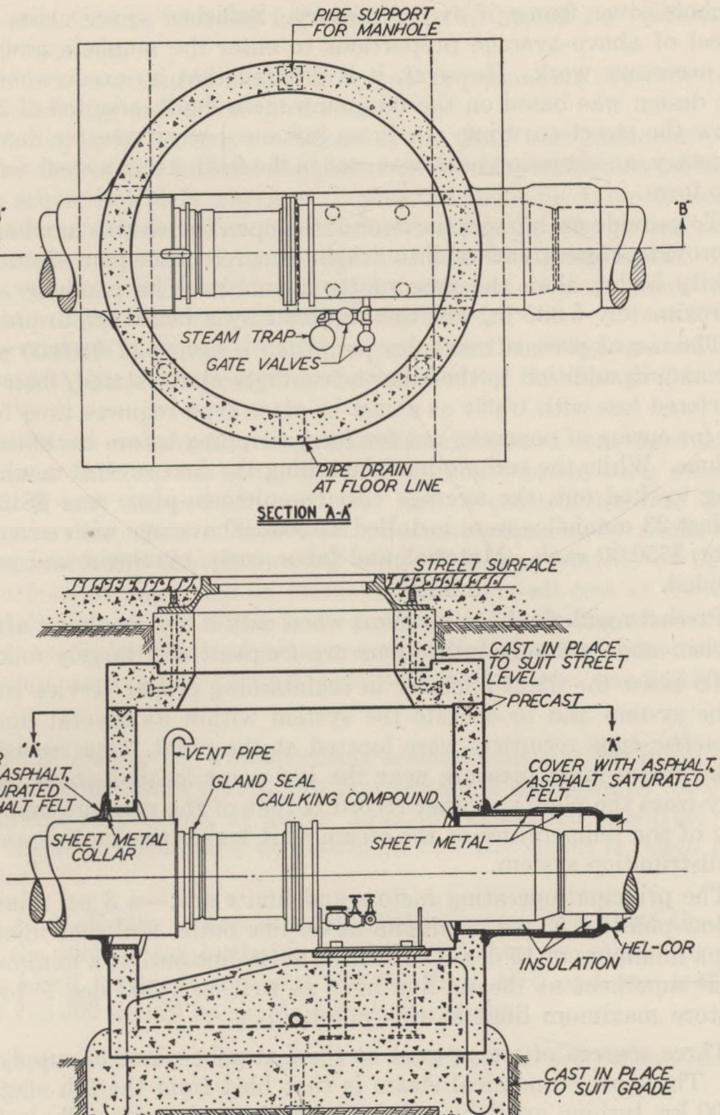

PIPE SUPPORT
FOR MANHOLE
'B'
'B'
STEAM TRAP
GATE VALVES
PIPE DRAIN
AT FLOOR LINE
SECTION 'A-A'
STREET SURFACE
CAST IN PLACE
TO SUIT STREET
LEVEL
PRECAST
'A'
'A'
VENT PIPE
COVER
WITH ASPHALT,
SATURATED
ASPHALT FELT
GLAND SEAL
CAULKING COMPOUND
COVER WITH ASPHALT,
ASPHALT SATURATED
FELT
SHEET METAL
COLLAR
SHEET METAL
HEL-COR
INSULATION
CAST IN PLACE
TO SUIT GRADE
SECTION 'B-B'

Fig. 2

manhole-cover frame if ever necessary. Sufficient space exists for personnel of above-average proportions to enter the manhole and perform the necessary work. However, it is granted that no excess space exists. The design was based on the minimum main depth adopted of 30 inches below the street covering. In those instances when greater depths were necessary, an extension neck was cast in the field, using a steel removable-type form.

To provide anchorage, the floor of the open trench was hand excavated to provide cross trenches into which concrete was poured to a grade slightly higher than the base of the manhole. The manhole, weighing approximately 6,800 lb, was then lowered by a *boom cat* to position.

The use of precast manholes permitted a saving of $100.00 per manhole and, in addition to the labor advantages above stated, their use also interfered less with traffic as a cast-in-place type requires time for forming, for curing of concrete and for form stripping before backfilling could be done. While the technique of installing the first several manholes was being worked out, the average cost complete-in-place was $813.00, but the last 23 manholes were installed at $660.00 average with several going in for $550.00 each. Material and labor costs, overhead and profit are included.

Precast manholes have no merit when only a few manholes are needed or when underground obstructions are frequent and largely unknown.

To assist the plant operator in maintaining proper service conditions in the system and to operate the system within its several limitations, *telemetric-type* recorders were located at the plant. One record is that of the steam-main pressure near the low point located about two miles away from the plant; another record is that of the pressure and particularly of the temperature of the steam as it leaves the tie line and enters the distribution system.

The principal operating factors and limits are:—a 3 psi minimum at the low point; a 25 psi maximum at tie-line outlet and thus inlet to system; a minimum of 15 deg F superheat at tie-line outlet; a minimum of 15 deg F superheat at the tie-line inlet as well as a 500 deg F total temperature maximum limit at this point.

Three sources of steam exist at the Lacombe plant to supply the tie line. The most economical steam is that bled from the 9th stage of the 35,000 kw turbine available up to 60,000 lb per hour for all electric outputs of 25,000 kw and over. This 9th-stage steam largely supplies the summer months' requirement.

Bled steam from the first stage of the same unit supplies all requirements above 60,000 lb per hour and below 200,000 lb per hour. The minimum electric loading of 8,000 kw varying up to 37,500 kw respectively or over is required.

Boiler-header steam is available for all requirements over the bled-steam availability and is the third source.

Depending upon loading conditions at the plant and particularly the electric loading on the turbine, the pressure and temperature of the steam for each source is widely varying. A pressure-reducing valve is located in each source, which valve maintains automatically the preset downstream pressure determined by the operator from the gauge board. Also, a spray-type desuperheater in each source automatically maintains a set downstream temperature as similarly determined.

These controls have satisfactorily coped with the changing conditions as required by the steam system and as caused by the changing turbine loading.

Although the construction work was carried forward on a tight schedule against a fixed service date, the over-all construction costs reflected a penalty of only about $5.15 per lineal foot of construction due to the effect of overtime. Part of this overtime was occasioned by traffic conditions necessitating the performing of work during periods of lighter traffic, such as at night and on Sundays. The over-all cost of the complete installation of the 13,162 ft of construction, including all items of manholes, expansion joints, drainage, sectionalizing, valves, pipe, insulation, conduit, excavation, backfill, permits, repaving, etc. was $43.50 per foot.

Robert B. Donworth: The operating arrangement was not quite clear to me. Do I understand that at low flows steam is extracted as far down in the turbine as possible, at higher flows the extraction is shifted to a point of higher pressure, and at maximum flow the steam is taken from the header?

John L. McKinley: That is substantially correct. We bleed the 9th-stage of the turbine for loads up to 60,000 lb, then we change over to 1st-stage bleed for loads to about 150,000 lb as bled and any loads in excess of 150,000 lb will be supplied with live steam.

Robert B. Donworth: Do you have superheat at the system end of the line?

John L. McKinley: That is right.

George K. Saurwein: That is an unusual way to operate, however, in order to have a minimum of 15 deg superheat at the distribution network, such a scheme is required.

Robert B. Donworth: There is no condensate in the line at all, but I suppose it is trapped, however.

John L. McKinley: Yes, the line is trapped. We can feed steam into that line from the old steam plant, which is an auxiliary source of steam.

Percy A. Hyde: Do you drain manholes, particularly in this new construction?

John L. McKinley: We have not been bothered with that problem. The terrain is sedimentary and drains naturally. It is gravel for the most part. We use natural drainage. The new manholes are equipped with drain pipes. In only one or two instances have we had to connect drains to the sewer; it is not our general practice.

Russell Cole (of Detroit): I am particularly interested in some of the structural details of your manholes. I presume they are heavily reinforced. Can you tell us something about that?

John L. McKinley: Yes, they are reinforced. There is mesh reinforcing in the 4-in. cylindrical wall and there are bars in the anchor block, base and top slab.

Albert F. Metzger: Were these manholes all tailored for the particular locations in which they were to go? They were not of uniform size, were they?

John L. McKinley: Yes, they were all of uniform size.

Albert F. Metzger: How did you regulate the elevation of the lines so they would all come out the same?

John L. McKinley: We made up a set of collapsible steel forms. Where we had to increase elevation we set the form on the top slab, poured the concrete in it, and set a cover ring on top of that. All are completely uniform from the bottom. It is very easy to do.

Albert F. Metzger: In other words, they had a neck on top of them?

John L. McKinley: No, they are like any open cylinder of uniform height. We extended the top section uniformally from the top slab somewhat smaller in diameter than the body of the manhole so that we could use a standard cover slab. The covers and rings are standardized.

Chairman Saurwein: Thank you, Mr. McKinley and gentlemen.

We will now have Everett C. Russell of Philadelphia present his paper. Mr. Russell.

. . . Mr. Russell then presented his prepared paper . . .