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The New Twenty-eight Inch, Three Hundred Pound Steam Main of the Paris, France District Heating System

By PHILIPPE SCHERESCHEWSKY*

The progress made in district heating in Paris, France would be remarkable had it been accomplished in times of peace. Such accomplishment in war years becomes astonishing. The following article on the subject by one of N. D. H. A's. most distinguished members; now in Washington with the Mission of the Ministry of Industrial Production of the Republique Francaise, is a welcome addition to our knowledge of district heating.—J. F. C.

The Bulletin of the National District Heating Association published in October 1930 an article by the writer describing various plans for the projected district heating System for Paris and the small experimental system then under construction, which was to operate at a pressure of 10 kilos (142.2 lbs) and 300° centigrade (572 F).

Operations started in October 1930 and satisfactory results were obtained from the technical as well as from the commercial viewpoint. During the first heating season 41,050 metric tons (90,500 M lbs) of steam were produced. The length of the network was 1039 meters (3,408 ft). Consequently, it was decided to proceed with a larger network operating on a higher pressure.

The original power plant of La Rapee (see Figure 1) was modernized with new high efficiency Rauber boilers operating at a relatively low pressure (20 atmospheres or approximately 290 lbs) as surveys had shown and experience gained during the first winter had confirmed: (a) that simultaneous production of power and heat was uneconomical, and (b) that the network could be operated at a profit only if steam could be produced at a very low price. This was due to the fact that capital expenditures in the network being very large, operating costs had to be kept very low.

A large main, 24 inches in diameter, was installed in a tunnel adjacent to the Seine River, in the Eastern and Central sections of the City, and operated at a pressure of 15 kilos (220 lbs). The cross-section of the tunnel was similar to those seen in Figures 6 and 7 of the 1930 article. The length of this first 24" main from the La Rapee Power Station to the Palais Royal was over 2000 meters (6,560 ft). A number of secondary mains with diameters measuring up to 16 inches originated at this tunnel. Operations of this extension of the system began during the 1934-35 heating season. The length of the system rose sharply from 1922 meters (6,300 ft) on December 31st, 1934, to 5,337 meters (17,500 ft) on December 31st, 1935, an increase of 180%.

The original project also called for the construction, in the Western part of the City, of a large network supplied with steam by another electric power plant located at Issy les Molyneaux. However as the demand in the first experimental district supplied by the La Rapee Power Plant was rapidly growing, it was decided to expand this first network and plans for the construction of the Issy network were postponed.

The system which was started during the 1930-31 heating season with a production of 41,050 metric tons (90,500 M lbs), produced

* Director of the Cie Parisienne de Chauffage Urbain.

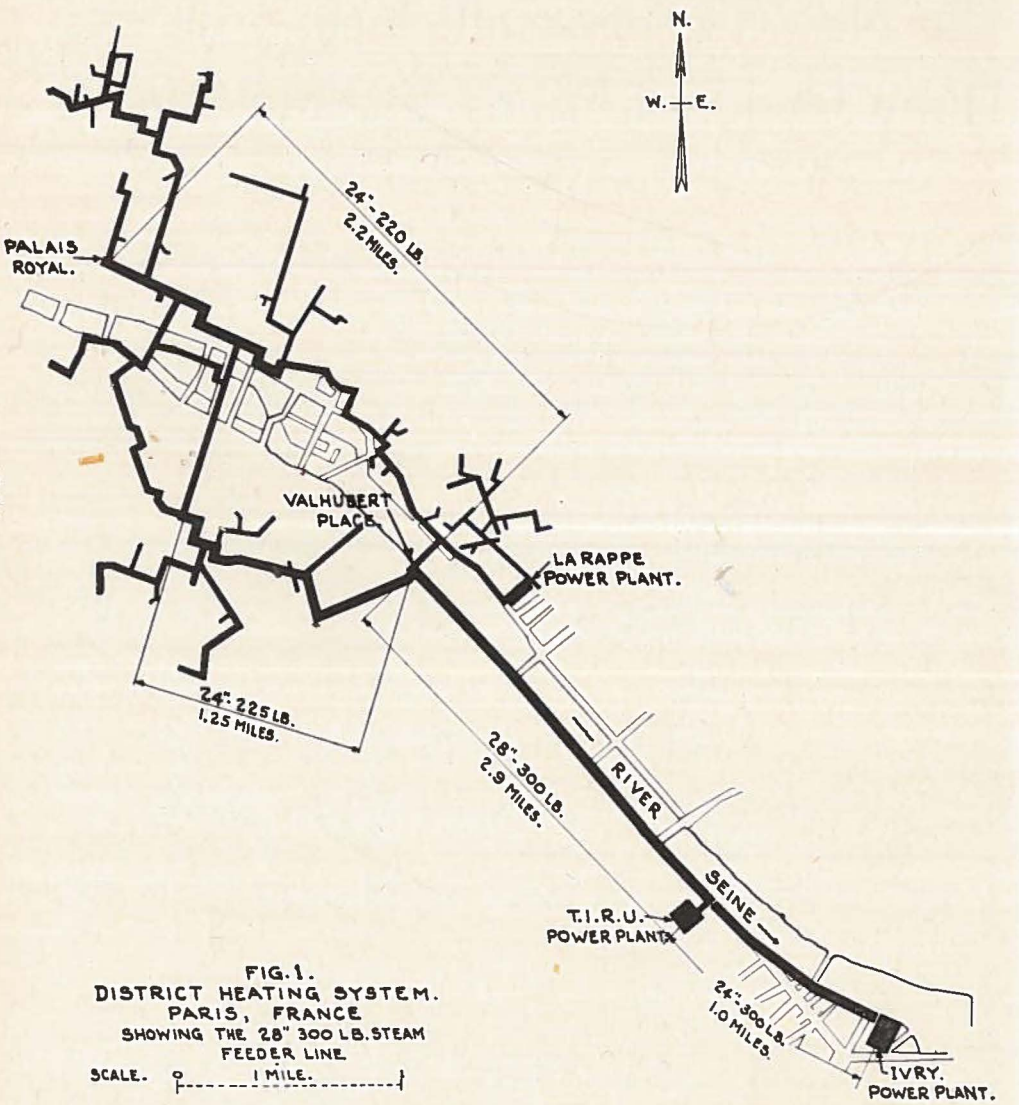


FIG. 1.
DISTRICT HEATING SYSTEM.
PARIS, FRANCE
SHOWING THE 28" 300 LB. STEAM
FEEDER LINE

230,650 metric tons (508,600 M lbs) of steam during the winter preceding the war (1938-39), an increase of approximately 460% in eight years. The total connected load as of December 31st, 1938, was 84.6 million calories (approximately 330 million Btu). The peak load during the heating season was 66.4 million calories per hour (approximately 275 million Btu, 135 metric tons or 298,000 lbs of steam per hour). Annual steam output, connected load and peak load for each heating season will be found in the following table:

Heating Season	Connected Load (million calories/hour)	Peak Load (million calories/hour)	Annual Output (metric tons)	Length of System (meters)
1930-31	11.8	unavailable	41,050	1,039.23
1931-32	13.9	unavailable	57,400	1,385.81
1932-33	17.86	unavailable	55,000	1,981.05
1933-34	18.3	unavailable	60,400	2,093.20
1934-35	28.1	unavailable	85,420	5,741.65
1935-36	39.5	unavailable	120,300	8,269.05
1936-37	52.75	43.1	177,310	11,506.07
1937-38	65.3	51.8	204,230	13,036.48
1938-39	76.3	66.4	230,650	14,511.37
1939-40	85.1	61.	226,930	14,645.50
1940-41	101.	65.	160,706	14,900.35
1941-42	150.	137.	263,856	27,237.80
1942-43	204.7	140.	272,397	29,702.49
1943-44	217.44	157.	295,068	30,180.81

1 million calories = 3969 Btu
1 metric ton = 2205 lb
1 meter = 3.281 ft

About 1938, the rapid expansion of the connected load made it necessary either to install additional boilers in the La Rapee Power Plant or to connect this plant with the nearest modern, and relatively idle, power plant, which was located at Ivry, at a distance of approximately 4.5 kilometers (2.8 mi). There was practically no load to be connected between the two power plants at La Rapee and Ivry. An economic survey of the situation showed that steam could be shipped to La Rapee from Ivry at a lower cost than it could be produced at La Rapee by means of additional boilers, provided the annual tonnage thus forwarded exceeded 100,000 metric tons (220,500 M lbs). From 1934 until 1939, the rate of expansion of the steam output was approximately 35,000 tons (77,000 M lbs) per year. It appeared probable that within the next five years the annual steam output would reach 400,000 tons (882,000 M lbs) and that consequently a feeder line from Ivry to La Rapee could be operated profitably and with a satisfactory load factor and correspondingly small heat losses. The heating plant at La Rapee would continue to be operated during the period of peak load (January, December and February), and also during the summer so as to avoid high heat losses in the feeder.

In order to keep the capital expenditure on the feeder as low as possible, it was decided to operate it at a relatively high pressure. For the same reason, the diameter was to be large, thus minimizing the capital expenditure per ton forwarded. However on the other hand to guarantee safe operation, care was taken to restrict operating pressure and diameter. A diameter of 700 millimeters (27½ inches approximately) and a pressure of 20 kilos (290 lbs) were chosen. The testing pressure was to be 40 kilos (580 lbs).

During the war, and especially after July 1940, the scarcity of coal created an additional demand on the facilities of the network. For this reason and also to relieve unemployment following the Armistice of June 1940, the City of Paris decided to assist financially in building the feeder. It was started in July 1940 and completed about December 1st, 1941.

The feeder has a capacity of 450 metric tons (1,000 M lbs) per hour which, with a 25% load factor, enables it to forward annually 1 million metric tons (2,205,000 M lbs) of steam to the network, thus allowing for a still larger expansion of the Paris district heating system. The actual load factor

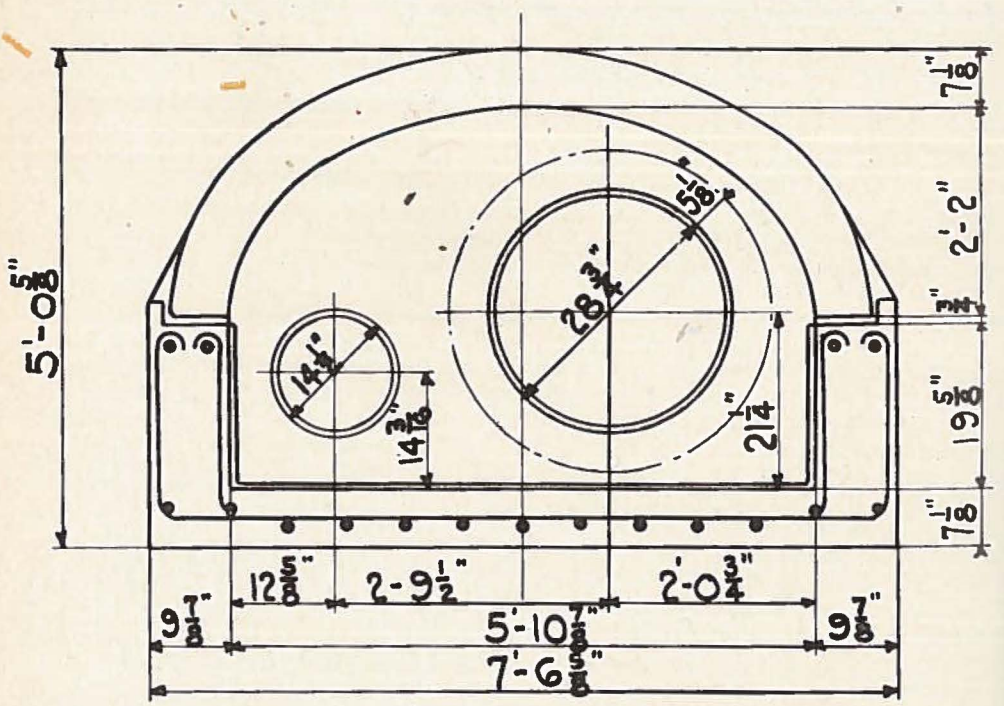
during the 1938-39 heating season was approximately 19%. As the La Rapee Power Plant is operated for a peak load, the load factor of the feeder line is higher than that of the system.

Actually two power plants supply the feeder: (1) The T. I. R. U. Plant, a small plant which burns City refuse and is located at 3000 meters (1.9 mi) from La Rapee; and (2) The Ivry Power Plant which is located at 1500 meters (1.0 mi) from the T. I. R. U. plant and 4500 meters (2.9 miles) from the La Rapee Power Plant.

The feeder consists of gas welded steel sheet pipes. It is insulated with 85% magnesia. The thickness of the pipe walls is 14½ millimeters (approximately ⅝ in.) between Ivry and T. I. R. U. — 17 millimeters ($^{11}/_{16}$ in.) between T. I. R. U. and La Rapee which corresponds to an outside diameter of 734 millimeters (28¾ in.). On the short distance between Ivry and T. I. R. U., the inside diameter is reduced to 600 millimeters (23½ in.).

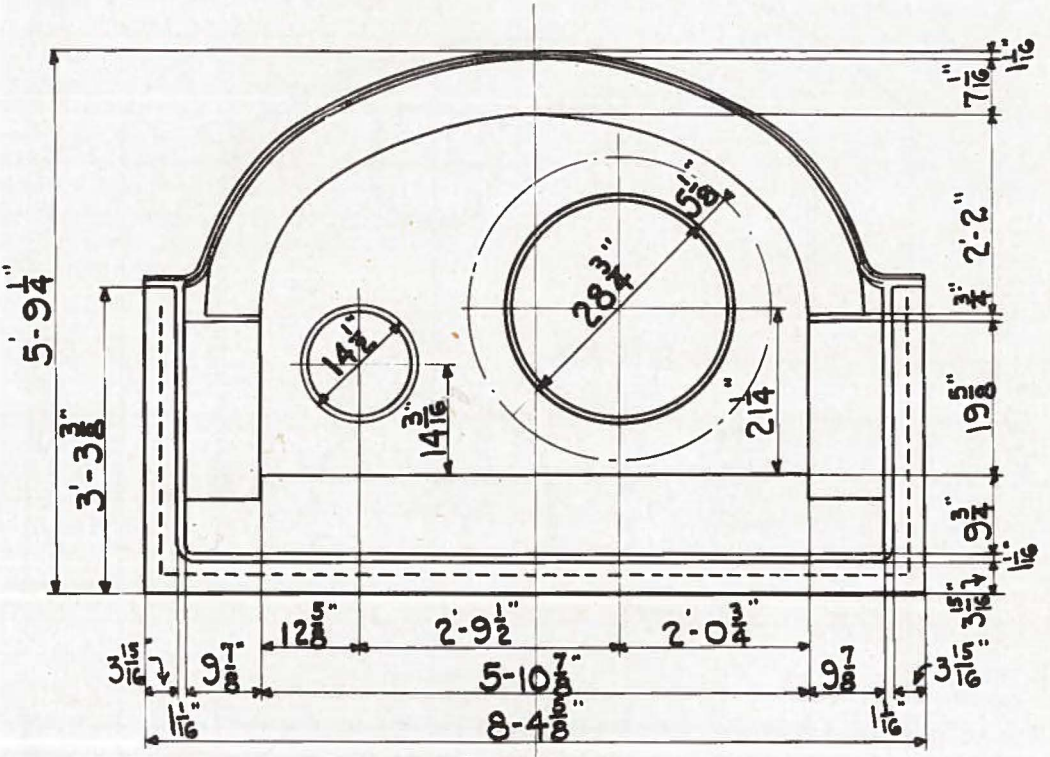
The feeder is operated at a constant temperature of 230° centigrade (446 F) and at a variable pressure according to the load between 6 and 20 kilos (87 and 290 lbs).

In order to avoid too great an expense for make-up water at the power stations, the feeder conduit includes a condensed water return pipe. This return pipe has an inside diameter of 352 millimeters and an outside diameter of 368 millimeters (14.5 in.) and is operated at a pressure of 4 kilos (58 lbs). It has been tested at a pressure of 8 kilos (115 lbs).



TYPICAL CROSS SECTION OF CONCRETE DUCT.

FIG. 2.



TYPICAL CROSS SECTION OF CONCRETE DUCT.

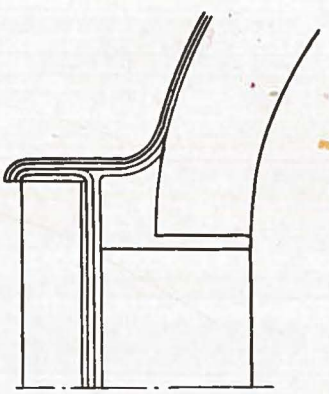
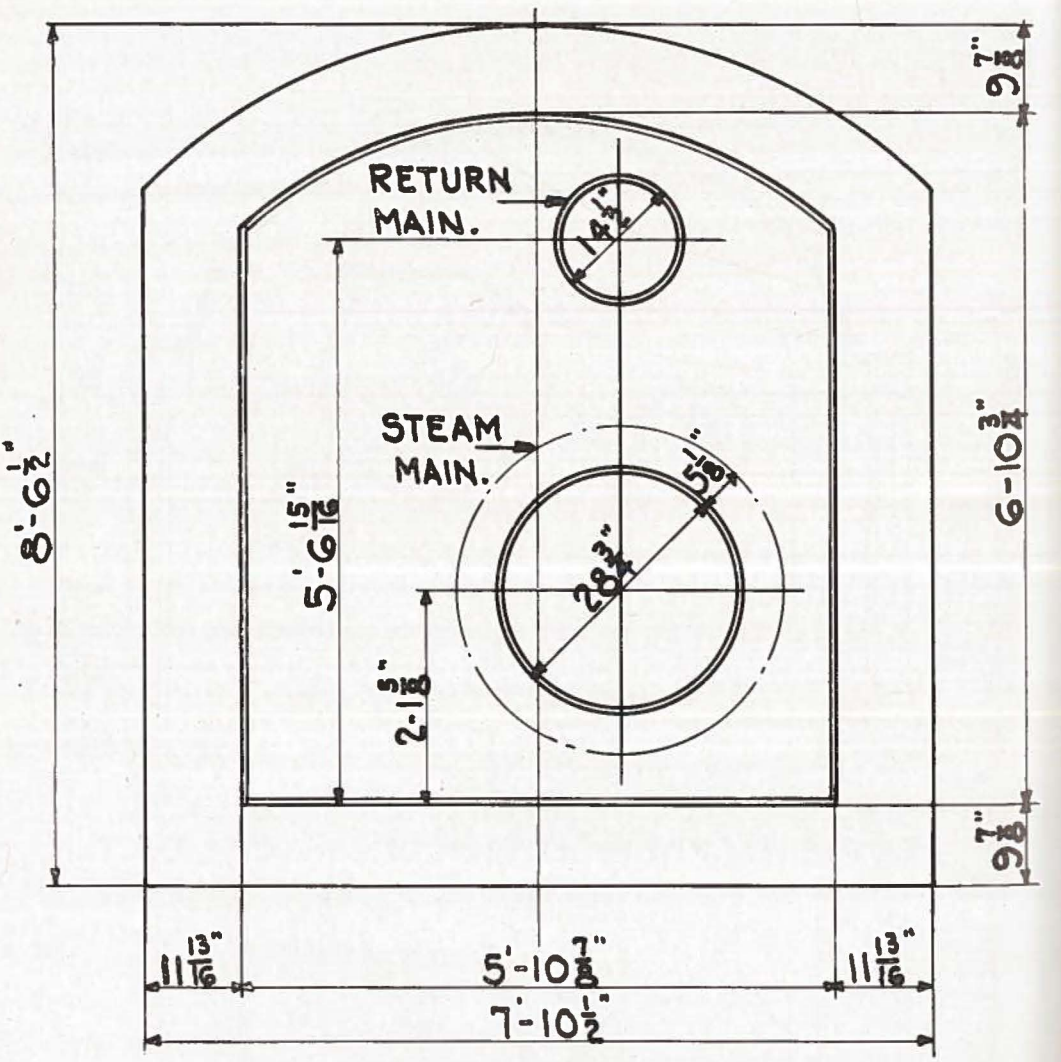


FIG. 3.

DETAILS OF WATER-PROOFING FEATURES.



TYPICAL CROSS SECTION OF CONCRETE DUCT.
FIG. 4.

The feeder is located entirely on the left bank of the River Seine and very close to the water, generally between 30 and 120 feet from the bank. There are 34 anchorage blocks altogether, located at an average distance of 130 meters (425 ft). There are 17 manholes; the lowest point of the feeder is at the terminus in town and is slightly below the average level of the river. The highest point is about midway or 2,700 meters (1.67 mi) from the Ivry Plant, approximately 7 meters (23 ft) above the average level of the river. The entire feeder unfortunately is located below the level reached by the 1910 flood. Consequently, the concrete duct is of special watertight construction so it can operate if necessary underneath 20 ft of water. (See Figures 2, 3 and 4).

The construction technique keeping ducts watertight has been tested several times during the operation of the network and has proven efficient. The feeder joins the network at Valhubert Place and feeds into two twenty-four inch, 15 kilos (220 lb) mains which jointly with the feeder constitute the backbone of the Paris District Heating System. The distances between the Place Valhubert junction and the ends of the two twenty-four inch mains is approximately 2,000 meters (1.25 mi) and 3,500 meters (2.2 mi) respectively.

This 300 and 225 pound, 28 and 24 inch, 6.2 mile long backbone of the Paris District Heating System is, the author believes, among the most interesting of its kind.

OPERATING DATA: During the war, the number of customers has rapidly increased from 148 on December 31st, 1939, to 436 on December 31st, 1943, and the connected load from 76.3 million calories to 217.5 million calories. Production of steam has been kept as low as possible due to the shortage of coal. During the heating season of 1943/44, with a connected load of 218 million calories, it has reached only 295,000 metric tons (650 million lbs). In 1938/39 with a connected load of only 76.3 million calories steam production was 231,000 tons (510 million lbs). With a connected load of 218 million calories in 1943/44 and the same load factor as before the war, steam production should have been 630,000 metric tons (1,400 million lbs), instead of 295,000 metric tons (650 million lbs).

It is hoped that this figure of 1,400 million pounds will be reached whenever circumstances will permit resumption of normal coal shipments from the mines to the City of Paris.

During the winter 1944/45 however due to the lack of coal, the system has been shut down entirely and district heating service discontinued for the first time. During the war years, the system, due to the scarcity of coal has not actually connected every consumer who had signed heating contracts. For instance, as per December 31st, 1943, the connected load was 217.5 million calories whereas the subscriber load was already 291.5 million calories, i. e. approximately 30% more than the connected load.

The 300 pound 28 inch feeder has been operated for 3 heating seasons in succession starting in 1941/42. It has supplied the Paris District Heating System with the major part of its steam consumption. Steam output at the La Rapee Power Plant has decreased accordingly as shown in the following table:

Heating Season	Steam Output per Power Plant (metric tons)		Total
	La Rapee	Ivry (feeder line)	
1938-39	230,650	.....	230,650
1939-40	226,930	.....	226,930
1940-41	160,706	.....	160,706
1941-42	141,459	122,397	263,856
1942-43	82,153	190,244	272,397
1943-44	69,877	225,191	295,068
1944-45	System inoperative (lack of coal)		

1 metric ton = 2205 lbs.

(Discussions received will be printed in the July issue.)