CORROSION IN

SELFOSS DISTRICT HEATING SYSTEM

R. #10,338
PC #3202

8/12/53

SAM TOUR & CO., Inc.
44 TRINITY PLACE
NEW YORK 6, N. Y.

R. #10,338,
PC #3202,
August 12, 1953

CORROSION IN SELFOSS DISTRICT HEATING SYSTEM

Introduction:

The district heating system in the City of Selfoss in southern Iceland was put into operation in 1948. The original wells were not free-flowing and the water was pumped from them. Due to contamination with surface water, the resulting mixture had a temperature of only 50°C. and carried 1 to 2 parts per million of free oxygen. The rate of corrosion was reported to have been excessive.

New wells were drilled at a slight distance from the original wells and a source of hotter water was obtained. Since 1951, the natural hot water has come from five free-flowing wells. The water is reported to have the following analysis:

Temperature	90°C.
pH	9.0
Primary Alkalinity as ppm $CaCO_3$	70.75
Secondary Alkalinity as ppm $CaCO_3$	140
Chlorine ppm.	469
SO_4 ppm.	103
Sulphur ppm.	0.45
SiO_2 ppm.	72
Calcium ppm.	60
Magnesium ppm.	3
Specific Resistance, Ohm.-Cm.	625
Free Oxygen ppm. approx.	0.3 (variable)

It is reported that the rate of corrosion has decreased materially since the new wells were put into operation. There is little specific information as to actual rates of corrosion with the new water. The system which had been in use several years with the original water was not cleaned or descaled prior to the beginning of the use of the new water. Considerable difficulty is being encountered due to external corrosion of the pipes laid through the city and to the various buildings.

In accordance with a contract negotiated through the Mutual Security Administration and between Sam Tour & Co., Inc. and the Icelandic Government, the writer went to Iceland during the month of May 1953 and spent several days in a rather detailed study of the situation in the City of Selfoss. Mr. Baldur Lindal of the State Electricity Authority accompanied me to the City of Selfoss each time and acted as interpreter in the various discussions there with Mr. Sigur Johnson, Superintendent of the Selfoss Heating System. The general situation was discussed in some detail with Mr. Gunnar Bodvarsson, Chief Engineer of the Geothermal Department of the State Electricity Authority and on one day a brief visit was paid to the City of Selfoss with Mr. Bodvarsson. Throughout this work, the writer met with complete cooperation from all concerned. Unfortunately, it was not possible to have a conference with the General Manager of the Selfoss Heating System in the City of Selfoss.

This report covers the observations made during this study of the System, the information obtained with regard to materials, waters and service life, the samples selected for laboratory study in the laboratories of Sam Tour & Co., Inc., the results of the studies made in the laboratories and the conclusions and recommendations derived therefrom.

Report R. #10,314 of August 3, 1953 on "Corrosion in Reykjavik District Heating Systems" contains a considerable amount of discussion regarding the relative effects of oxygen and sulphur in water, the necessity for having sufficient magnesium present to obtain protection against corrosion by the presence of silicates, the question of heating efficiency and how to obtain it, etc., etc. Those comments will not be repeated in this report as it is assumed that those interested in the problems of corrosion in connection with the heating system in Selfoss will have available to them the report on corrosion in the Reykjavik District Heating Systems.

<u>Description of System:</u>

The natural hot water flowing from the wells passes to a collecting tank. The collecting tank is partially buried in the ground, has a capacity of approximately 8 cubic meters and was reported to be a steel tank set on a concrete bed and insulated with pumice or volcanic ash approximately 1/2 meter thick. The portion above ground is covered over with soil. There were five inlets in the collecting tank but only four were delivering hot water. The inlets seemed to be near the middle of the tank. The collecting tank is not equipped with a flow control. There is a level glass inside of the pump house to indicate the level of the water in the collecting tank. Next to this collecting tank is a corrugated iron Quonset hut housing the pumps. The collecting tank and the pump house are shown in Fig. 1.

The water is gravity fed to the pumps. The pump house contains three horizontal centrifugal pumps, one single-stage pump and two three-stage pumps. Only one pump was in use at the time. The single stage pump has a reported capacity of 8 liters per second, whereas each of the triple-stage pumps is claimed to have a capacity of 22 to 28 liters per second. The maximum water available at any time is reported to be 22 liters per second. The water was reported to be flowing at an average temperature of 87°C.

In the pump house, it was noticed that there were heavy incrustations of salt around leaks in the end packing of the pump in use and around a valve stem.

The delivery pipe from the pumps is buried in the ground for a distance of about 20 meters where it joins a two-bellows steel expansion joint, then a 45° elbow, then a four-bellows steel expansion joint and is there connected above ground to an asbestos pipe. This 6" asbestos pipe above ground is supported on crude wood supports about every three meters. The supports are not set on concrete footings. The line of the asbestos pipe is not held rigid or smooth. There are leaks at several joints. It is reported that some difficulty is being had in keeping the joints in line and in keeping the rubber gaskets in the joints from deteriorating and permitting leaks. Figures 2 and 3 show this asbestos line as it travels above ground a distance of approximately 500 meters to a position where the first wells were and where the pump house was originally installed. This asbestos pipe was installed in 1951. The water is delivered from this asbestos tank to the line in the old pump house. A five-bellows expansion joint between the asbestos pipe and the steel pipe leading into the storage tank shows evidence of a leak having been repaired by welding. It was reported that this was an old expansion joint in service elsewhere before being installed in this position so that the question of whether it corroded in this position or was badly corroded before installation could not be answered.

In the basement of the old pump house is one horizontal shaft centrifugal pump not removed from its base. There was evidence of a leak and salt incrustation around the leak in the line going through the old pump house. A pressure of 3.8 kg. per square centimeter was noted on a gage in the old pump house. From the site of the old pump house, an 8" line runs a distance of 1400 meters to a storage tank near the edge of the City of Selfoss. This 8-inch line is reported to be wrapped with three to four centimeters of mineral wool plus bitumastic sheet and to be laid in volcanic ash in a trench in the ground and covered with soil. The line was not laid in a concrete conduit with drainage facilities. Some trouble is reported to have occurred due to outside corrosion from ground waters.

It is reported that approximately 20 expansion joints are installed in this line. Many of the expansion joints are of the slip sleeve type. Some have chrome plated inner sleeves. Most of them have rusted and frozen so as to be in a fixed position as a result of this freezing. About 6 or 7 expansion joints are of the steel bellows type.

The storage tank is made of steel insulated on the outside by dried grass or straw within a corrugated iron shell. The inside of the steel tank is painted each year with a Portland cement-plus-water paint for a thickness of about 1 millimeter. The tank is reported to be about 4 years old and to have shown some corrosion during the first two years of service, with water from the old wells, but to have given no trouble during the past two years of service with water from the new wells.

The storage tank and the adjacent pump house is shown in Figure 4.

The storage tank has a capacity of 640 cubic meters, has an 8-inch inlet at the bottom and an 8-inch outlet to the pumps. The tank is equipped with an overflow to waste, has a hydrostatic height gauge installed on it, but has no other controls.

In the pump house adjacent to the main storage tank are two pumps for repumping purposes. The pumps are of the horizontal centrifugal three-stage type. One pump in use was pumping at a pressure of 8 kilograms per square centimeter and the thermometer showed the water to be at 84°C. It was estimated that the pump was operating at the rate of about 6 liters per second. With all outlets closed, it was found that the maximum pressure that the centrifugal pump would develop would be 8.5 kilograms per square centimeter. Heavy salt incrustations were noted around the packing on the pump shaft. Valve stems in the pump house showed heavy salt incrustations from leaks.

The line running from these pumps into the city is laid in a concrete trough about 18 inches by 18 inches which is just buried in the ground with its top at about ground level. The top of this concrete trough consists of flat cement slabs not thoroughly cemented to prevent water getting into the trough. The tunnel or trough for the pipe is not pitched for drainage and is not provided with drains at low spots. When surface waters get into the trough or if the pipe leaks at any place the water cannot get out of the trough to leave the pipe dry.

The pipe is not covered throughout with mineral wool. Part of it is covered with natural wool and part is covered with a layer of straw plus an asphalt wrap. At one place in town where the tunnel had not properly drained and where surface waters as well as leakage waters accumulated in the trough, the straw had rotted and decayed. Underneath this decayed and rotted organic matter, the corrosion damage was of the pot-hole variety and quite severe.

Some of the street mains are installed inside of cement pipe which is supposed to be pitched so as to drain to various low spots. However, it is reported that in the Spring when the river overflows, the water level rises above the cement pipe as it is installed in the ground and the cement pipes become filled with ground waters. The cement pipes are not equipped with air vents so that it is very difficult for them to dry out once they become loaded with water. Even though the drains may take out the surplus water the pipes remain wet for long periods of time.

All of the three-inch and four-inch distribution lines are equipped with welded steel bellows type of expansion joints. These expansion bellows for the street lines are made in a local welding and machine shop who claim to have a hydraulic press adequate to form the disks and the welding facilities to weld them together to form the complete bellows.

No flexible couplings are installed between house connections and the street mains. No explanation was offered as to why this was not done. Apparently, it was not specified in the original engineering plans.

The house connections are welded direct to the sides of the mains laid in the streets. The house connections are wrapped in wool and laid in cement pipe to the house foundation. No particular effort is made to make the cement conduit watertight although it is usually pitched from the house to the street main for drainage.

Indications are that none of the pipe was given a good coating of paint before being installed.

No complete layout drawing of the system is available. It is reported that one had been made by the engineers of the contracting firm who installed the system but that the drawing had been borrowed about two years ago and never returned.

The entire installation is reported to have cost 4.2 million Kroner. It is operated with one man on full time and one man on part time, with all repair work and maintenance work jobbed out to a local shop. It is reported that the water delivered to the various buildings through meters is being charged for at the rate of 4.5 Kroner per cubic meter.

<u>Building Systems:</u>

The heating system installed in the cooperative building in the City of Selfoss was examined. This building is equipped with a heat exchanger and a building recirculating system so that the natural hot water is not being used in the building itself but only in the heat exchanger. The heat exchanger was reported to be equipped with 3/4" diameter copper tubes, brass tube sheets and with cast iron heads. It has been in operation for less than one year and its internal condition is not known. A recirculating pump circulates the water through this heat exchanger and through the various radiators in the building and back to the pump. Just what kind of water is being used in this system was not learned.

An examination of the radiators in the building showed a severe state of corrosion. Bad corrosion is occurring at all steel nipples and at many of the valves. Undoubtedly, the water being used in this system has not been de-aerated and the principal cause of corrosion is free oxygen.

The Post Office was visited to inspect the installation in that building. This building is not equipped with a heat exchanger and recirculation system. In the basement is a furnace for use in case of the need of additional heating. The 1-inch feed line from the city system enters this furnace and connects to the system in the building. The pressure gauge on this furnace showed that the pressure in the whole system could be varied by the main feed valve from the city line. This system was reported to be one in which the hot water overflowed to a drain in the attic so as to keep the system full of water at all times and to allow free-flowing to the sewer. A trip to the attic resulted in finding that the overflow box was dry and that the valve leading into the box was closed so that the overflow system was not working. A further study indicated that there was a drain valve elsewhere in the line going direct to the sewer rather than through the overflow, although Mr. Johnson reported that there was an overflow pipe running up into the chimney with an overflow onto the roof of the building. It was quite evident that if there was such an overflow, it was an emergency or safety overflow only and that actually the water was flowing through the system and to the sewer through some other pipe rather than through the reported overflow box or overflow standpipe. This was proven to be true by opening the feed valve wider and having the pressure gauge register a total pressure of 20 meters which is higher than the top of the building. In this case, it is difficult to see how the system can be kept free of air at all times.

An examination of the radiators in this building, however, showed them to be in better shape than those in the cooperative building previously described. Cast iron radiators were installed throughout. Each radiator is equipped with a special air-bleed valve which requires a special socket wrench to operate it. No test was made to see whether or not the radiators were free of trapped air.

Warehouse:

A trip was made to the warehouse to examine the pipe in stock for repair and replacement purposes. Two-inch, three-inch and six-inch pipe in stock showed a single coat of a fairly cheap, thin red iron paint.

Rock wool blankets with wire mesh wrapping were in stock. The blankets were of approximately 3/4-inch thick, raw, unoiled rock wool.

The six-inch pipe was all of the threaded joint variety, rather than flanged joints.

Internal Corrosion:

The situation with respect to internal corrosion in this system is not clear. A general belief that the rate of corrosion was excessive with the first water used for the first two years and that the rate of corrosion with the present water is less may be true. The analysis of the current water shows a high chloride content and a low resistivity which would be conducive to a greater rate of corrosion. However, the analysis shows a rather high silica content and a small amount of magnesia being present (3 parts per million). It is entirely possible that excessive corrosion is not being encountered due to the protective action of the siliceous film deposited by this combination of silica plus magnesia in the water.

A 2½" water main which had corroded through from external corrosion was being replaced during the time of the writer's visit. A sample of this 2½" pipe was taken as it was removed by the workmen. This sample was brought back to the laboratories of Sam Tour & Co., Inc., was sectioned longitudinally and some of the scale from the inside was removed for analysis. The sample and the scale are shown in Figure 5, Plate #14925.

When thoroughly dried the rust scale from the inside of this pipe was found to be brown to black with a considerable amount of a white or grey siliceous material in it.

A sample of the rust on the outside of this pipe was taken for analysis also. The results of the analyses of these two were as follows:

Element	Inside Scale	Outside Scale
SiO_2	34.1%	9.8%
Fe	39.7	57.9
MgO	9.0	Not found.
CaO	Not found	1.4
SO_4	0.5	Not found
Chlorine	0.2	0.6
Sulphur	0.5	----

It is quite evident that the magnesium is sufficient to deposit with the silica and to cause the silica to deposit to form a protective film. Undoubtedly, the pipes are being protected somewhat by the silica-magnesia combination in the water being used at present. It is difficult for such pipes to be protected if they were previously corroded and had developed a heavy incrustation of rust. However, even under such conditions the continuing corrosion can be inhibited greatly by the silica-magnesia combination present in the water.

Engineering:

It is surprising that the Selfoss District Heating System did not take advantage of the experiences in Reykjavik District Heating Systems through many years prior to the installation at Selfoss. It is apparent that efforts were made to install the system as cheaply as possible. Apparently it was thought that some of the precautions taken by the engineers in the Reykjavik system were unnecessary and could be eliminated. I refer specifically to adequate drainage and ventilation of conduits, to the use of mineral wool insulation, to the use of flexible couplings between building connections and mains to avoid stresses at welded T-joints, to instrumentation in pumping houses, etc., etc. In view of the fact that the water in the Selfoss region is much higher in chlorides than that in the Reykjavik region and is lower in resistivity, the precautions against excessive corrosion should have been a matter of major concern in designing this installation. Apparently these matters were disregarded in total.

Not only was the installation of a low order of excellence but the maintenance is poor. A system of this size cannot be properly maintained on such limited help basis as 1½ men.

Another item was the installation of the cheapest type of water meter of the impeller blade type rather than of the displacement type. This meter is a few dollars less in original cost than the type of meters being used in Reykjavik but does not register properly at slow rates of flow, which the superintendent of the Selfoss system has now learned. It will be necessary to replace many of these meters with a better grade of meter if accurate metering of water delivered to the buildings is desired.

Corrosion Prevention:

Although the report is that no excessive corrosion is occurring in the main storage tank as illustrated in Figure 4, there may be danger of such corrosion initiating in the future. Due to the high chloride content of the water and its accompanying low resistivity, it should be possible to apply cathodic protection to the inside of this tank by means of magnesium anodes. The tank could be equipped with approximately six magnesium anodes about three or four inches in diameter by 10 feet long hung at 60° intervals, halfway between the center and the outside of the tank and supported by connectors of high electrical conductivity to the steel roof and thus to the sides of the tank. Such magnesium anodes would require replacement occasionally but not oftener than every year or so and could be inspected at the regular shut-down and inspection period. Such magnesium anodes would introduce a slight additional amount of magnesium into the water which together with the magnesium already there and the silica content of the water would afford still better protection against corrosion in the mains in the house connections and in the house or building systems being fed from this tank.

Questions and Answers:

During the course of the discussions, Mr. Johnson, Superintendent of the Selfoss Heating System, asked several interesting questions and they were answered as follows:

1. - Should galvanized pipe be used?

   Answer: The zinc on galvanized pipe would not last long enough on the inside of piping to be worth while but would offer some protection against outside corrosion. It is doubted that the use of galvanized pipe to prevent outside corrosion should be resorted to in place of keeping ground waters away from the outside of the pipes.

2. - Should the whole system be shut down in the Summer time, or should the pumps be run in order to keep the lines free of air? There are no valves outside of the houses which the city can get to to shut off the water and, although the owners of the buildings can be asked to close the lines, they can't be forced to close them. Check valves are not perfect.

   Answer: It would be desirable to get as many lines as possible closed and to run a small pump at all times to maintain pressure and to keep all lines full, otherwise the lines will siphon the water from the houses and will draw air into the house system and from there into the main line systems.

3. - How about grounding of radios in houses to the radiator systems?

   Answer: All efforts should be made to avoid such, but it will be practically impossible to avoid it at all times. The principal thing to avoid is wet ground in contact with the steel mains anywhere in the city. To conduct current away from the steel mains, there should be copper conductors attached to the steel mains and carried away to points where they can be attached to iron buried in wet soil. Such connections would take the current that might leak into the piping system off of the pipe and to the wet ground through the connector and prevent electrolytic corrosion of the pipe.

4. - Meter wheels tend to bind, how should they be lubricated?

   Answer: An axle grease or cup grease has been found satisfactory in Reykjavik for the type of meters they use. For the paddle-wheel type of meter used in Selfoss, the gears are surrounded by water and the wheel and gears should be made of nickel and no grease should be necessary, although some help can be obtained by use of flake graphite rubbed in periodically with a small amount of oil or grease. In general, the paddle type of meter should not be used as it does not register on low rates of flow.

5. - Could lines be laid above ground to keep dry?

<u>Answer</u>: It would be preferable to have the lines laid above ground as they are in the line from Reykir to Reykjavik. In the city it is necessary to go under streets but wherever possible the conduits for pipes should be above ground or above ground water level. In any event, all conduits should be pitched properly to drains and should be drained properly and kept dry. All conduits should have adequate vents.

6. - Can 6-inch threaded joints be made up in the field with hand tools, such as chain wrenches and 10-foot length of pipe handles?

<u>Answer</u>: It is doubted that this can be done adequately in the field. One coupling should be threaded up tight in the shop on the end of each length of 6-inch pipe. In assembling in the field, the other half of the coupling should be screwed on as well as can be with the use of chain wrenches, etc., and then should be bead welded to seal the field threaded joint.

7. - What kind of wool should be used for insulation?

<u>Answer</u>: Oiled water-repellant rock wool should be satisfactory. Straw or dried grass will rot, will support bacteria, will turn acid and will promote corrosion.

8. - Should pipes be painted before installation and with what kind of paint?

<u>Answer</u>: The single coat of mineral red paint on pipes in stock is inadequate protection against corrosion. All pipes should be painted with a good heavy coat of high temperature bitumastic paint.

Conclusion:

The internal corrosion problems in connection with the Selfoss District Heating System are not so serious as to be alarming in nature. The external corrosion problems are quite serious. It will be necessary to replace a considerable percentage of the street mains within the next few years. If replace lines are not properly installed, they will not have a long life. Plans and specifications should be drawn in a re-engineering of the pipe lines. As each line fails and is replaced, the replacement installation should be along good engineering lines which require:

(a) - Corrosion protective coatings on the pipe.

(b) - Proper insulation of the pipe.

(c) - Pitched conduits that will drain.

(d) - Adequate drains.

(e) - Top sealing of conduits.

(f) - Air ventilation of conduits.

(g) - Allowances for expansion and contraction:

(1) - Expansion joints
(2) - Flexible connections.

Throughout this study of the Selfoss District Heating System, Mr. Gunnar Bodvarsson, Mr. Baldur Lindal and Mr. Sigur Johnson were very cooperative. Their assistance is gratefully acknowledged.

Respectfully submitted,

SAM TOUR & CO., INC.

Sam Tour

Sam Tour,
General Manager

s
ST:AR

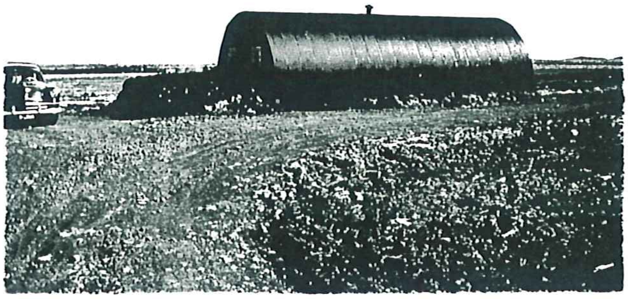


Figure 1

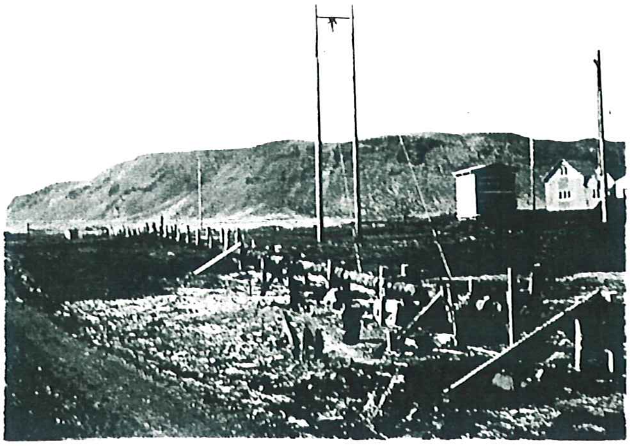


Figure 2

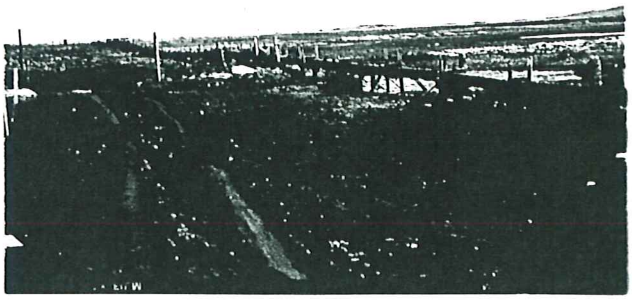


Figure 3

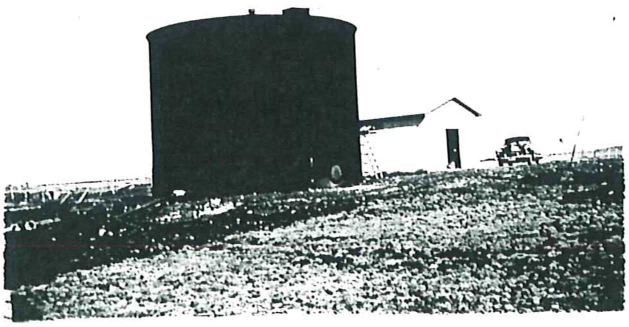
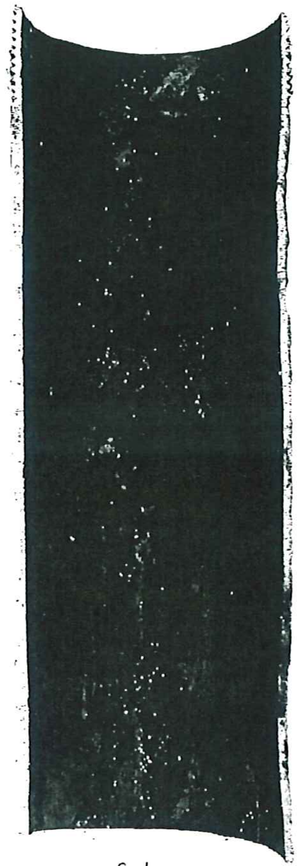
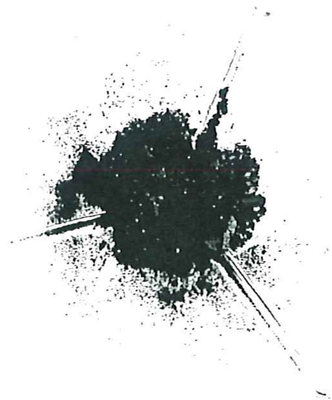


Figure 4

SAM TOUR & CO., Inc.



S1



S1A

Figure 5 Plate #14925