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PUMICE INSULATION: A PRACTICAL SOLUTION FOR RURAL GEOTHERMAL PIPELINES

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ABSTRACT

Geothermal pipelines from heat-resistant plastic, insulated with pumice fill, are gaining acceptance in Iceland in rural heating systems. Initial savings with this technique are at least 50% compared with conventional steel piping, but heat losses are relatively high. Ground moisture is a problem, and K-value fluctuates with rainfall levels. Tests conducted by the National Energy Authority demonstrated that this application is practical for rural pipelines, where nearby geothermal sources exist.

INTRODUCTION

Of the various designs used for geothermal pipelines in Iceland, buried steel conduits insulated with polyurethane are by far the most common. They predominate in urban distribution systems, for one thing. Many of the supply pipelines are also from steel, typically insulated with rockwool in aluminum sheathing, resting on concrete supports. From most technical standpoints, steel conduits are desirable in geothermal pipelines, but that design is often prohibitively expensive for small district heating utilities.

Some supply pipelines in Iceland are from asbestos cement, either partially insulated or laid uninsulated in a ridge of soil covered with turf. One problem with asbestos pipes is moisture diffusion which, if trapped inside a vapor barrier, may render the insulation useless. An asbestos pipeline can be built for just 30-40% of the outlays required for a conventional steel installation, but the tradeoff is heat losses that are up to seven times greater for uninsulated pipelines. Under Icelandic legislation taking effect next September 1, laying of asbestos pipes by heating utilities must be limited to repairs of existing conduits and to new systems that otherwise would not be feasible.

A design of the third type has won growing aceeptance in recent years: pipes from heat-resistant plastics supplied by domestic manufacturers. The first of these that became available, in 1978, were small-diameter units (3/4" to 2") from cross-linked polyethylene (PEX). While that production has been discontinued, polypropylene (PP) pipes suitable for the purpose are being made locally - only in small sizes so far, but larger diameters will be offered before long.

Diverse materials have been used in Iceland to insulate geothermal pipelines - foamed plastics, mineral fibers and pumice, among other things. Pumice, the standare material for insulation of buildings in Iceland until recently, has fairly good insulating properties while dry, but it is highly moisture-absorbent. To study the heat-loss fluctuations in geothermal pipelines from plastic insulated with pumice, the National Energy Authority has conducted tests at a rural locality in the south.

PUMICE-INSULATED PLASTIC PIPELINES

In recent years, plastic pipelines for geothermal utilities have been laid by a S-Iceland contractor using a plow-type tractor attachment. That equipment makes it possible to fill with pumice for insulation around the pipe as it is being placed in the ditch, with a plastic sheet laid on top to deflect water. Fig. 1 shows a cross section of such a pipeline. Initial savings with this technique are at least 50% in relation to conventional steel piping, but heat losses are twice the level that is normal in the case of insulated steel conduits. Because the pumice fill is vulnerable to moisture, care must be taken to select well-drained terrain for placement of such pipelines; a common procedure is to lay the pipe alongside drainage ditches.

The main advantages of pumice insulation are its low price, relatively high insulation value in cost terms, easy handling, and plentiful supplies from domestic sources. The worst drawbacks are pronounced fluctuations of the total heat transfer coefficient (K-value), vulnerability to ground moisture, and the need for routing the pipeline through special terrains. Besides, the domestic production of heat-resistant plastic conduits has been limited thus far to small-diameter units. Huge accumulations of pumice exist at three general localities - the Mt. Hekla area in the central south, the environs of the Askja caldera in the eastern north, and near Snaefellsjökull Glacier in the central west. Scoria, a volcanic material with fairly good insultation properties, can be mined in many parts of Iceland.

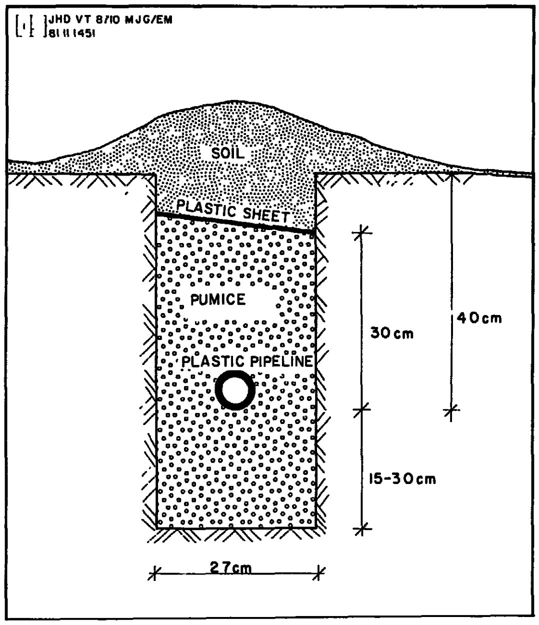

Figure 1: Cross section of a geothermal pipeline insulated with pumice.

THE RELATIVE MERITS OF PUMICE FOR PIPELINE INSULATION

The effectiveness of a given material as insulation stands in inverse relation to its thermal conductivity (lambda value) measured in W/m°C units. Generally, materials of low density (porous) rate low on the conductivity scale as trapped dry air is a superb insulation (see Table 1). On the other hand, the strength of materials is generally a function of their density so the lowest density does not necessarily make for the best choice as insulation. For example, urethane produced for insulation purposes ranges from 30 to 100 kg/m3 - while a minimum of 70 kg/m3 is required for insulation of geothermal pipelines. As noted in the foregoing, moisture is a special problem when pumice fill is used for insulation of geothermal pipelines. The tests conducted by the National Energy Authority showed that heat losses through the largely unprotected pumice varied extensively with rainfall levels.

TABLE 1: THE THERMAL CONDUCTIVITY OF SOME INSULATION MATERIALS USED FOR GEOTHERMAL PIPELINES

Insulating material	Dry density kg/m3	Thermal conductivity value W/m°C
Pumice	350-400	0.07-0.10
Scoria	600-1200	0.15-0.30
Rockwool	150	0.034
Fiberglass	75	0.031
Polyurethane	80-90	0.023

THE PIPELINE TESTED

The testing under discussion involved a rural pipeline serving a few farms in southern Iceland. It was laid in 1981. Roughly one-third of this pipeline is from conventionally insulated steel conduits, but the remainder is from plastic ones insulated only with pumice fill. The second application was used where placement alongside drainage ditches was feasible. The length of the pumice-insulated pipeline section that was monitored is 1,410 m. The pipe diameter is 63 mm. The water enters at about 90 °C and at a pressure of 3-4 kg/cm2. Data were collected for seven months, from November 22, 1981, to June 27, 1982.

FACTORS MEASURED

The monitoring (at the farm Efra Sel) covered the following factors:

Inlet temperature	°C
Outlet temperature	°C
Inlet pressure	bar
Outlet pressure	bar
Flow rate	l/s
Ambient air temperature	°C
Precipitation	mm/24 hrs

The instruments were generally read at 6 a.m. in order to get data comparable to those collected at regular weather observation stations. Table 2 shows samples of the instrument readings at Efra Sel and of the K-values (total heat transfer coefficient, W/m °C). The K-value was established for each set of measurements by applying the formula

$$\Delta T = \frac{K \cdot tm \cdot L}{m \cdot c_p}$$

where ΔT represents heat loss, tm the logarithmic mean temperature differential between the geothermal water and ambient air, L the pipeline length, m the mass flow rate, and c_p the heat capacity.

The definition of tm is $tm = \dfrac{T_{in} - T_{out}}{\ln\left(\dfrac{T_{in} - T_\infty}{T_{out} - T_\infty}\right)}$

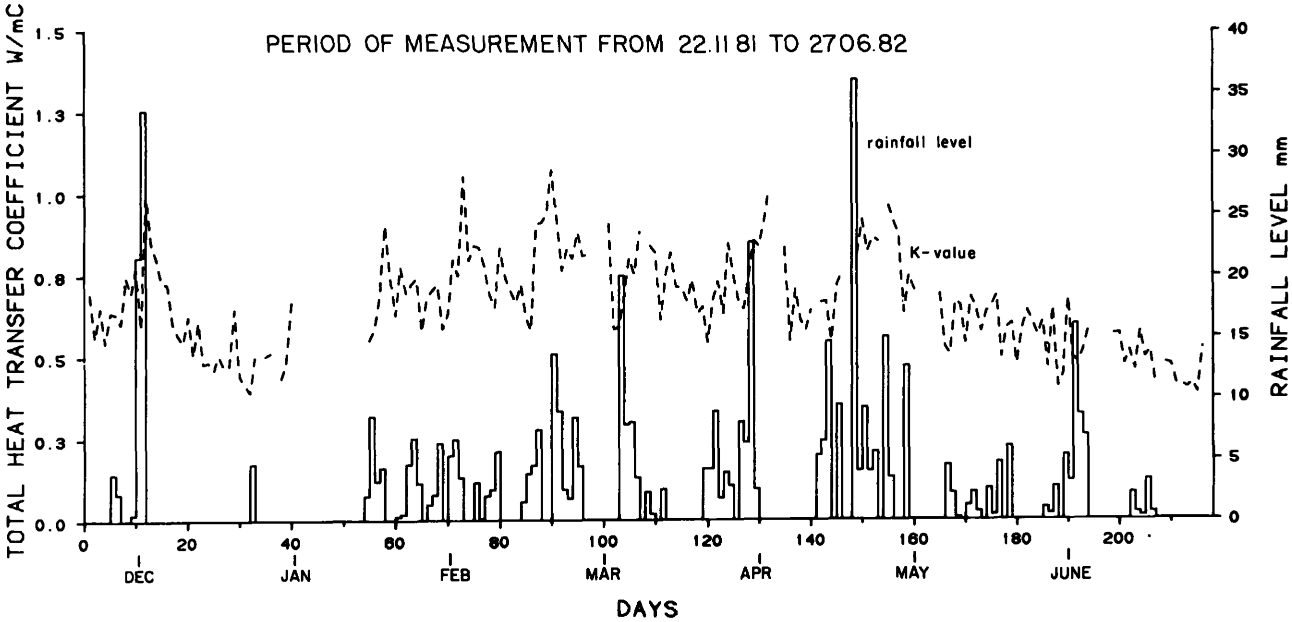

Figure 2
Measured total heat transfer coefficient for
a pumice insulated pipeline and local rainfall level

TABLE 2. Typical data collected

Date	Outside Temp. °C	Precipitation mm/24h	Water Temp T_{in} °C	Water Temp T_{out} °C	Pressure P_{in} bar	Pressure P_{out} bar	Flow l/s	Total heat transfer coefficient K W/m°C
81.12.01	7,0	0,5	89	77	3,8	2,3	1,64	0,771
81.12.02	7,0	21,5	82	73	3,8	2,8	1,56	0,593
81.12.03	4,0	33,5	87	63	3,2	3,2	0,98	0,994
81.12.04	-3,0	0,0	89	74	3,0	2,0	1,60	0,846
81.12.05	0,0	-	89	74	3,2	2,5	1,46	0,801
81.12.06	-4,0	-	88	74	3,0	2,2	1,49	0,731
81.12.07	-6,4	-	88	75	3,0	1,8	1,65	0,727
81.12.08	-11,0	-	88	77	3,6	2,2	1,73	0,606
81.12.09	-5,0	-	88	78	3,8	2,7	1,68	0,568
81.12.10	-8,2	-	88	77	3,8	2,7	1,51	0,545
81.12.11	-8,1	-	90	78	3,6	2,6	1,61	0,624
81.12.12	-8,2	-	90	79	3,8	2,8	1,43	0,505
81.12.13	-6,0	-	90	79	3,8	2,4	1,69	0,611
81.12.14	-8,0	-	90	79	3,8	3,1	1,36	0,481
81.12.15	-6,0	-	90	75	4,0	3,7	0,96	0,484
81.12.16	-5,0	-	90	78	4,0	3,3	1,15	0,461

CONCLUSIONS

Figure 2 summarizes the conclusions from the analysis of the data. Among other things, it seems clear that the pronounced fluctuation of the K-value, from 0.4 to 1.1 W/m°C, relates with changing precipitation levels. The average K-value over the 8-month period is 0.663 W/m°C. Table 3 compares K-values for different designs of geothermal pipelines with diameter of 2".

TABLE 3: COMPARISON OF K VALUES FOR SOME PIPELINE DESIGNS

Buried steel pipe, insulated with urethane:	0.25
Asbestos pipe, uninsulated in soil:	1.78
Asbestos pipe, insulated in soil:	0.32
Heat-resistant plastic pipe, insulated with pumice:	0.66

The findings from the pipeline tests confirmed that pumice insulation is a practical solution in building rural pipelines, especially where geothermal water is plentiful and low-priced.