THERMAL SIMULATION - REGINA GEOTHERMAL WELL

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Internal Report No. 79-3

Geothermal Service of Canada
Division of Seismology and Geothermal Studies
Earth Physics Branch
Deaprtment of Energy, Mines and Resources
1979.

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A 2000m+ well is being drilled in January, 1979, to test the geothermal potential of the sedimentary basin below the campus of the University of Regina. Temperatures around 70°C are anticipated within the target zone; if feasible, production of hot brine is planned at a rate of $0.0222 m^3 s^{-1}$. The geothermal fluid would be used for space heating of a building on the campus, after which it would be returned to the formation through an injection well some distance away.

The purpose of this study is to make an assessment of the heat losses in the egina geothermal test well under sustained production conditions. An estimate of the heat loss (and temperature drop) experienced as the production fluid moves to the surface is made and the thermal benefit in using an insulated discharge pipe above the submersible pump is calculated.

The simulation was carried out through a finite difference program described by the author (Taylor, 1978).

1. Simulation of heat losses in attainment of steady state

During production, the geothermal fluid will be at a temperature different from its surrounding formation. The rate at which the radial heat loss approaches a steady state was simulated by impressing a fixed temperature on the wellbore at two depths where the geothermal temperature is 5K and 35K lower than the wellbore (radius 0.089m).

The results (figure 1) show a heat loss decreasing rapidly after start up, to within 1/e of steady state values by 15 days after start-up.
The heat loss is linearly related to the contrast in wellbore and geothermal temperatures; the curve at 35K, for instance, is simply 7X that for 5K.

These heat losses and temperatures within the formation can equally well be :tracted from published tables, e.g. Jaeger (1956), Jessop (1963, 1966), and Taylor (1978).

2. Simulation of heat losses during production

At start-up, fluid at 70°C will travel up the well, losing heat to the formation. The loss will be large initially, but as the formation surrounding the well warms, the radial gradient will decrease, reducing the heat loss considerably.

The author's numerical program is not capable of directly modelling heat and mass transfer. However, once production has stabilized and a near-steady state thermal regime is attained, an estimate of heat lost by the upward moving fluid may be made.

The well is divided into a number of segments vertically and the heat loss and temperature drop of the production fluid in each segment is calculated. This is based on the temperature of the fluid entering the segment and the disturbed thermal regime of the formation at the mid-point of the segment. Rather than adopting the steady state thermal regime, the disturbed state that exists after .5 days in the transient solution is taken as a more conservative estimate of the heat loss.

The division of the well into segments is shown in figure 2. For segment 1 (2040m to 1700m) fluid was assumed to enter at 70^{o}C, and pass through a disturbed formation (as described) for transit time of 380 seconds (a pumping rate of 0.0222 m^3s^{-1} through casing of radius 0.089m). After 15 days, the heat loss was 28W per metre length of fluid. Taking this rate as typical of the entire segment, the fluid will decrease about 0.1K in transitting this section. Hence, fluid at 69.9^{o}C can be assumed to enter the segment above.

This calculation may be made from the published tables, or may be seen on figure 1. The wellbore/geothermal temperature contrast for section 1 is 70^{o} - 66^{o} = 4K. :aking 4/5 of the lower curve in figure 1 at 15 days is 28W per metre length, as above.

The well segments and the temperature drop in each are tabulated below.

Segment	Depth (m)	Temperature drop (K)
6	350 - surface	1.11
5	700 - 350	0.88
4	1000 - 700	0.57
3	1400 - 1000	0.63
2	1700 - 1400	0.27
1	2040 - 1700	0.09
		3.55

These results are plotted in figure 3, emphasizing the considerable increase in temperature drop nearer the surface. Figure 4 shows the variation of heat loss with depth; the discontinuity at 1000m arises from the hypothetical change in :thology, resulting in an increased temperature gradient in the upper half of the well and a corresponding decrease in rock thermal conductivity.

Both thermal conductivity values are probably high, but were used since they are mid-range values between sandstones and the much lower conductivity of shales.

Had a larger number of segments been used, the calculated temperature drop would be slightly less. The effect, for instance, of performing only one calculation on the entire well (i.e. only one segment) is to give a temperature drop of 4.1K. Hence the technique used here may be considered a conservative calculation at this time.

3. Reduction of heat loss with insulation

Examination of figure 3 shows that one half of the temperature drop occurs in the upper one third of the well. Reduction of the loss in this area may be achieved by insulation.

Two completion arrangements are proposed for the Regina well:

. a smaller production tubing (radius 0.045m) inside the principal casing (0.089m) above a submersible pump.

2. no special casing above the pump.

The first arrangement would allow the intervening annulus to be filled by an insulating medium. The author's program is capable of simulating this and comparison is made to the same completion but with the annulus filled with cement of thermal conductivity similar to the formation. The program is incapable of modelling heat loss when a convecting annulus, such as air or water, is present.

Perhaps several types of insulating materials are technically feasible; polyurethanes and silicate foams have been documented in the literature (Penberthy et al, 1974;

Kennedy 1971; Sinha et al, 1972; anonymous, 1972; and others). The following properties are typical and have been adopted in this simulation:

thermal conductivity, 0.017 $Wm^{-1}K^{-1}$

density, 200kg m^{-3}

specific heat, 837 $Jkg^{-1}K^{-1}$

The insulating effect may be appreciated by noting that this conductivity is a factor of 200 lower than that of the formation.

For this simulation, a fluid temperature of 67°C and an average geothermal temperature of 15°C were adopted for the region above the pump, at 430m (figures 2 and 3). The heat loss without insulation is about 335W per metre length of fluid, 15 days after the start-up; a transit time of 123s results in the inevitable drop of 1.4K calculated previously (Fig. 3). (Heat loss is practically independent of well size for a constant pumping rate).

Two thicknesses of polyurethane insulation were simulated; 1.8cm and 4.3 cm, the latter filling the entire annulus between the production tubing and casing.

Insulation	Heat loss (rate)*	Heat loss (above pump)	Temperature drop
none	335W	41,000J	1.4K
1.8cm	16	1,970	0.067
4.3cm	8.1	1,000	0.034

* watts per metre length of production fluid.

'igure 5 compares the heat loss in the three cases, and the production fluid temperature with depth is shown in figure 3.

Conclusions

1. Substantial temperature drops in the production fluid are expected shortly after pumping starts in the Regina well. Steady state conditions will be attained at increasingly later times at shallower depths, but a time of 15 days is satisfactory for calculations at this stage.

2. After 15 days, the heat loss expected in pumping at $0.0222m^3s^{-1}$ is 1.7×10^7 Jm^{-3} of fluid, resulting in a temperature loss of 3.6K from production zone to surface.

3. If the pump, placed at 430m depth, discharges into tubing one-half the diameter of the casing, an opportunity exists to reduce heat losses by using insulation. A layer of polyurethane or silicate foam at least 1.8cm in thickness should reduce heat losses in this 430m section by 95%, resulting in a saving of 38% over the entire well. This saving is 6×10^6J per cubic metre of fluid, equivalent to 140 kW at the planned pumping rate of $0.0222m^3s^{-1}$. This is approximately the power needed to operate the pump itself.

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Figure 1. Variation of the heat loss with time at two depths in well where the difference between wellbore and geothermal temperature is 5 and 35K .

Figure 2. Hypothetical geothermal temperature profile, with a change in lithology at 1000m. The division of the well into segments for the heat loss calculation is shown.

Figure 3. Decrease in temperature of production fluid as it moves up the well. Compared to calculation by Vandenburghe (private commun.)

Figure 4. Variation of radial heat loss with depth.

Figure 5. Average heat loss above pump (430m) without insulation and with two thicknesses of polyurethane.

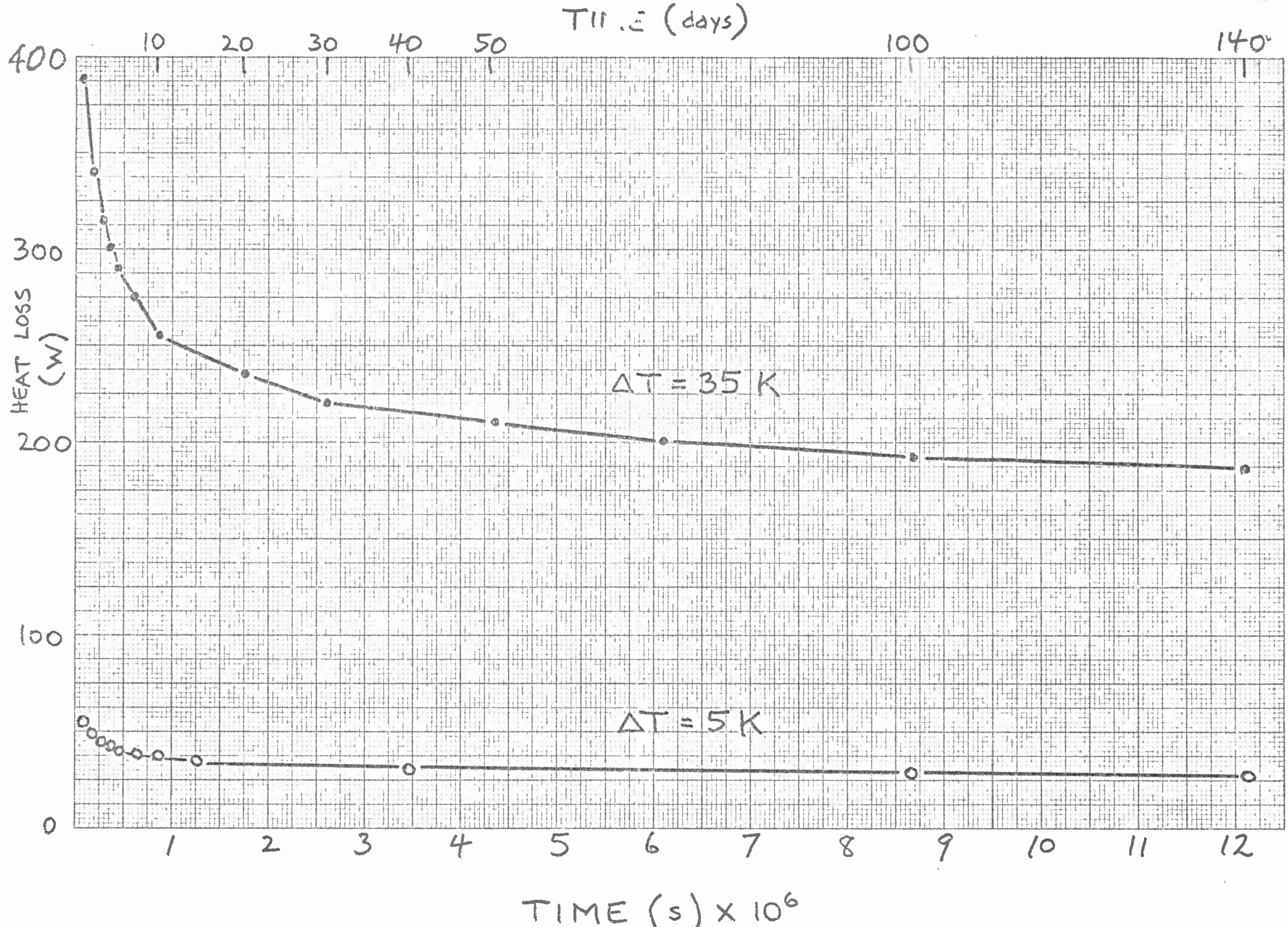

TIME (days)
10
20
30
40
50
100
140
400
300
200
100
0
HEAT LOSS (W)
ΔT = 35 K
ΔT = 5 K
1
2
3
4
5
6
7
8
9
10
11
12
TIME (s) x 10^6

FIG. 1

PRODUCTION WELL
GEOTHERMAL TEMPERATURE

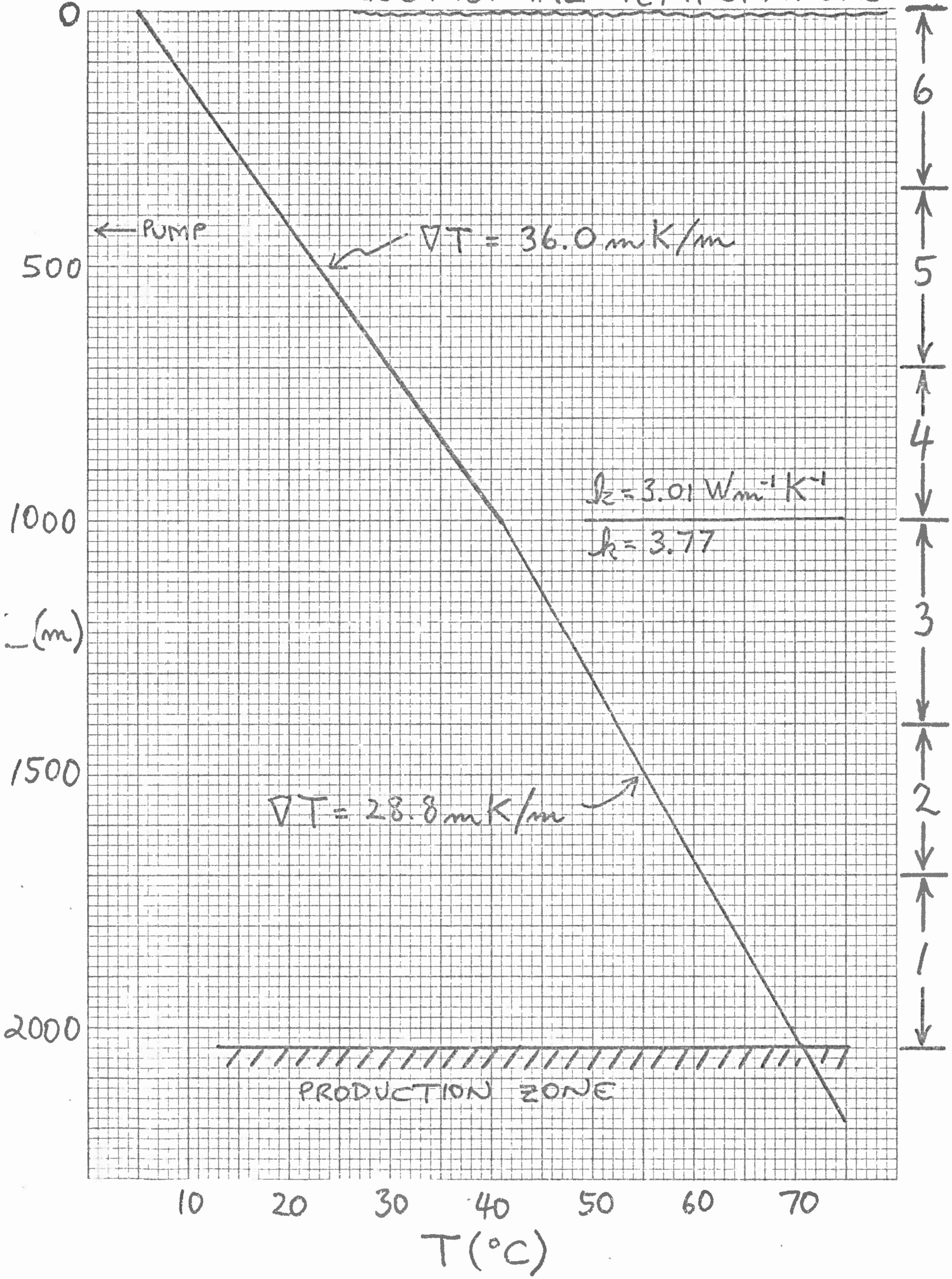
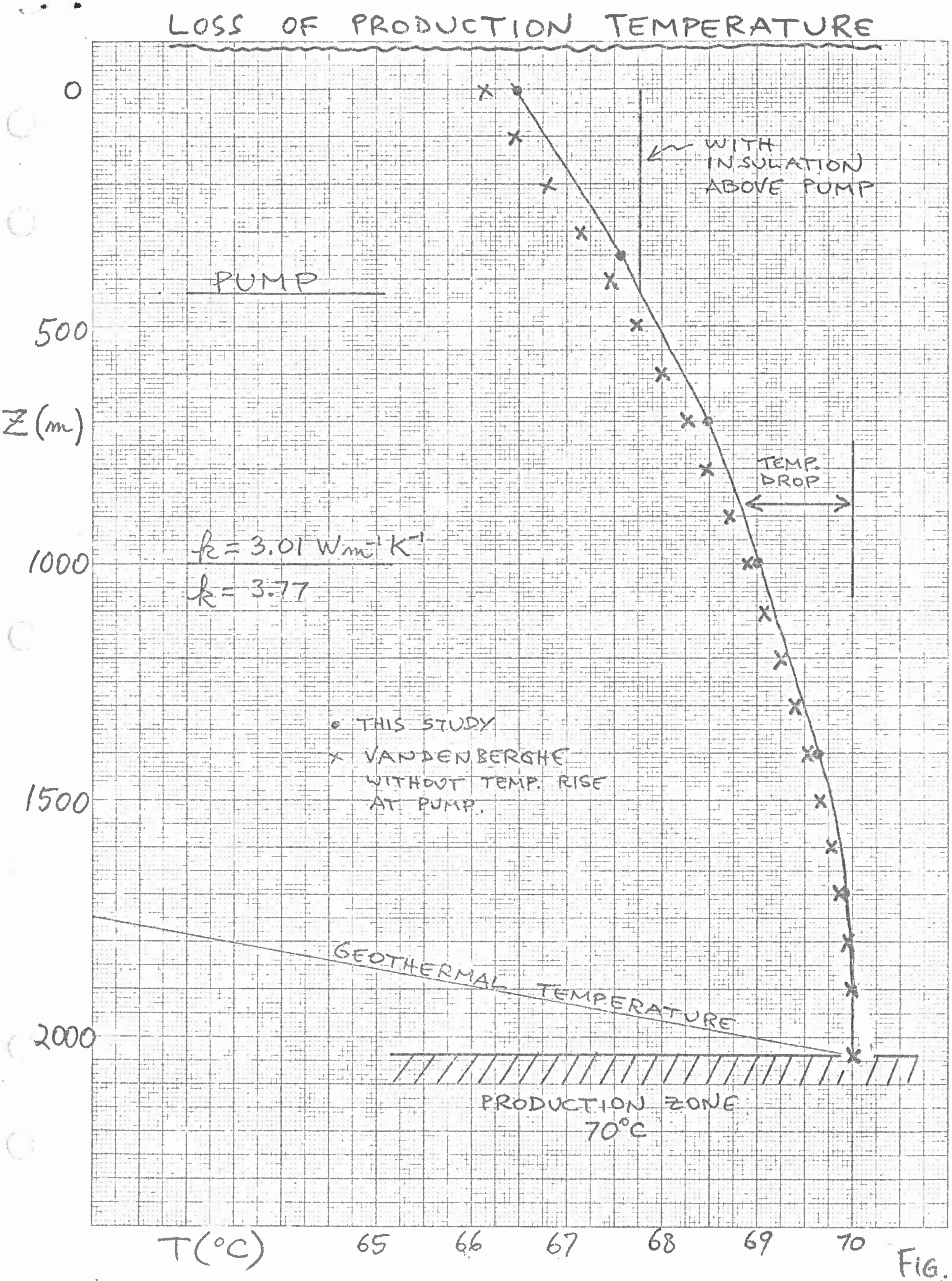


FIG. 2



LOSS OF PRODUCTION TEMPERATURE
0
500
1000
1500
2000
Z (m)
WITH INSULATION ABOVE PUMP
PUMP
TEMP. DROP
k = 3.01 W m⁻¹ K⁻¹
k = 3.77
• THIS STUDY
× VANDENBERGHE WITHOUT TEMP. RISE AT PUMP.
GEOTHERMAL TEMPERATURE
PRODUCTION ZONE 70°C
T(°C)
65
66
67
68
69
70

FIG. 3

AVERAGE HEAT LOSS

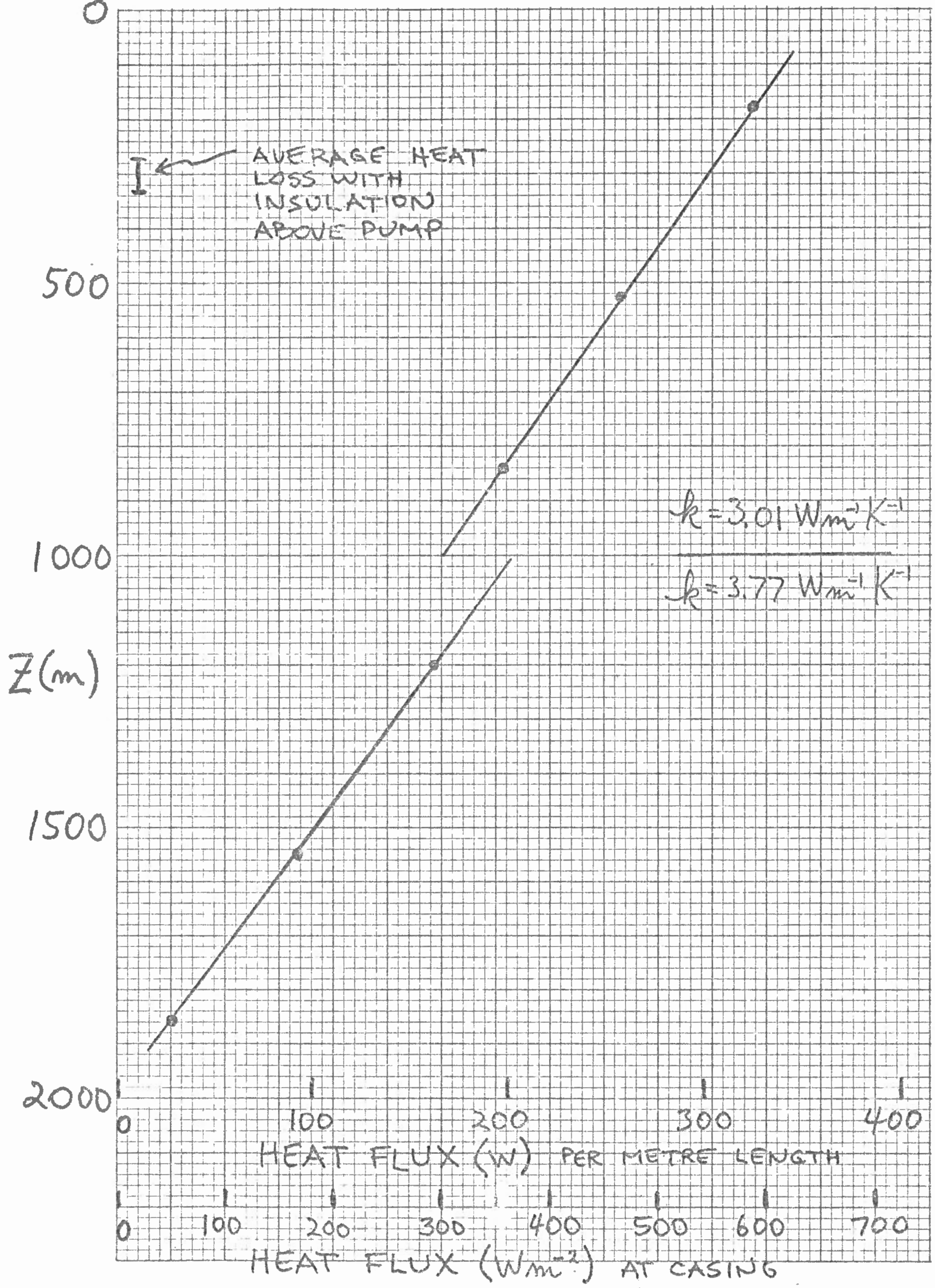


FIG. 4

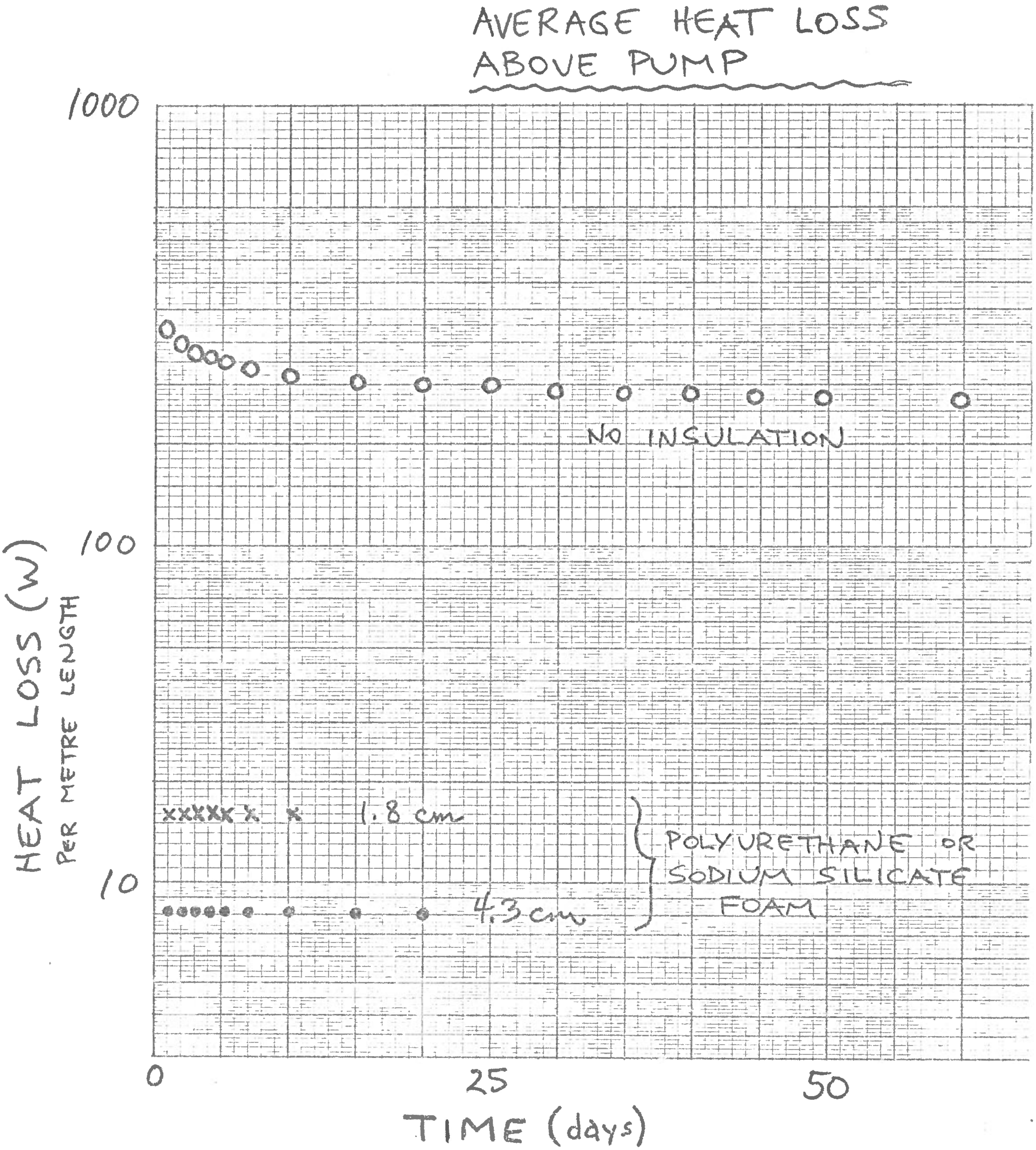

AVERAGE HEAT LOSS ABOVE PUMP
1000
100
10
HEAT LOSS (W)
PER METRE LENGTH
0
25
50
TIME (days)
NO INSULATION
1.8 cm
4.3 cm
POLYURETHANE OR SODIUM SILICATE FOAM

FIG. 5