GLO1278

Geothermal energy heats campus

Almost unbelievable savings are provided by the Oregon Institute of Technology's on-campus geothermal heating installation.

By **JAMES HITT**, Geothermal Coordinator, Physical Plant Superintendent, Oregon Institute of Technology, Klamath Falls, Ore.

Klamath Falls, a city of 16,000 population, is near the center of an elongate, northwest trending structural valley called the Klamath graben. It is a complex structural valley about 50 miles long and 10 miles wide. Upthrown rocks, or horsts, bound the valley on both east and west sides. Upper Klamath Lake, Oregon's largest lake, and numerous other smaller lakes, ponds, and swamps occupy the lowest parts of the valley. Unlike the other large graben valleys of the basin and range geomorphic province of the western United States, which have internal drainage, Upper Klamath Lake is drained by the Klamath River that flows south and then west through the high cascades to the Pacific Ocean.

In the early days of Klamath Falls, several groups of hot springs and boiling mud pots were present in the flats and low, rolling hills where the city is now built. The Indians were the earliest users of the hot springs, and they cooked fish and game and also, because they had great faith in the healing power of the water, bathed and soaked in the overflow pools.

The early settlers used them frequently for various things, including the scalding of hogs, and by 1915 there was a greenhouse built over one of the hot springs. By 1928, Klamath Falls boasted a modern hot springs natatorium in which the pool water was completely changed daily. At the present time, there are more than 360 relatively shallow wells that tap the natural hot water to heat schools, industrial buildings, apartments, and houses.

Complex faulting, most of which occurred in late Pleistocene time, has broken the whole Klamath area into a characteristic pattern of northwest trending fault block ridges and intervening down-dropped graben valleys. Tilted fault blocks are numerous within the Klamath graben.

Perhaps nowhere else in the United States is the geologic evidence of recent faulting so well displayed. At nine separate locations, the shiny, polished fault surfaces are exposed. All are high angled normal faults and dip from 55 to 70 deg into the valleys. One of the most spectacular faults has been exposed along the east side of Upper Klamath Lake, where removal of talus has uncovered the fault plane for nearly a third of a mile in length and as much as 250 ft in height. Grooves in the slick sided surfaces indicate that the last and perhaps all of the displacement has been vertical. At least 1600 ft of vertical displacement is indicated in the vicinity of Klamath Falls, and movements of this order of magnitude can be estimated at other places where the steep fault escarpments are elevated about this much above the valley floors.

The Klamath Falls geothermal area is near the center of the graben in slightly tilted fault blocks that are elevated a few hundred feet above the valley floor. These tilted blocks are made up of impure diatomite, thin beds of tuff sandstone, clayey tuff, and intercalated basalt flows. The blocks have, in turn, been co ly faulted into elongate ridg generally trend northwest. B they are so easily eroded, th now seen as low, rolling hil

Well logs indicate that th tomaceous tuffs and layered ments are at least several hu feet thick in most places, ar pervious to the flow of wate act as a cap at the surface. B lava flows and zones of scor cinders are encountered at v depths, and in most cases i thermal areas, these horizons large quantities of live hot At least one strong northwest ing fault is present on the eas of the geothermal area, and rise of hot water from a de reservoir could be associated the brecciated rocks that are mon to this type of fault. Alth the heat source is not known no surface rocks of recent ag present, the Pliocene-Pleist dikes and sill-like masses th intercalated in the lacustrine d its may indicate the presence larger intrusive rock mass co at not too great a depth.

A long history of hot spri tivity is shown by the prese bleached silicified rocks, depo calcite and gypsum, and mercury mineralization in a halo surrounding the geoth zone.

Klamath Hills is a large, is fault block within Klamath about 10 miles south of Kl Falls. Large volumes of hot

—A dark gray to black dense to fine grained rock that consists of basic plagioclase, augite, ually magnetite.

a—A rock consisting of sharp fragments em- in a fine grained matrix (as sand or clay).

mite—A light easily crumbled siliceous material chiefly from single celled algae remains.

—A tabular body of igneous rock that has been while molten into a fissure.

pment—A long cliff or steep slope separating mparatively level or more gently sloping surfaces ulting from erosion or faulting.

—A fracture in the earth's crust accompanied displacement of one side of the fracture with to the other and in a direction parallel to the

graben—A depressed segment of the earth's crust bounded on at least two sides by faults.

horst—A block of the earth's crust separated by faults from adjacent relatively depressed blocks.

magma—Molten rock within the earth's crust.

Pleistocene—An epoch within the Cenozoic Era of the geological time scale, usually taken to embrace the last two million years.

Pliocene—An epoch within the Cenozoic Era.

scoria—Small fragments of porous volcanic rock.

talus—A slope formed especially by an accumulation of rock debris; a rock debris at the base of a cliff.

tuff—a rock composed of the volcanic detritas usually fused together by heat (tuffaceous, adjective).

tufa—A porous rock formed as a deposit from springs or streams.

) are found at shallow depths rrow zone along the south-. The geologic environment thermal zone is similar to the Klamath Falls area, and or border of silicified lake ts and tufa are present. ngled normal faults with a northwest trend are com- and again, the recency of is shown by slick sided surfaces. Basalt flows and ted breccias, scoria, and cin- predominate in the Klamath ult block. Drillers' logs from water wells indicate several d feet of lake sediments and tuffs in the lower Klamath. A large area in the south- part of the Klamath Hills lain by cinders, scoria, and itic tuff breccias, indicating re a basaltic magna encoun- water or saturated sediments e surface and violent explo- uptions resulted.

original hot springs of Kla- Falls have disappeared lowering of the water table ultural changes. Of the 360 that have been drilled, the of the wells range from as s 100 ft to a maximum of ft. Most are in the 200 to 350 e. The water table generally to coincide with the elevation Upper Klamath lake, and water level depths vary with ography. Much of the rock ated in the geothermal zone e "tight" or impermeable, perched water influences the of the local water table in cases. Drillers report drops of levels amounting to as much as 50 ft from levels initially encountered as drilling proceeds to greater depths.

Temperatures of the wells in our geothermal zone range from 140 to 235 F.

Klamath Falls is 297 miles southeast of Portland and 383 miles north of San Francisco. Major cities within an approximate 1000 mile radius are: San Francisco and Los Angeles, California; Reno and Las Vegas, Nevada; Salt Lake City, Utah; Boise, Idaho; Portland, Salem, and Eugene, Oregon; and Seattle and Spokane, Washington. Because of its geographic location, it is at the center of population of more than 26 million people.

The Oregon Institute of Technology campus is located approximately three miles north of the downtown business district of Klamath Falls. Elevations on campus range from 4250 to 4400 ft.

A carefully chosen move

Oregon Institute of Technology was founded in 1947. Dr. Purvine, the founder of the school, concluded that numerous factors present at this first site created heating problems and high costs at the original location.

In 1959, the Oregon State Board of Higher Education was willing to gamble with funds granted to them to establish a new campus on the site that Dr. Purvine had selected, after careful study of the winter conditions (early morning dissipation of ground frost as opposed to earlier afternoon dissipation of frost. Dr. Purvine's knowledge of the area prompted him to determine that the heat that warms the water more than likely rises to the surface through fault zones. He carefully charted every fault or faults known to exist near to the campus. Based on these findings, he directed a drilling crew to a portion of the campus above what he considered to be an old fault and gave orders to begin drilling. The well was drilled to 1205 ft. They found water, but it was a mere 78 F. He moved the crew to the other side of the fault. Again water was found, but this time it measured 176 F. A total of six wells were drilled, three hot and three cold. The campus today consists of eight buildings and is heated with water from just one of the six geothermal wells. The three cool wells measure temperatures of 65, 78, and 92 F. Information on all wells is listed in Table 1.

Well No. 1 is approximately 1205 ft deep, and the water temperature is 78 F. This water is used for irrigation and domestic purposes. It is located at an elevation 4530 ft above sea level and produces 510 gpm.

Well No. 2 is the original hot water well. It produces 107 gpm and is available for emergency purposes. It is 4355 ft above sea level in elevation. The temperature is approximately 191 F.

Well No. 3 is 1150 ft deep and was tested at 175 gpm of 65 F water. It was capped as uneconomical for domestic and irrigation uses. It is located at an elevation of 4352 ft.

Well No. 4 is used for domestic and irrigation purposes. It is situated 4402 ft above sea level. It yields 400 gpm of 92 F water. (Thus, wells No. 1 and No. 4 supply the domestic and irrigation needs of the campus.)

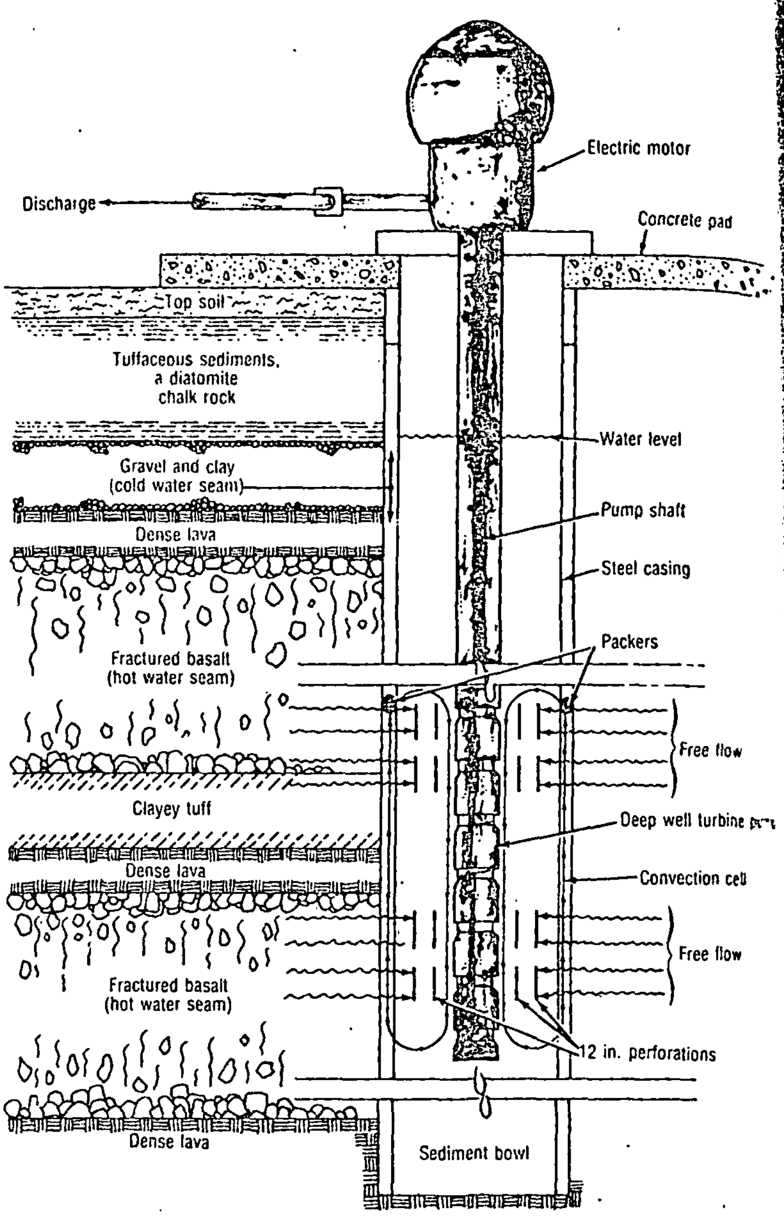
Well No. 5 is one of the two hot water wells used for hot water production. No. 5 is situated at 4374 ft above sea level and produces 442 gpm. The water temperature is approximately 191 F.

Well No. 6 is the second of two wells to be used for heating purposes. It produces 250 gpm of about 191 F water. This is the deepest of the wells with a depth of 1800 ft.

By alternate pumping, it was determined that the three hot water wells have a common underground source. At the highest use level, drawdown of the static water level has been experienced at a minimum of 2 ft and a maximum of 7 ft. This seems to relate to the general groundwater levels in the area. The water appears to be a portion of the normal groundwater since it contains no impurities indicating direct contact with molten rock or water from such magmatic sources. A comparison of the corrosive effects of some hot water wells in the Klamath Falls area determined the water there to be carrying chemical elements corrosive to metals. Due to the comparatively pure characteristics of the Oregon Institute of Technology well water, it is forced through the heating system and discharged at about 120 F and flows via the storm sewer into Klamath Lake. All geothermal water waste is allowed to naturally discharge into Klamath Lake. The discharge is controlled by the city and is based upon a ratio formula of cubic feet of waste of geothermal water allowed versus the square feet of floor space heated.

All geothermal hot water is maintained in a closed system, and corrosion is very minimal. Slight, but apparently increasing, subsidence originating from the geothermal wells is producing cracks in excess of 1000 lineal feet across the campus. Serious consideration is being given to geothermal reinjection to stabilize this condition.

During the first few seasons, considerable expense was incurred while operating the hot water wells.



1 Section of one of the geothermal wells.

Submersible pumps were installed with the bowl located well below static water level. Engineering assumptions had been made that water lubricated bearings would be satisfactory as had been demonstrated in cold water wells. This proved to be an error. The lubricating capability of hot water was so low as to cause frequent bearing failures.

Another problem was associated with the rate of expansion of the pumping components. As the pumps operated, hot water was forced up through the pump column made of pipe with the drive shaft from a surface mounted electric motor located in its center. Variable rate of expansion of the pipe and the shaft produced a requirement of 5.5 in. expansion allowance, both at the motor mounting and in the bowl. Eventually, redesign a installation produced a su operating mechanical sys added lubrication.

From $94,000 to $14,000

Original costs of this ex perimentation came to ab 000 or an average of $10 year for mechanical ren

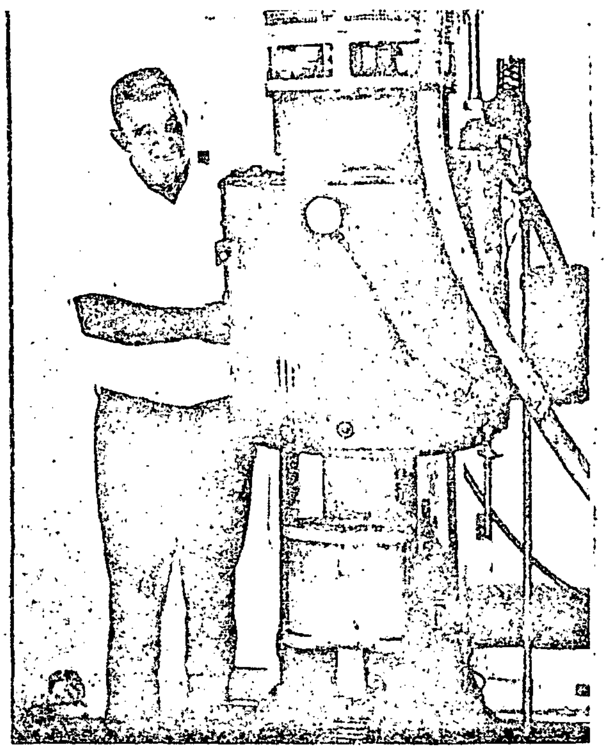
The original campus p extremely high heating co heating of housing and inst buildings amounted to an of $94,000 per year. The f mal heating system at the n pus is now a valuable The costs range from $1 $14,000 per year to hea 440,000 sq ft of building

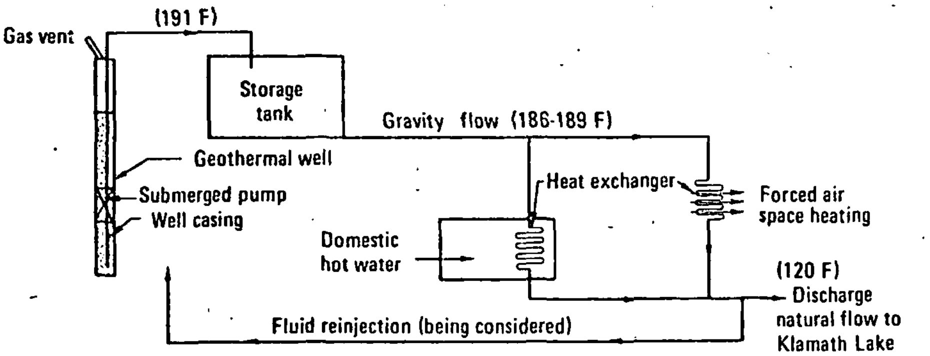
The unique factor of the

the use of standard motors ping equipment without the expensive custom built . I was called upon to series of problems encoun- the initial phase of con- . Lack of proper cooling . shaft stretching, and of pipes were the basic to be overcome. These accomplished by first the pumping equipment to ground level. This permitted of all motors. Secondly, termined that the 550 ft would initially expand as 3 in. in a 3 min period. custom made 5 in. lateral substituted for the normal lateral bowls, the expansion eliminated. Finally, air released corrosive gases caused much corrosion of

the preliminary installations, span of $8000 motors where from 10 min to months. Since the problems been solved, one motor has running continuously for 24 day for the past five years any problems. A motor in with a clutch type that water to be supplied on is used in the installation. system is probably the only type in the United States, water from an 550 ft

original motors had insuffi- ventilation and frequently out. In the beginning, these motors were set down in a and later on, it was found to raise them above and to build housing ventilation and to the equipment from vandal- first, there were some periods during which boiler was required. This been necessary for the past . After numerous altera- original equipment was adequate and serviceable for needs. In a region moderately severe winters are Oregon Institute of has benefited greatly use of natural hot ground heating not only in com- also economically.





2 Schematic of heating system.

Table 1—Summary of data on the six geothermal wells at Oregon Institute of Technology

Data	Well No. 1	Well No. 2	Well No. 3	Well No. 4	Well No. 5	Well No. 6
Depth of well	1205 ft	1288 ft	1150 ft	1224 ft	1716 ft	1800 ft
Static water level	449 ft	332 ft	110 ft	315 ft	358 ft	359 ft
Water level at testing	532 ft	550 ft	355 ft	550 ft	393 ft	540 ft
Temperature of water	78 F	191 F	65 F	92 F	191 F	191 F
Volume of water pumped at testing	510 gpm	107 gpm	175 gpm	400 gpm	442 gpm	250 gpm
Water use	*Domestic,* irrigation	*Domestic* heating	*Domestic,* irrigation	*Domestic,* irrigation	*Domestic* heating	*Domestic* heating
Casing used						
12 in.	—	441 ft 3 in.	—	733 ft	530 ft 3 in.	416 ft 4 in.
10 in.	—	—	—	315 ft 6 in.	814 ft 6 in.	867 ft 6 in.
8 In.	686 ft	803 ft	707 ft 7 in.	207 ft 7 in.	318 ft 6 in.	294 ft 6 in.
6 in.	544 ft 10 in.	515 ft	—	—	648 ft 1 in.	677 ft 8 in.
Cost of well						
Drilling	$10,038.00	$11,082.50	$ 7,418.00	$15,317.75	$20,322.50	$21,466.50
Testing	2,076.00	3,425.00	1,325.00	1,750.00	1,750.00	2,000.00
Casing	4,836.12	7,592.00	3,012.87	5,939.32	9,180 00	8,816.74
Total	$16,950.12	$22,099.50	$11,755.87	$23,007.07	$31,252.50	$32,283.24

eothermal energy rediscovered

A. FIELD, London, England

existence of vast quantities of
ed underground water has re-
ly been verified in France. A
housing development is al-
y drawing some energy from
source, and an intensive study
gram has been launched by the
ch government to find the best
s of exploitation.

1973, the two geothermal
r stations at Larderello and
te Amiata in Italy produced
0 million KWH. The current total
rating power from geothermal
rces in the country is 406 MW,
like France, Italy wants to boost
with new drillings. Professor
giorgi, head of the International
thermal Energy Center in Pisa,
announced a new geological
ey to identify the major heat
ducing zones in Italy.[1] Very
is known about the geothermal
ntial in Italy, and it is generally believed to be very much higher than ever imagined in the past. The uncertainty of the present state of knowledge is illustrated by the recent explosion of a geothermal stream from an area declared sterile by the National Research Council only a few years previously.

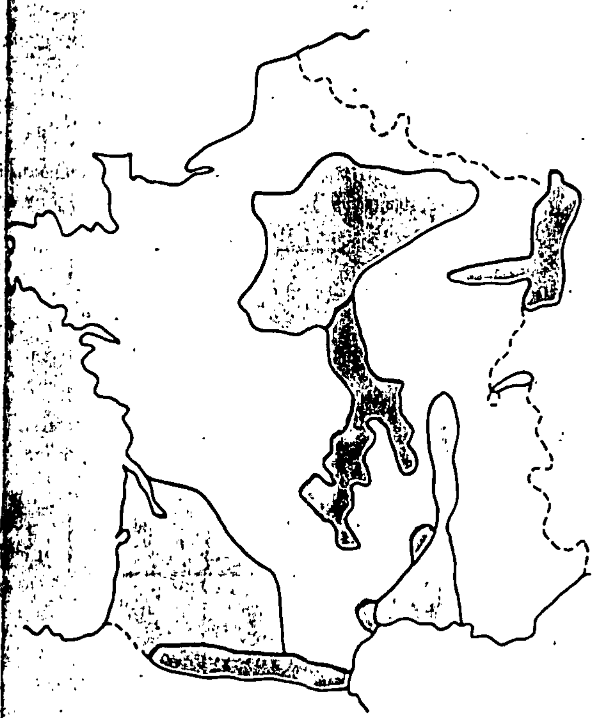
France

Fig. 1 shows the distribution of medium and high temperature deposits revealed by the recent survey by the Bureau de Recherche Geologique et Miniere. Temperatures of 212 F and above are regarded as power sources for turbines, and temperatures below this range can be used for district heating. In addition to these deposits, there are others that as yet have not been delineated but are generally considered to be equally as large with temperatures ranging from 90 to 160 F. In the upper temperature band, water can be used as the primary medium in a heat exchanger, but in the lower temperature range, more sophisticated recovery techniques are necessary—for example, the heat pump, or a combination of counter flow heat exchanger and heat pump.

Geothermal temperature gradients can vary from 0.5 to 5 F per 100 ft. The steeper gradients are associated with volcanic areas. In general, the gradient in France is around 2 F per 100 ft. This means that usable deposits begin at around 3000 ft.

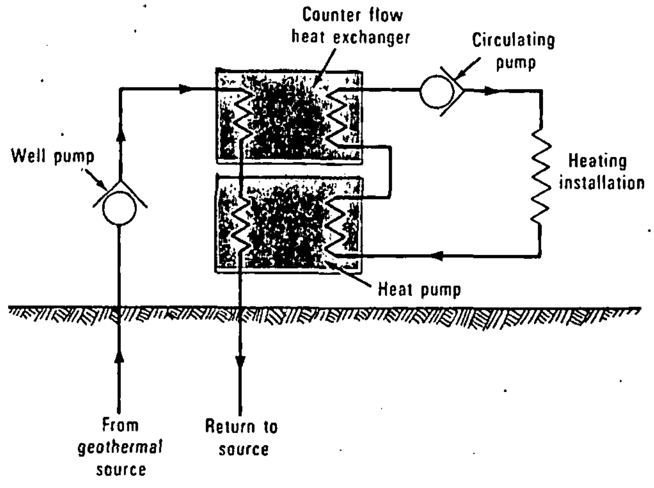
Depending on its temperature, water can be used to drive a steam turbine (212 F plus), act as a primary medium for a heat exchanger (140 to 200 F), or form the source for a heat pump (90 to 110 F). It generally follows in heating applications that the deeper the bore hole, the less complex the hardware needed to utilize the heat; but low temperature water needs a heat pump to raise it to a realistic temperature.

R. Cadiergues, director of the French HVAC research center of CoSTIC, presented some interesting ideas on the combination of



1 Distribution of geothermal resources in France. Water temperature ranges from 160 to 180 F in light areas. Dark areas indicate water temperatures over 212 F.

2 Geothermal water used in a two stage heat recovery technique.



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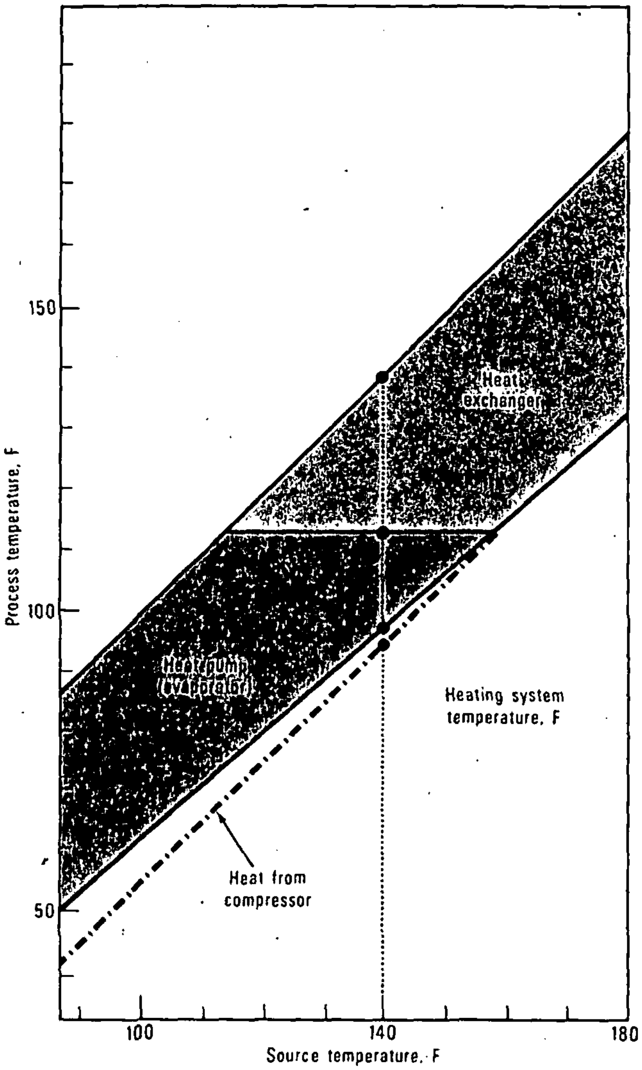
d of article.

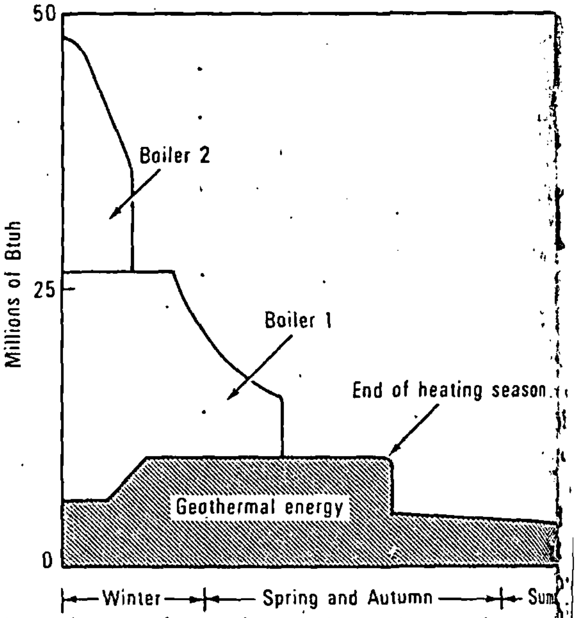
heat exchangers and heat pumps in a paper to the journal *Promoclim A*.[2] By using a counter flow heat exchanger for the first stage of the transfer, it is possible to keep the exchanger to a reasonable size while leaving a moderate second stage entry temperature. For example, water from a well enters the first stage of a heat exchanger at 158 F and leaves at 122 F, producing a 158 F exit temperature from the secondary (heating installation) side (Fig. 2). The water then enters the second stage unit, which in this case is the evaporator or the heat pump, and is cooled to 68 F before finally being reinjected into the underground source. For an expenditure of 1 KW in the heat pump, the amount released in the two stages (for the sake of continuity, this will be expressed in kilowatt units also), would be: heat exchanger, 2.85 KW; and heat pump, 5.15 KW. This represents a total input of 8 KW for only 1 KW expended at the heat pump. Water pumping costs have been omitted since they are fairly small by comparison.

This arrangement obviously makes the best use of the source, but the initial cost may be difficult to justify since at 158 F, the water could be used directly. Heat pumps alone would be the only solution when the source temperature is 110 F or less. In this temperature range, it would be possible to reach a coefficient of performance of about 4 or 5 with a heat pump, pr the heating system was desi work at 120 F—for exampl bedded floor or ceiling pa warm air systems.

By studying economic an nical models of geothermal s the CoSTIC laboratory con that the optimum flow rat the well could be determined in relation to a temperature d 45 F and not the temperatur itself. Fig. 3 is based on t STIC analysis and shows th nical and economic chan points for the three systems exchanger only, heat exchang heat pumps, and heat pump The ratios of energy used i various stages can be derive the intersection points on th cal ordinates from the sourc

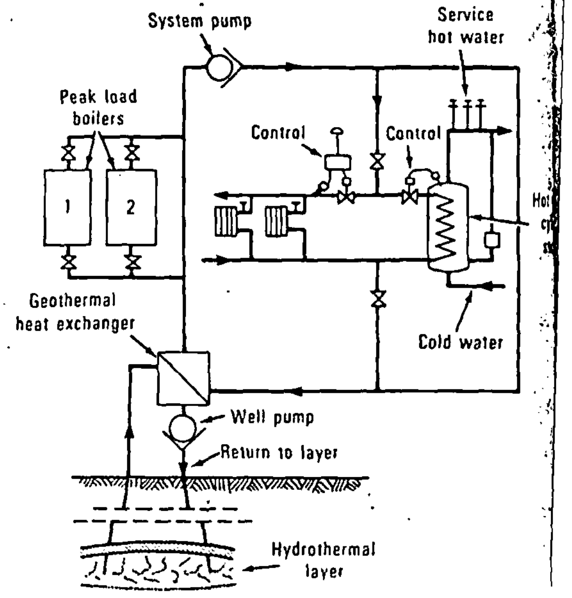


3 Optimization of heat recovery techniques for geothermal sources.



4 Load curves for the installation at Melun, France.

5 Piping hookup at the Melun geothermal installatio



perature. A small proportion is heat from the compressor.

Paris systems

The principal heated water layers in the Paris region are the Albien layer at 86 F, and the Dogger layer at 158 F. The first layer has been used for some time by the water authorities since the water is particularly pure. Further exploitation, however, is limited by law. Water from this layer is still serving as the source for the heat pump installation at the Radio Paris building, commissioned 12 years ago.

While water from the Albien layer must be treated by a heat pump to make it usable, water from the Dogger layer can go straight to a heat exchanger. However, it is much more aggressive since it contains a high proportion of dissolved salts. The Dogger layer is nevertheless the most extensive, covering an area of 2700 sq miles located between 5200 and 6200 ft below the surface.

The Radio Paris building at the time it was built had a total volume of 16 million cu ft, of which 5.3 million required air conditioning, 9 million required heat only, and the remaining 1.7 million cu ft is comprised of underground areas and other spaces. The heat pump installation has an output of 8 million Btuh into a low temperature water circuit that serves heated acoustic ceilings. A 108 F condenser exit temperature gives a gas condensing temperature of 117 F. During the summer, the heat pump is used as a refrigerator for the air conditioning plant.

A cost comparison at the time showed almost the same figures for boiler plant and heat pump systems, including sinking the well (see Table 1).[3]

A running cost comparison ranks the heat pump installation much lower than the traditional boiler plant, even based on oil costs and electricity rates at the time. A further bonus was that the source water was so pure that it could be reused for water services in the building and thus avoid the cost of purchasing water from the city.

More recently, geothermal energy from the Dogger layer has been used to heat part of a 3000
ing development of social
near Paris.[4] In this devel
2000 of the dwellings, wh
mostly apartments, are co
to the scheme. The struct
sulation for the units wa
particularly high at the
construction, which result
load of only 0.05 Btuh p
per deg F. Each apartmen
total floor area of 900 sq
a total cube of 7000 cu ft.
design conditions in this
France and for an average
temperature of 65 F, the h
per apartment is 17,000 Bt

Two wells were sunk at
and each is pumped at a
370 gpm. Each well is co
to heat exchangers, indi
rated at 10 million Btuh. T
thermal input over the yea
under half the total require
heating and hot water servi
remainder is provided by t
load boilers, each rated 22
Btuh. The total investment
$1.75 million.

Heating was charged a
rate of $0.2 per sq ft of flo
and hot water was billed
per 100 gal. Consumers p
four installments. The fir
covered 95 percent of the
rate charge, and the fourt
up the balance and the cos
water service over the year

Analysis of the load cur
sented in Fig. 4 shows tha
year, geothermal energy
for 60 billion Btu. The
heavy oil to generate this
of heat would have been $

Table 1—A comparison of rel
first costs between a tradition
heating system and the geoth
system installed at the Radio
building. The comparison is ba
on 1957 prices.

Item	Relative fir
	Traditional
Boiler plant and chimneys	188,000
Fuel handling and storage	50,000
Refrigeration compressors	250,000
Evaporative coolers	62,000
Well sinking and pumping gear	—
Heat exchangers	—
Standby electric boiler (possible failure of source)	—
Pipework	—
Total:	$550,000

for 2000 tons in May 1974.
The piping hookup for th
thermal system was designe
that the system would alway
dominate at low load and f
permanent base load at all
Water was taken from the w
a rate of 370 gpm, yielding
F drop in the heat exch
Water enters the secondary s
the exchanger at 130 F and
about 11 F. The oil fired b
boost temperature to 185 F
the network. When the h
circuits are closed down in
summer, geothermal heat is
nected directly across the co
the hot water storage cylinde
The system has been in ope
since 1970, and the only
trouble encountered was the f
of the heat exchanger afte
months due to corrosion. The
tery has since been replaced
one in titanium, and the failu
not repeated since.

The future of geothermal ene

R. Cadiergues gave the pot
for geothermal energy as 3
10^{12} KWH per year (based
consideration of radioactive r
in cold and temperate coun
Compared to other hitherto
lected sources of energy, su
wind or solar energy, geoth
energy offers perhaps the gr
reserves, with a steady outpu
affected by climatic conditio
question that is not entirely c
at the moment is the size o
reserves in terms of heat pr
tion, and how they will be
enced by reinjection of water

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4) Guichemerre, A., "Les Eaux
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*Figs. 2 and 3 are based on dia
from Reference 2. Figs. 4 and
based on diagrams from Referen*

INTERNATIONAL FORUM

DISTRICT HEATING IN SWITZERLAND

Road traffic, air-polluting individual oil-fired systems for space heating and hot water supply services account for about 40% of Switzerland's total energy consumption and represent a corresponding hazard to the environment. The author has developed a general model concept which shows how, in years to come, oil-fired heating can be replaced by a method of heating which is less injurious to the environment. In residential and recreation areas the supply undertakings will resort to the only clean forms of energy—electricity and hot water.

R. HOHL

Switzerland can be divided into two distinct areas: The 40 or more urban concentrations of at least 20,000 to 30,000 inhabitants each, which by the year 2000 will house about 60-65% of the population; and the sparsely populated areas, including villages and mountainous areas, which will account for the remaining 35-40%. Urban areas will be provided with district heating plants, beginning with plants to heat definite sections of a town, until at least 90% of all buildings are heated. The heat will be carried by hot water at 70-120 C, depending on the time of year and the ambient temperature. Apart from the well-known advantages of district heating, hot water can be produced by any kind of fuel, especially that which will be most appropriate during the period under consideration, not only as regards the political aspects affecting supply, but also from an environmental viewpoint.

In addition to fuel oils, and probably nuclear energy in the future, district heating plants can be fired by natural gas, the cleanest form of fossil fuel. But since the world's reserves of natural gas are by no means plentiful, it would not be economical for Switzerland to extend costly distribution networks to every single household. The capital thus saved can be invested in developing hot-water supply systems, because they will continue to be useful *ad infinitum*, regardless of the source of energy used. Perhaps it will eventually be possible to resort to coal again, the world's reserves of which are known to be one order of magnitude greater than all other fossil fuels put together.

SPACE HEATING

One or more district heating plant will be installed in every urban concentration, each plant containing a boiler and back-pressure turboset, or a gas turbine in the smaller plants. All waste heat will be transferred to the heating system. Since it does not involve such heavy capital investment, this type of power plant is more appropriate in relation to the low utilization of space heating over the year. The load imposed on the environment by exhaust gas is only a small fraction of the corresponding load due to individual firing systems, because the firing is always optimally controlled, effective flue-gas cleansing systems are incorporated and very high stacks ensure that the gases are well diluted. Extraction-condensing turbines, though more flexible, are less likely to be installed because they are accompanied by *all* the problems of dissipation of waste heat, such as temperature rise of lakes and rivers, the problem of cooling towers with the associated location problems and the thermal load imposed on the environment (low efficiency).

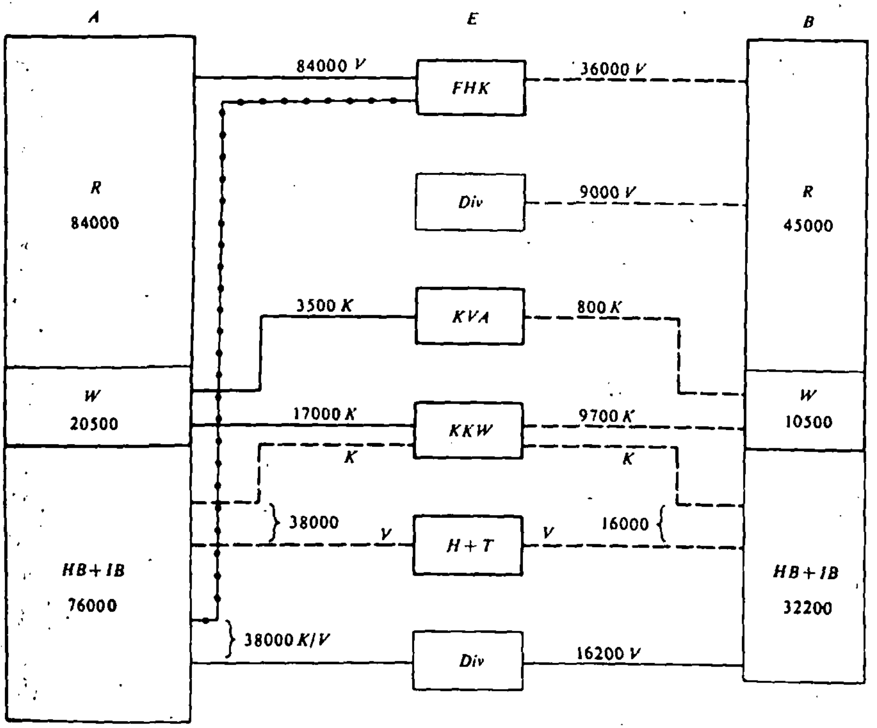
In a back-pressure district heating plant the demand for heat and the output of electricity are strictly proportional to one another, on an annual or an hourly basis, which explains why the generated power does not fit into the load diagram of the general electricity supply system. But by combining t
generation of power and heat on a lar
scale, far more electricity than is real
needed would be produced on co
days. In order to benefit from the e
cellent overall efficiency in spite of th
the discrepancy is overcome in the pr
posed model by utilizing the electric
generated in the district heating pla
for direct electric space heating in ot
areas. This would dispense with the
dividual oil-fired heating systems t
prevail there. When the ultimate ph
of the concept is attained, a state
equilibrium can be visualized in wh
an almost negligible fraction of the h
required (5-10%) would have to
supplied by individual systems (elec.
cal storage heating at night, h
pumps, oil and wood-fired systems, a
the like).

PROVISION OF HOT WATER

Present-day nuclear generating pla
—since they involve very heavy cap
investment—are unlikely to prove su
able for the supply of energy to us
having a poor annual utilization fac
like space heating. This obstacle ho
ever, does not apply to hot water, t
demand for which remains practica
constant throughout the year. It
counts for about 20% of the over
heat energy demand and therefore,
the model for the urban cities is sho
as being provided by the intermedi
nuclear plants of the public electric
supply system. It would be quite su
cient if every second plant of the
1000 MWe nuclear plants which
be expected to be erected by the y
2000 were to feed, on the avera
about one third of its waste heat
about 120° C into the urban dist
heating systems. The loss in electri
output of such a nuclear plant wo
only amount to about 12%, but
load imposed on the environment
heat would be 33% less.

As a result of the very cheap

R. Hohl is with Brown, Boveri & Co. (BBC) Baden, Switzerland.



K = Relatively constant load
V = Widely variable load
A = Urban centre (over 20,000 to 30,000 inhabitants), total 5 million inhabitants = 62.5% of population
B = Remaining residential areas = 3 million people = 37.5% of total population
R = Space heating } including places of employment
W = Hot water services } including places of employment
HB = Domestic sector } excluding R and W
IB = Industrial sector } excluding R and W
E = Suppliers of delivered energy (total 268,200 Tcal/a of which 160,000 Tcal/a for R and W)
FHK = Combined heat and power stations at edge of urban centers. Primary energy: Natural gas, fuel oil, nuclear energy
KKW = Nuclear power stations between urban centers
KVA = Refuse incineration plants at edge of urban centers
H + T = Hydroelectric and thermal, fossil-fueled power stations
Div. = Other energy supplies
———— High-temperature hot water in district heating networks (max. 120 C)
— — — Electricity
———— Industrial process heat from natural gas, fuel oil, coal, nuclear energy
—•—•— Industrial process heat from combined heat and power stations
— — — Individual space heating (electric storage heaters, heat pumps, fuel oil, coal, wood)

Fig. 7—Model of energy supplies in Switzerland in the year 2000. Main emphasis on space heating and hot water services. Account taken of power, light and industrial process heat, but not of transport, storage pumps and losses. Figures in Tcal/a of secondary (delivered) energy.

clear fuel, the break-even price for the extracted heat when operating year-round is so low (5-10 Fr/Gcal, compared with 15 Fr/Gcal (1972) for light fuel oil with an efficiency of 100%) that the cost of transporting the heat in the form of hot water over a distance of 20 to 30 km is quite tolerable.

The municipal rubbish incineration plants would have to be equipped with back-pressure turbosets, the waste heat of which would also be fed into the district heating networks.

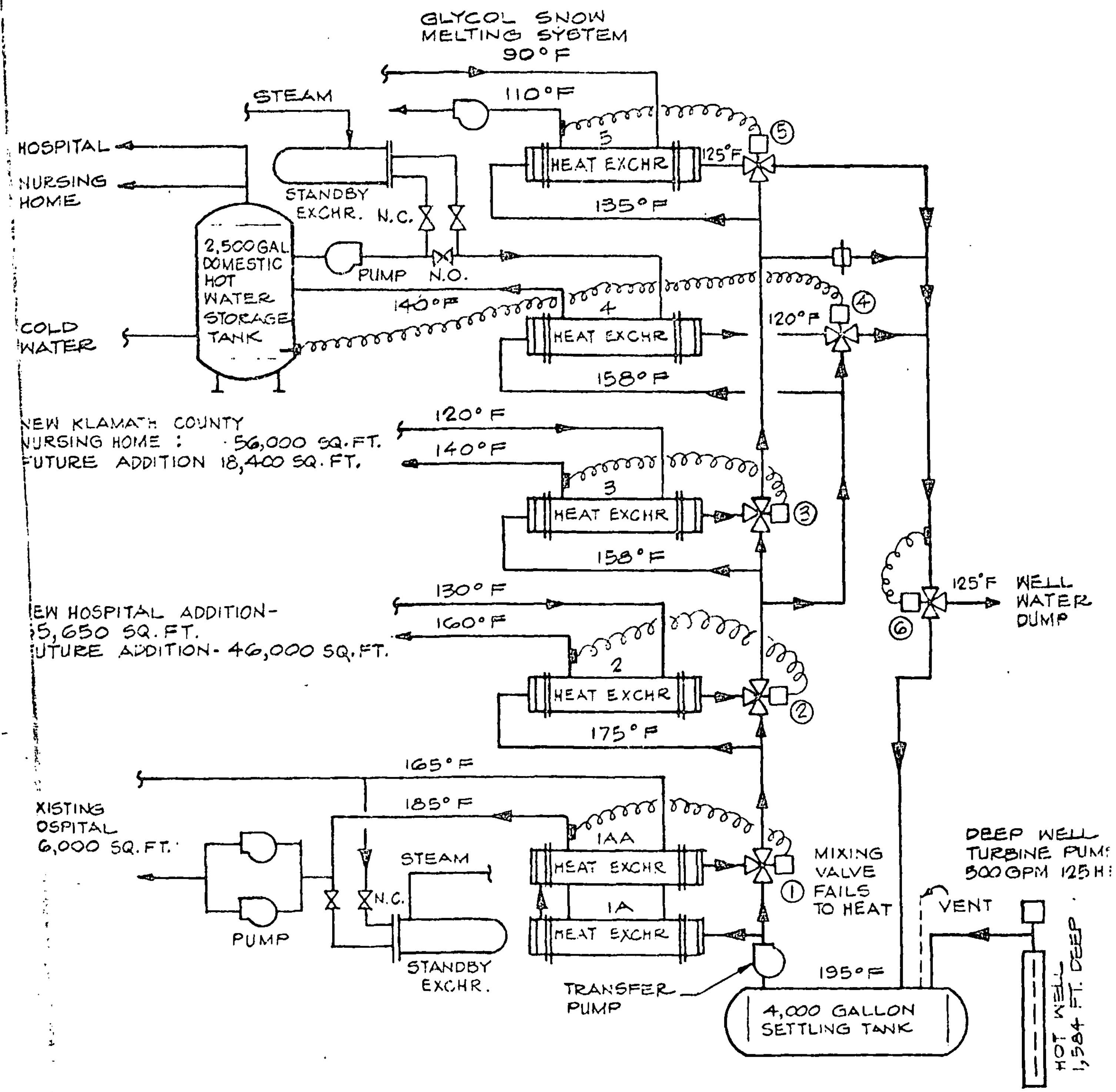
In the other populated areas, which are heated with electricity, the hot water required for day-by-day consumption would be produced with the surplus electricity generated by hydro and nuclear power plants at night, a common practice even today.

CONSEQUENCES

It will cost a lot of money to realize the model: Heat distribution networks, district heating plants, upgrading the electricity distribution systems in the second area, and so on, although investment can be spread over 30-40 years. But today a healthy environment is no longer free for all. In the long run the recommended approach will probably prove cheaper than trying to make good the damage done by polluting the atmosphere. It is our duty to impart future generations with a concept which will create a better environment. As has been shown, we can already make a start in the heating sector.

The model prescribes what form of energy the user shall employ, according to where he is situated, so that finally it will be necessary to charge the same price per unit of heat everywhere, whether it comes in the form of hot water, electricity or a fossil fuel. In the initial stage a contribution could be made by those consumers who still provide their own heating, thus helping to finance the construction of the district heating plants and the extension of the electricity distribution networks.

Before this concept can be realized, it will be essential for cantonal and local government bodies, electric, oil and gas companies, as well as private undertakings and building contractors to collaborate on all levels. □□



NOTE: STANDBY PUMPS AND STANDBY STEAM HEAT EXCHANGER WERE ALSO PROVIDED FOR THE NURSING HOME AND NEW HOSPITAL WING.

GEOTHERMAL HEATING

PRESBYTERIAN INTERCOMMUNITY HOSPITAL

BALZHISER & COLVIN ENGINEERING
EUGENE, OREGON
DATE : 1976

hospital. Pertinent facts are listed below:

Well Depth	1,584 feet
Water Temperature	195°F.
Maximum Water Flow	500 GPM
Pump	100 HP deep well turbine pump

Water is pumped from a depth of 450 feet to a 4,000 gallon settling tank which is vented to the atmosphere.

From the settling tank, water is pumped through several heat exchangers in the Mechanical Room by a transfer pump.

The heat exchangers are of the shell and tube type. They are used because the well water, while relatively clean, contains too many impurities to be pumped directly into the hot water heating system.

Fouling in the heat exchanger tubes can be controlled by periodic cleaning.

From the heat exchangers system water is pumped to the terminal units, where it is used for space heating, domestic hot water, and a glycol snow melting system.

The following description of system operation refers to the attached schematic.

1. Well to Settling Tank

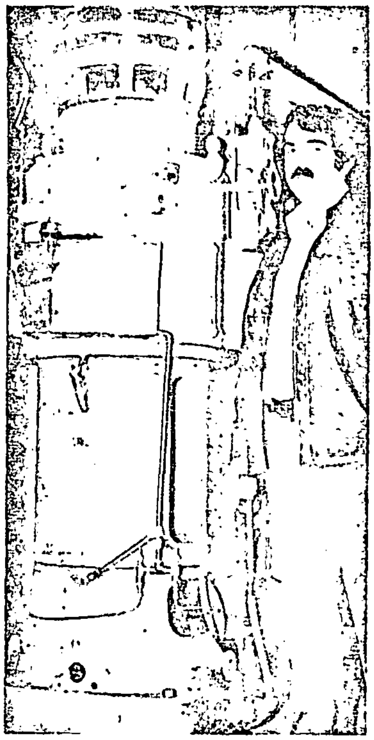
The well pump supplies water to the settling tank. A constant water level is maintained in the tank by varying the output of the well pump to match the amount of water drawn from the tank. To accomplish this, a water level controller sends a signal to a fluid drive clutch on the well pump, which in turn governs the performance of the pump.

2. Settling Tank Heat Exchanger Loop

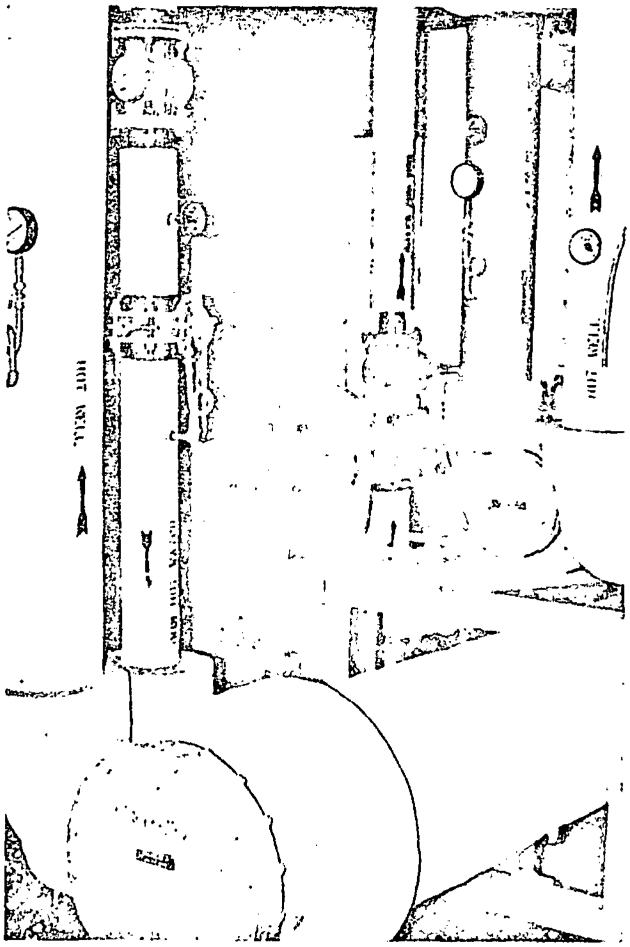
A 20 HP transfer pump, pumps well water from the settling tank through the heat exchangers. Energy is extracted from the water and its temperature drops. If the water temperature drops below 125°F. it is dumped into the storm sewer by mixing valve #6. Above 125°F., the water is returned to the settling tank. As can be seen, the hot well pump will always replenish the settling tank with an amount of water equal to that being wasted.

3. Heat Exchanger Operation

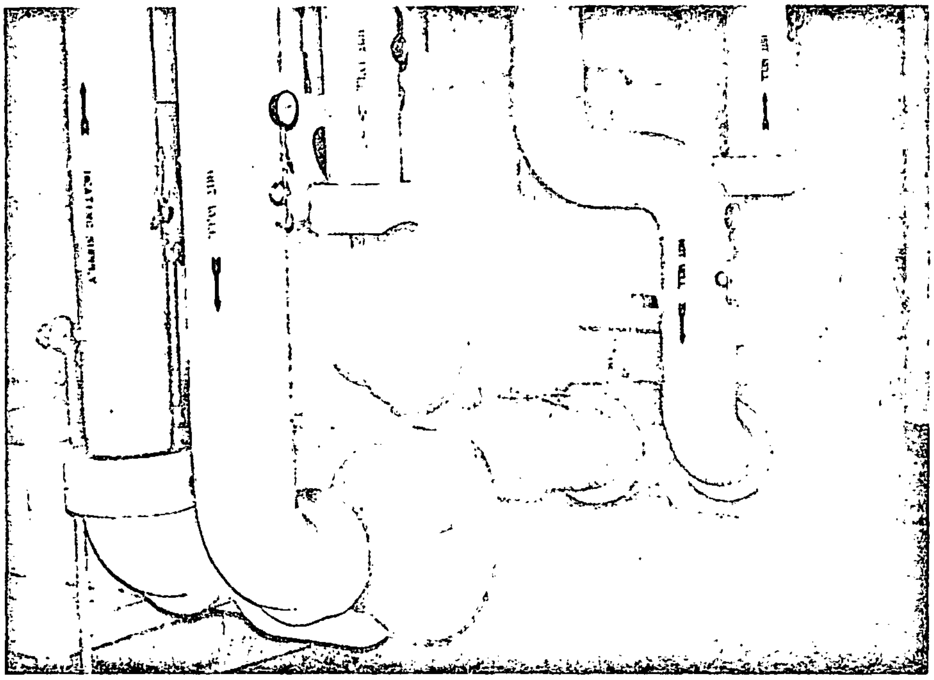
a) Heat Exchangers 1A, 1AA, 2A and 3A and Automatic Mixing Valves #1, #2 and #3 divert water through or around their respective heat exchangers, depending on the leaving system water temperature. If the building heating demand increases, more well water is routed through the heat exchanger. As the heating demand becomes satisfied well water is by-passed around the heat exchangers.



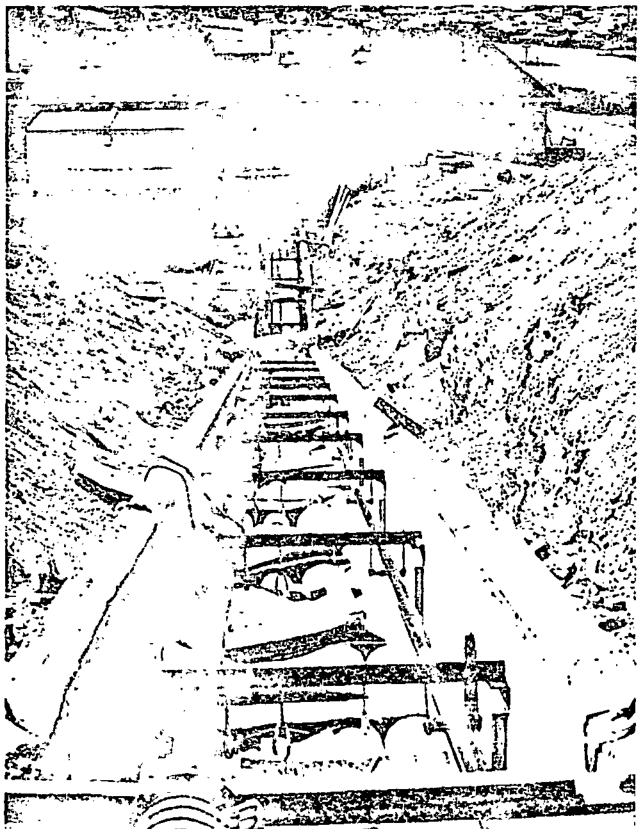
This pump unit is 10' high with 100 HP motor. It has a Nelson drive unit below the motor.



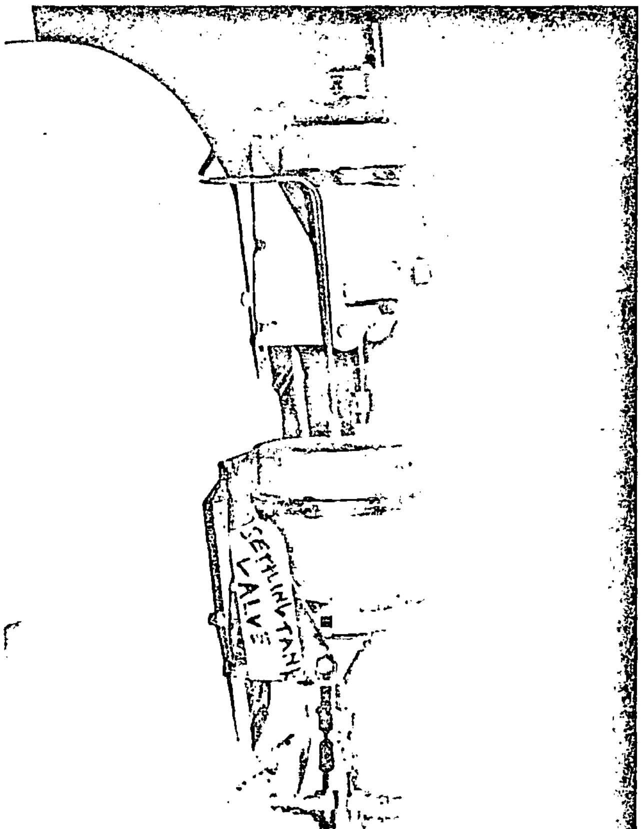
Heat exchangers #4 and #5 as shown on line drawing.



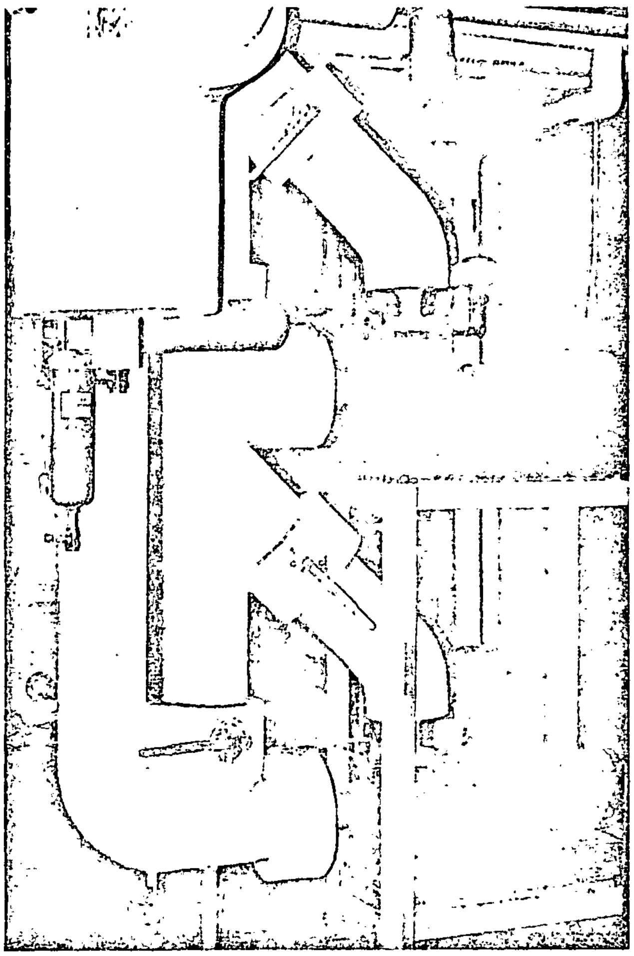
Heat Exchanger #1A & 1AA, 2 & 3 as shown on line drawing.



Pipe trench to K.C. Nursing Home.



Bypass to drain or return to tank. Pneumatic Diverter Valve. Valve #6 on line drawing.



Heating water building's supply pumps.

The mixing valves are reset by outdoor air temperature. When the outdoor air temperature is mild, the required leaving system water temperature is lowered, as less heat is required to sustain space temperatures. On very cold days, the maximum temperature is maintained (185°F. leaving water temperature for exchangers 1A, 1AA).

b) Heat Exchanger #4: This exchanger supplies heat for the domestic hot water storage tank. Automatic Mixing Valve #4 modulates well water to maintain 140°F. in the storage tank.

C) Heat Exchanger #5: A glycol snow melting system was added to remove snow from the sidewalks and roadway at the entrance to the hospital emergency care area.

Automatic valve #5 is controlled by a sensor in the leaving water supply pipe and is set to maintain 100°F. supply temperature.

Heat Exchangers 1A, 1AA, 2A, 3A and 4 are duplicated by steam heat exchangers to provide the hospital and nursing home with 100% standby. The steam heat exchangers are supplied by the existing steam boilers.

4. Building Heating System

From the heat exchangers the heating water is pumped to a standard hot water heating system which incorporates fan coil units, reheat systems and unit heaters.

When the entire project is completed an average annual savings of $104,300.00 is predicted. The cost of the geothermal changeover, including the new mechanical system building was $320,000.00. The result is a very attractive payback period.

The conversion of this system to geothermal has been a resounding success, and should serve as a fine example for the feasibility of similar projects where geothermal heat is available.

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[1] Peterson, Norman V. and Edward A. Groh, "Geothermal Potential of the Klamath Falls Area, Oregon—A Preliminary Study," *The Ore Bin Vol. 29, No. 11,* State of Oregon, Department of Geology and Mineral Industries, Portland, Oregon, November, 1967.

[2] Peterson, Norman V. and James R. McIntyre, "The Reconnaissance Geology and Mineral Resources of Eastern Klamath County and Western Lake County, Oregon," *Bulletin 66,* State of Oregon Department of Geology and Mineral Industries, Portland, Oregon, 1970.

Solar-Energy Conclave Set for Palm Springs

What are the latest developments in alternate energy technology? This and other questions will be the subject of the first international solar-energy conference and exhibit in Palm Springs April 30 to May 4.

The five-day event named the Helioscience Institute is expected to bring together nearly 1,000 prominent energy scientists, educators and technologists from throughout the world, as well as government officials involved in the development of energy policy and the application of alternate energy sources.

The original concept of the institute was developed by the Palm Springs Solar Energy Development Institute, a non-profit foundation established by the city's Chamber of Commerce to promote research, development and application of solar-related energy.

Jointly assisting SEDI with this project are the Pollution Control Research Institute, the Southern California Solar Energy Association and Northrop University, which is serving as a coordinating sponsor.

"The Coachella Valley is one of the prime locations in the world to develop alternate energy sources, using solar, geothermal and wind energy," said SEDI president Walter Hutchinson.

"We feel the Helioscience Institute will contribute invaluable assistance in helping to solve the world-wide energy crisis."

The institute will include a three-day technical conference and a four-day public exhibit.

The conference will consist of a series of workshops, panel discussions and the presentation of significant technical papers conducted by an international group of energy experts.

Objective of the conference will be the production of a "White Paper" assessing the existing and near-term alternate energy technologies for use by federal, state and local governments in the formulation of a national energy policy.

Ed. Note: The Geothermal Energy Magazine will exhibit at this conference, as well as others in May and Geothermal materials and publications will be available. Public interest has been increasing in geothermal but it is not yet a household word as is "solar."

GEOTHERMAL PLAN FOR MAMMOTH LAKES UNVEILED

Los Angeles Herald Examiner, Feb. 24, 1977— Residents of the popular Central California ski resort community of Mammoth Lakes Village may be heating their homes and businesses with geothermal energy by 1980.

The Ben Holt Co., a Pasadena engineering and construction firm, has undertaken a 12-month technical, economic and environmental study of the geothermal concept under a $120,755 contract with the federal Energy Research and Development Administration.

In addition to the study, the firm will design a space and water heating system that will draw hot water from Casa Diablo Hot Springs several miles from the village said Ben Holt, the firm's president.

The water would be stored in tanks and on demand would supply heat and hot water to residential, commercial and governmental buildings now operating on electricity by the Southern California Edison Co.

"SCE will assist us in the study. It is interested in seeing the feasibility of converting from electricity to geothermal energy," Holt said.

Mammoth has a total energy need for 50 megawatts of electricity, but can only generate 10 to 15 megawatts. The remainder must be imported from the Los Angeles area at great expense, he noted.

"The Mammoth area spends $2½ million a year on heating. We think we can do a lot better than that with geothermal heating," explained W. Craig Racine, senior project engineer at Holt.

Preliminary estimates indicate the Mammoth geothermal heating system could be saving 50,000 barrels of oil a year by 1980 and up to 120,000 barrels annually by 1990, he said.

Douglas B. Campbell, Southwest District director for ERDA, said the Mammoth project is one of several such projects aimed at developing immediate energy sources to reduce the demand on shrinking oil supplies.

"California is blessed with an abundance of geothermal energy. There is probably enough geothermal energy in the Imperial Valley to power the entire Los Angeles area," he said.

BOG HOT SPRINGS, NEVADA

THE GEOTHERMAL CYCLE

CONCHEETA MILLER

Nestled below the snow-capped Pueblo Mountains, at an altitude of 4,280 feet, lie the vast high desert valleys of northern Nevada, alive with stark beauty, unmatched anywhere else on this earth. The purest air is combined with untouched silence, except perhaps, the scream of a Golden Eagle after its prey or the haunting call of the wild Canadian Geese. Here, too, are the steaming boiling hot springs, eons old, forever the same.

This land is where the Piutes dwelled, clad in nothing but their braided rabbit fur robes. Their whole existence depended upon roots and the pounded sunflower seeds, the hunting of antelope and the driving of jack rabbits into their nets made from softened desert plants. Their feet were protected by sandals woven from coarse sage brush. Here they camped and lived and died, by these same steaming springs. And now, in modern times, we too exist and enjoy the comforts of these bubbling eternal cauldrons.

In the center of one of these valleys is Bog Hot Springs Ranch, owned by the C2 Cattle Company. It is the second largest ranch owned by them in Nevada. All Nevada ranches are managed by Mr. Buster Dufurrena.

My husband, Jack, operates Bog Hot and knows by memory the meandering miles of ditch systems that make up the irrigation patterns. Bog Hot Springs itself is the one main source for watering a three mile long by a quarter of a mile wide pasture. From one cutting of hay we average 320 tons of baled hay for our winter feeding. This usually consists of 350 to 400 head of cattle.

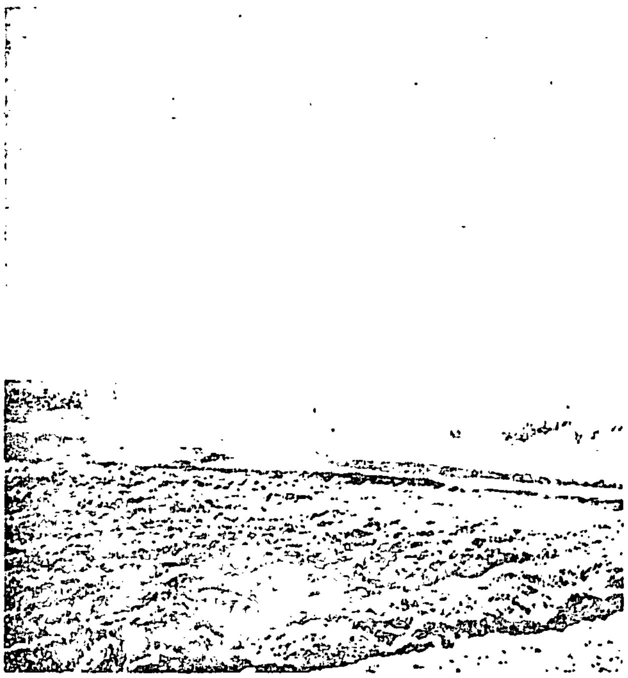
There are many estimates of Bog Hot Springs flow; everything from 500 to 3,500 gpm. That is a big variance to be sure, but asking for the latest flow, the new estimates are 2,500 gpm. Most experts agree on that amount. The temperature at the source in the winter months are 125 degrees F. cooling to 98 degrees F. at our bathing area a quarter of a mile below the springs. Bog Hot Springs can fill our holding lake in three weeks.

Once the lake has been filled to capacity in the early spring, the land is then flooded acre by acre to the end of the pasture. This process takes twenty-eight days. The water gates are then turned off and the lake is filled again.

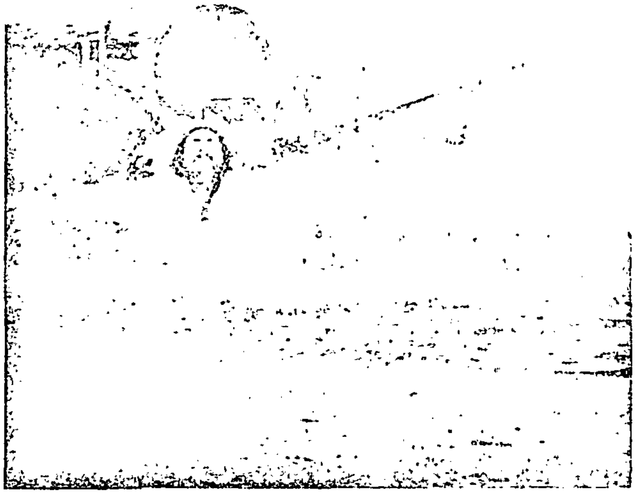
In July the water is turned off completely to let the fields dry and ready the wild grass for the hay crew. Once the fields are cut, baled and stacked, the water is turned on again to grow another full crop. This time, however, the grass is not baled but saved for the fall feeding when the cattle have been rounded up from the high hills and brought in to the fenced pasture area.

The cattle feed on this grass until hard frosts kill the pasture grass or snow covers the feed completely. This is the time for hard work, as each bale has to be loaded by hand onto the hay wagon. My husband does this heavy work, of course, while I drive the truck or tractor into the fields, pulling the wagon behind me. Jack cuts the bales free while the cattle run happily along beside us.

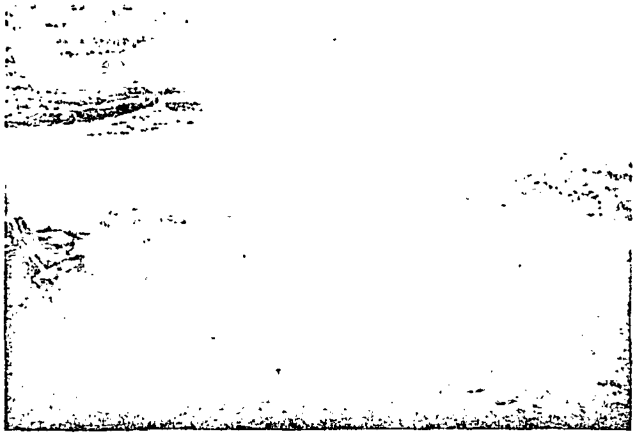
In February most of the calves are born. Sometimes the younger cows have trouble calving and then we have to help, but usually nature takes her course, and we greet newborn healthy calves everyday.



The source of Bog Hot Springs in mid-winter with our ever-faithful Willy's jeep.



Jack enjoying the waterfall at the pool.
—Photo by C. Miller



The source of Bog Hot Springs.

Often it is icy cold or snowy, but no matter what the elements are, the cows have to be fed every single day. They are completely dependent upon the dried bales of hay.

Finally spring arrives and with it branding, dehorning and castrating. After that the cows and calves are happily set free and head for the hills. Once more they feed on the virgin grasses of the Pueblos. The holding lake is full by this time, thus the Bog Hot Springs cycle beings once more.

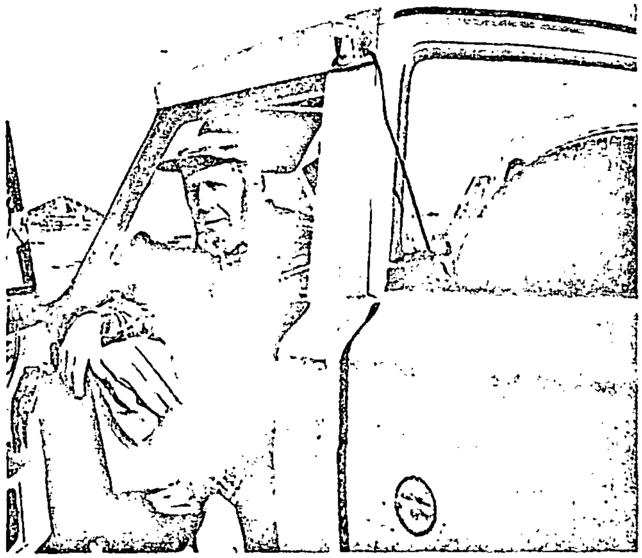
One of the greatest pleasures of our hot springs is the bathing area. My husband and I use it winter and summer. We do, however, try to pick a sunny day. We have actually been in the water when the outside temperature was 22 degrees above zero. You learn to wash your hair last on those days as it freezes the minute you come out of the water. We bathe, jump into our robes and run for the jeep. The ride back to the ranch is less than a mile. That's when we catch our breath and realize how super clean only a hot springs bath can give us. Total freshment!

About seven miles, and to the east from Bog Hot Ranch, is Continental Lake. It is listed on every map as a dry lake, but in the four and a half years we have lived here, it has been full most of the year. When full, it reflects the surrounding mountains in a crystal clear panorama. On the edge of this lake is another fascinating hot springs. I interviewed the previous owner, Mr. Henry Houck, to gain the following information:

The Balzor Hot Springs, now owned by the Warm Springs Development Company of Reno, Nevada, was first developed by a Mr. Balzor, but no one in the area could remember his first name. People did remember, however, that he built several cabins there in 1912. Friends came for miles around to enjoy his family's hospitality and sample the spring water after it cooled. There are three separate springs in the immediate area. One is very close to a house on the property, about thirty feet from the front door, in fact.

The temperature of this small spring is 185 degrees F. on the surface and 212 degrees F. further down. It is boiling at both of the other locations in a nearby pasture. When Henry lived there, he used geothermal energy to heat the house from the smallest and closest spring. This was by use of a vacuum process. Henry said, "You had to stay there and tend it, but it did work and quite well." He also had a metal basket set up outside for cooking his meals and said it worked like a slow cooker. Everything was perfectly done if timed correctly.

The author, through the steam at 22° above zero. Water temperature 98°, Bog Hot Springs Pool.
—Photo by Jack Miller



Mr. Henry Houck, former owner of Balzor Hot Springs.
—Photo by C. Miller

It was another story at the main spring. A tall tale from this area goes like this: A man was coming through the country by team and wagon. He had decided to camp the night at the hot springs, so before he unhitched his team he put a whole smoked ham in the water to cook for supper. He unhitched, washed up and when he came back to check his ham, there was nothing left but the bone and the twine he had tied it to a stake with.

Henry also told me that the water is quite potable with a trace of borax and soda. Many tourists still stop by to take home a gallon or two. These hot springs are always unique in the timeless feeling they give you as you peer into their bubbling depths; the strange hollow sounds you hear as you walk near the source to the constant moving of the earth, not discernible but constant through the ages.

At Balzor Hot Springs is one of the strangest mysteries of all. Every year on September 11th, one of the springs ceases to flow. Henry said, "I know it sounds impossible, but I can prove it!"

The next day it always bubbles merrily away and continues to do so the rest of the year at 1 cubic foot per second. Sometimes it stops a few days earlier but almost always on September 11th.

My husband and I are going to watch it next year.

Such are the mysteries of these ancient hot springs. They hold me fascinated with all their internal energy and all their many limitless uses for the future.

NATIONAL GEOGRAPHIC WILL FEATURE GEOTHERMAL ARTICLE JUNE, 1977

Kenneth Weaver, associate editor of the National Geographic, has been working for a year on an extensive article dealing with geothermal energy. Originally planned for publication in May 1977, it has now been scheduled for the June 1977 issue. The article will deal with the latest developments in geothermal on a worldwide basis, and will be of great interest to educators, industry, and the general public.

If you are not a subscriber to National Geographic, you are missing out on the best magazine this country has to offer. Start your subscription now. Write to Kenneth Weaver, National Geographic Magazine, 17th & M Street, Washington, D.C. 20036. Enclose $10.00 for a 1 year subscription.

The Environmental Bi-Weekly
High Country News
Vol. 9 No. 5
Friday, March 11, 1977
Lander, Wyoming

Boise rediscovers geothermal

by Bruce Hamilton

Using geothermal energy to warm your home and heat your water may sound like a far-fetched idea, but many of the residents of Warm Springs Avenue in Boise, Idaho, are sold on it. They know using naturally-occurring hot water is a cheap, renewable, practical energy source because it's been used in their neighborhood for over 85 years.

Boise's geothermally-heated homes look the same as homes in other parts of the city heated with gas or electricity. Radiators in each room provide even, reliable heat. The only detectable difference is a slight sulfur odor when you first enter a geothermally-heated home. The other difference is heating bills. Residents on the geothermal line pay less than one-half as much as Boise residents who heat with natural gas. And geothermal rates are more likely to remain relatively low.

'RIGHT FROM HADES'

Indians were the first to use Idaho's geothermal resources for bathing and cooking. Later, when white settlers traversed Idaho on the Oregon Trail, they stopped to cook meals in hot springs about halfway between Snake River Crossing (near Glenns Ferry) and Boise.

As Boise developed, two rival companies fought for control of the municipal water business. One, Boise Water Works, decided to go into the hot water business as well to gain an edge on their competition. In December 1890 the company drilled a well that produced hot water with enough sulfur that the whole supply was identified as coming "right from Hades."

Later, the company ran a wooden pipe full of 178 degree water from the well field to Warm Springs Avenue residences and businesses. The wooden pipe didn't last long, and was soon replaced by a metal one. An 1892 issue of the **Idaho Daily Statesman** reported: "In time, this hot water will come into general use. All houses will be heated by it, and the heating will be done without care or annoyance on the part of the occupants, while the savings in expense will be enormous."

The system did expand, and at its peak it served about 400 residential and commercial customers, including the original Boise City Hall and Boise's famous Natatorium. However, when cheap natural gas was introduced to Boise in the early 1950s, geothermal use declined. In 1972 Boise Water Company had fewer than 200 geothermal customers and planned to cap off the wells and discontinue hot water service.

The company's decision to cap the wells could have ended Boise's geothermal era, but residents on the line organized to save the system. In 1974 local residents set up the Boise Warm Springs Water District (BWSWD) and acquired the geothermal assets from Boise Water Company.

"We could see fossil fuel energy costs were rising, and we liked being on geothermal heat so we decided to band together and save the system," says BWSWD President Joe Hansen.

EXPANSION PLANS

Hansen says his organization is ready to extend its service to other customers whenever the market develops. One new customer has already signed up for service — the state of Idaho.

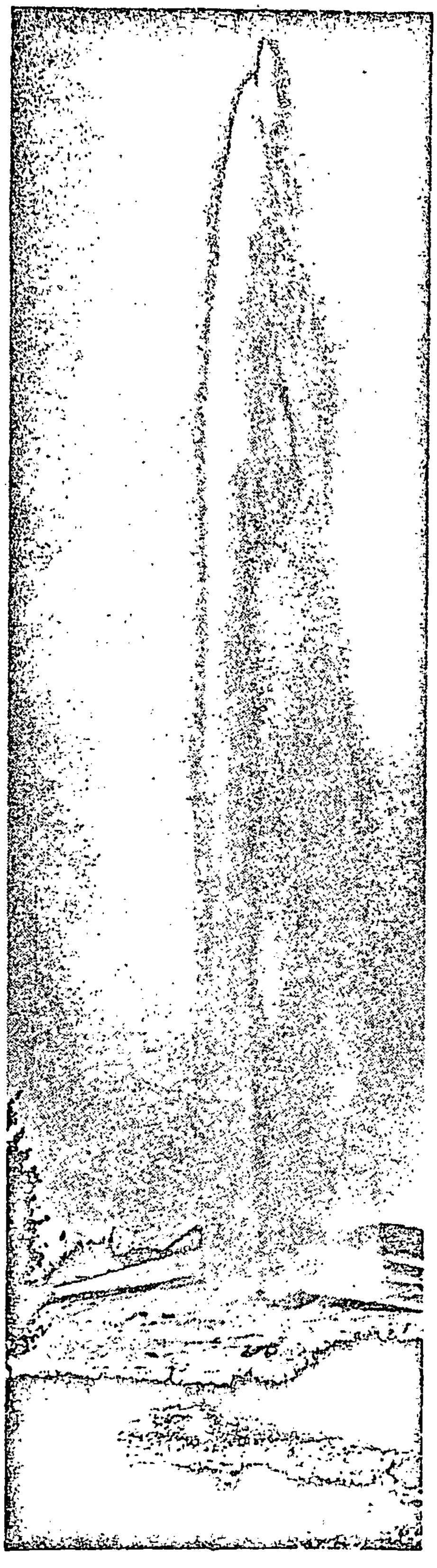
With a $355,000 grant from the Pacific Northwest Regional Commission, the state plans to convert three state buildings near the BWSWD wells to geothermal heat. The buildings contain offices and labs for the state departments of Health and Welfare and Agriculture. Solar and wind energy systems are also being studied to complement the buildings' new geothermal system.

"Estimates indicate the geothermal water will heat the building complex at one-half the cost of the current gas-fired steam heat system," says Ralph Comstock of the Idaho State Office of Energy.

Comstock says converting the three state buildings to geothermal is only the "first stage of what may become the largest geothermal space and water heating project in the Western Hemisphere."

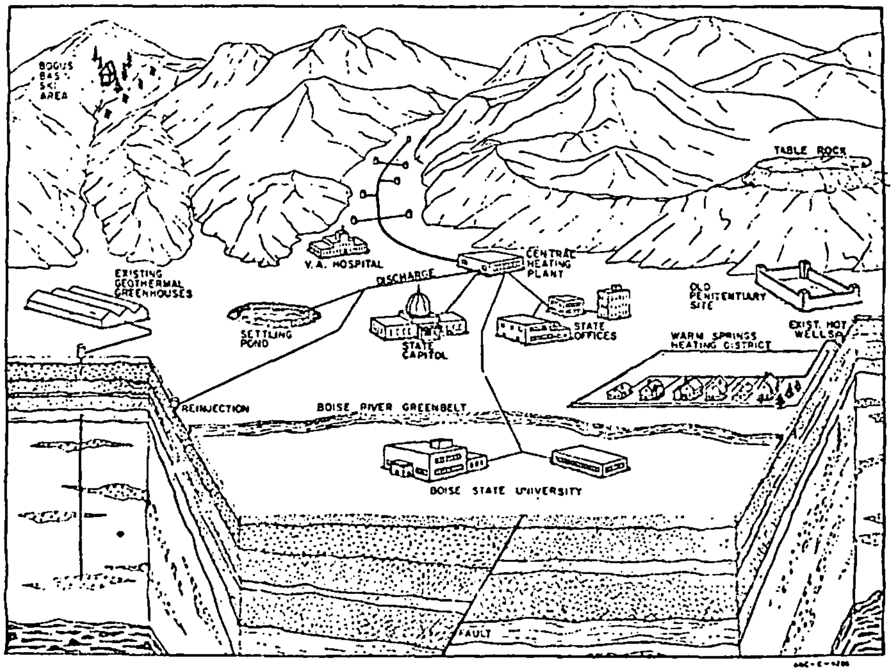
The Idaho National Engineering Laboratory (INEL) prepared a report last year on an expanded Boise Space Heating Project. The report stated that for $5 million, 38 large buildings or the equivalent of 4,000 average homes could be served with geothermal energy from another geothermal well field near the city. The study recommended heating buildings at the state capitol complex, the Veterans' Administration grounds, and Boise State University.

"INEL has concluded that no major resource or engineering difficulties exist that would prevent this project from being completed successfully with a significant long term savings in both scarce fossil fuels and total heating costs to the state," the report stated.



NATURAL HOT SPRINGS are found all over Southern Idaho. In Boise, hot springs are used for space heating and hot water. Photo of springs at Soda Springs, Idaho, by the Idaho Department of Commerce and Development.

WARM SPRINGS AVENUE. Most of the older homes along Warm Springs Avenue in Boise are heated with geothermal water. Some of the oldest homes have been on the system since the 1890s.



BOISE SPACE HEATING PROJECT. At right, the existing geothermal wells by the old penitentiary. These wells serve residences in the Warm Springs Avenue area and will heat three state laboratories. In the middle, the Idaho National Engineering Laboratory has proposed developing a new well field to heat the Veterans Administration grounds, the Capitol Mall area, and buildings at Boise State University.

EYES ON BOISE

Dr. Kenneth Hollenbaugh, head of the geology department at Boise State University, says the plan to heat 38 buildings with geothermal "is just phase one of what will surely be a very long and continuing" project. "I'm sure we will be able to supply all kinds of nonprofit businesses . . . as well as the private sector," he told the **Idaho Statesman.**

Already subdividers are trying to cash in on the renewed interest in Boise's geothermal resources. A recent ad in the **Statesman** read: "Geothermal Heat!!! You've heard about it! You've read about it! Nature's answer to high heating costs! It could be available to you in your new home in 'Morningside Heights' in the near future."

THE C.W. MOORE HOUSE on Warm Springs Avenue was the first house in Boise to be heated with geothermal energy. Moore, one of the developers of the system, began heating his home geothermally in 1892.

The city of Boise is also anxious to see geothermal development. Lee Post, head of the Boise City Energy Task Force on geothermal energy, says, "Boise's leadership has determined that now is the time to thoroughly study geothermal as an important alternative energy source for the city. It appears that the abundant hot underground water can be transported to heat the Boise City Central Downtown Business District. Boise has a unique and ideal market and should develop the resource to its fullest extent."

LEE POST, head of the Boise City Energy Task Force on geothermal energy, says citizens from other geothermal hot spots in Idaho are waiting to see how Boise's system works before they proceed with their own development.

Post says there are geothermal hot spots all over Southern Idaho with similar potential for development. "The rest of Idaho and the whole nation are waiting to see what happens in Boise with geothermal," she says.

LEGAL QUESTIONS

In October 1976 Boise received a grant from the U.S. Energy Research and Development Administration to investigate and define the legal and institutional problems related to geothermal development. Post, who is heading up the study, says many legal questions remain unanswered because the courts have not dealt with geothermal energy issues.

Idaho law treats geothermal resources as neither water nor mineral but "sui generis" — a thing unto itself. The state claims police power authority to oversee development and make sure it does not damage public health and safety or the environment, but ownership of the resource is still in doubt. Both the state and the federal government have leased surface lands for geothermal development. But whether geothermal rights are linked with surface rights or with subsurface mineral rights is still undetermined.

Matt Mullaney, an attorney who has held positions with the state Department of Lands and the Public Utilities Commission, says he doesn't think the question of who owns the resource is substantially holding up development. People will assume ownership until a test case is brought, he says.

ENVIRONMENTAL PROBLEMS

Geothermal development in the Boise area seems to have few environmental problems. The key problem seems to be how to dispose of geothermal water after it is used. The water from the BWSWD wells is potable except for a high fluoride level. Present users dispose of their waste water in the city sewer system, in irrigation ditches, or in reinjection holes. Disposal is the responsibility of the individual user.

Mullaney says future development will have to involve delivery and disposal of geothermal water. He notes that the city has objected to receiving any more geothermal effluent from new installations.

Comstock reports that the three state buildings that will be hooked up to the BWSWD system will either discharge their waste water into the Boise River or reinject it. If river disposal is chosen a series of spray fields and settling ponds will be used prior to discharge to lower the effluent temperature and to raise the dissolved oxygen content. The water is expected to be 120 degrees F. when it leaves the state buildings.

INEL notes that reinjection is probably the "most environmentally suitable method of disposal. This method will increase the number of wells required, and will increase pumping costs. Reinjection has increased the seismicity in some areas. However, the Boise area does not appear to be seismically active."

INEL believes that most potential environmental problems associated with Boise geothermal development can be avoided "as long as proper project management is maintained. There has been no indication of seismic activity, subsidence, or aquifer interference resulting from operation of the Warm Springs Avenue System during the past 86 years. The production from the wells supplying this system has not measurably changed with years of use; thus it appears the geothermal reservoir would be capable of sustained long-term production at the levels proposed."

In Klamath Falls, Ore.

Klamath Falls, Ore., is the only other U.S. city besides Boise, Idaho, where geothermal heat is used extensively. Dr. John Lund with the Geo-Heat Utilization Center at the Oregon Institute of Technology in Klamath Falls notes that geothermal heating has been used since the turn of the century in his city, but development has been largely unplanned, inefficient, and marginally economic.

Most Klamath Falls residents using geothermal have individual wells which only serve one or two houses each. At a cost of $4,000-$5,000 per well it takes 10 years to pay back the cost of the well, he says. Residents pump cold city water down into their wells which is heated and pumped back into their homes at up to 170 degrees F.

Lund says "district heating" — having a central well and heating plant which served a neighborhood — would be more attractive.

The university in Klamath Falls uses the geothermal water directly rather than pumping city water into its well. The university system not only heats the buildings, but also is used to heat greenhouses and raise shrimp.

Lund says it would cost $250,000-$300,000 per year to heat the university with fossil fuels — but the geothermal bill is one tenth of that. Half the geothermal bill is for maintenance of the system and the other half is for amortization.

The university has just finished a feasibility study on geothermal district heating for the city. Also, the Oregon legislature just passed a geothermal district heat law which allows residents to band together to develop a geothermal resource by selling bonds and purchasing or condemning land.

GEOTHERMAL ENERGY USE IN HUNGARY

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ABSTRACT

The Carpathian Basin is characterized by high value of terrestrial heat flow. The first heat flow measurements in the European continent were made in Hungary, which lies in the central part of the basin. These measurements showed twice as much terrestrial heat flow as the world average value.

This causes a geothermal temperature gradient of 50-60°C/km, twice as much as the normal value elsewhere. The virgin rock temperature at 2000 m depth reaches 110-130°C.

Between a depth of 1500 and 2500 m there are porous pliocene strata of good permeabilities and a 6-5/8"-well is able to produce 60-120 m^3 /hour hot water of 60-99°C temperature depending on the depth of the well.

In the last decade, intensive exploration and geothermal development has taken place and at present the production capacity of 131 geothermal wells amounts to 11760 m^3 /hour hot water of 56-99°C temperature. The heat equivalent of the hot water, referend to 20°C temperature is about 770 MW.

The chemical composition of the pliocene hot water is very agreeable. The water is soft, contains 1800-2500 ppm dissolved solids, more than 90 per cent of it is sodium hydrocarbonate. Scaling rarely present serious problems; there is no corrosion since the hot water is free of oxygen. The gas/water ratio is generally 0,1-1,2 m^3 /m^3 at the wellhead. The gas is mainly CH_4 and CO_2 Some of the wells produce considerable amounts of methane-ethane gas which after separation is used in the geothermal project.

The wellhead armature is suitable for the production of 60-120 m^3 /hours hot water which flows into the gas separator, where the combustible gases and some CO_2 is separated. The main separation of CO_2 take place in a reinforced concrete storage tank. In this tank $CaCO_3$ deposits as flakes and can be cleaned away easily. In the heating pipes practically there is no deposition.

Geothermal hot water is used directly for

1. Heating greenhouses, cattle stalls, milking rooms, pigsties, chicken houses, auxiliary rooms
2. District heating, space heating in hospitals, factories, etc.
3. Industrial processes (food industry, paper mills, textile, ceramic industries, etc.).
4. Cooling and drying in agriculture.
5. Warm water supply for washing, bathrooms, municipal swimming pools, schools, etc.

Cooling and drying, and additional warm water supply is needed not only in winter but all throughout the year. In winter, warm water is supplied by the water of 50°C temperature leaving the heating system.

At the end of 1973, 2100 apartments, 1,2 million m^2 greenhouses, several hospitals, and factories are heated geothermally. In Budapest, 5600 apartments are supplied with geothermal warm water. There are 195 swimming pools, and balneologic establishments fed by geothermal warm water in Hungary.

The cost of geothermal space heating, even before the rise of oil prices, was considerably less than half of the alternative coal, oil or natural gas heating costs.

of low enthalpy thermal water has been used in Hungary since 1962. The author proposed to the Government of Hungary the large scale exploitation of this new form of energy in 1958, after investigating the geothermal characteristics of the Hungarian Basin.

The UNO-Congress on New Sources of Energy in Rome in 1961 gave an impetus to the development of the geothermal energy as the most important one among the "new sources" including solar and wind energy.

These "new sources of energy" are the most ancient forms of energy used by mankind, but geothermal energy, mainly in the form of hot water springs had been used only for balneological establishments before the development of the Larderello steam field.

From the practical point of view, geothermal energy is a very slight fraction of the internal heat of the earth, which can be used in many ways. The amount of the internal heat of the earth is at least 10^{33} cal and is more than ten times as much as the added calorific value of all exploitable fossil energy on the earth, and the nuclear energy of fissionable materials to be obtained by mining.

As a matter of fact, geothermal energy is essentially nuclear energy of the big natural nuclear reactor shell situated in the crust and mantle of the earth. The nuclear fuels are the K^{40}, Th^{242}, and U^{238} atoms dispersed chiefly in acid crustal rocks.

The amount of geothermal heat of the earth is not only immense, but it is well isolated and only a small fraction is conducted over the surface into the space. The heat accompanying volcanic activities is negligible compared to the conductive heat. It may be that radioactive heat production is even more than the heat loss and the earth is actually heating up itself.

The connection of hydraulic systems and hyperthermal rocks under suitable circumstances may give the possibility of commercial geothermal fluid production either in form of superheated and saturated steam or by hot water. Hyperthermal territories exhibit higher than normal heat loss either by local concentration of steam and hot water vents or by elevated regional terrestrial heat flow. In the first case, convection takes the foremost part; in the second one, conduction is the main agency of the transport of surplus heat.

The presence of the following main simultaneous factors are prerequisites of geothermal areas:

1. Warm or hot rocks near to the surface owing to relatively recent volcanic or subvolcanic activity (hyperthermal areas).

2. Energy transporting agent, in most cases water, filling the fissures and pores of the heated rocks (hydraulic systems).

Thermal springs, geysers, fumaroles, and solfa-

energy produced is moderate but thos manifestations are very important in the disc commercial geothermal fields.

Large scale exploitation of geothermal solved technically by drilling steam and h wells. Porosity, permeability and the amou water to be mobilized are the most importan teristics of the hydraulic systems.

At present two types of productive geo energy systems can be distinguished:

1. Volcanic or subvolcanic processes in c tion with recent or Quaternary activities, pro superheated steam or hot water.

2. Subsidence basins or depressions with than normal heat flow filled up with porou tured sediments, containing hot water under pressure.

The first type has been considered up to now important owing to the higher concentratio energy.

Along the worldwide Alpine orogenic belt th locations are: Larderello, Monte Amiata in Denizli-Aydin in Turkey, Indonesia, Philipp New Guinea, New Britain, New Hebrides, Wairakei and Waiotapu in New Zealand, Ta Japan, Paushetsk in Kamchatka, the Geyser California, Cerro Prieto and Hidalgo in Mexico, Salvador, Guatemala and northern Chile.

The geothermal areas in Iceland are connecte the Mid-Atlantic ridge which is also a Tertiary fe of the oceanic orogenesis. Some areas in Afric connected to the tectonic system of rift valleys. these locations are well described in the national literature and the exploration for geothermal locations of this system has not al been successful, since the evolution of a st deposit depends on peculiar geothermal, hydrau and thermodynamical conditions.

The second type of geothermal systems are widespread and are also located along the Al orogenic system. Few of them are known and less are exploited for practical ends, althoug percent of the prospective areas for superhea steam produce actually hot water instead. surplus heat, manifesting itself in higher normal heat flow, takes its origin in subcru magmatic processes, which are in connection, perhaps are the cause of the evolution of continental crust and the growing of the contine masses.

These hyperthermal territories has been subsid since the beginning of their formation and have b filled up by sediments having been eroded from emerging mountains in the surroundings. The hyperthermal regions in most cases are connected to volcanic manifestations.

The higher than normal terrestrial heat flow cau rapid increase of temperature versus depth. In t

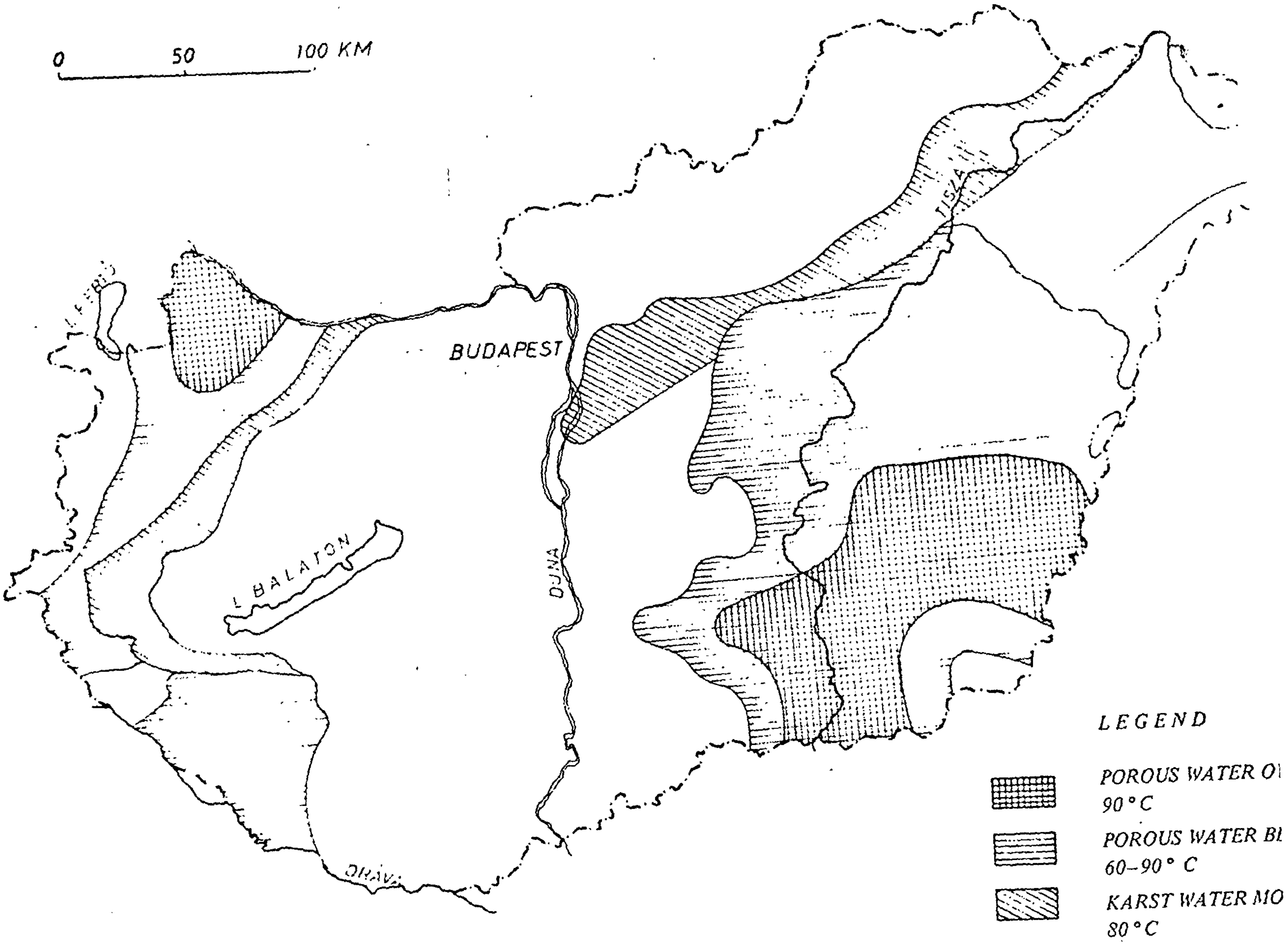

Fig. 1. Geothermal energy potential of Hungary.

Hungarian basin the gradient of temperature is between 50-70°C/km, which means that at 2000 meters depth the temperature of water is 110-150°C and outflow temperatures may be a few degrees less than the boiling point of water under atmospheric conditions. The high permeability of the sandstones enables the production of great volume rates, and consequently the amount of energy produced by a well is enough for practical aims.

The most important example, and at the same time, the most intensively explored and exploitated subsidence territory is the Hungarian basin which will be described later in detail. Another important location, where development is in an advanced stage is the Piedmont region of the Caucasus, where at Krasnodar, Stavropol and Mahachkala important hot water deposits are stored in the porous sediments. Temperature gradients are between 40-50°C/km and commercial production is said to have been started.

At the northern slope of the Pyrenees, in the Arzacq basin the temperature gradient is about 60°C/km. From the Lacq-field hot water production is possible but not practiced.

In the Paris basin in France, where the heat flow is normal, hot water production for space or district heating is considered as an economic alternative. Projects are underway there now.

In Western-Siberia, an immense sedimentary basin with moderate heat flow can produce hot water for space heating. The climate is very cold, but the population is sparse. In the future, geothermal heating will surely play an important part since important oil and gas fields are being developed primarily for transporting it outside this territory, and little local use.

In the Great Artesian Basin in Queensland at Springleigh, temperature gradients of about 50°C/km has been observed. At a depth of 1740 m the virgin rock temperature is 110°C.

The Salton Sea geothermal area presents an interesting mixed type with both volcanic and subsidence effects. The structural trough in the vicinity of the Salton Sea is 120 kms wide. It is filled up by Neogene sediments. The fill is more than 6000 m thick at the center of the depression. Volcanic domes and recent mud volcanoes indicate that the thermal anomaly of this depression is in connection with Pleistocene volcanic activities. Hot brines of exceptional high concentration of dissolved material characterize this unique geothermal area.

A high heat flow value was measured in the Hungarian basin in 1954 (Boldizsar, 1956) and further measurements has confirmed that the Hungarian basin which lies within the Carpathian arc and the Dinarics is a geothermal high with terrestrial heat flows between 1,0 and 3,4 /'cal/ cm^2 sec (Boldizsar, 1964). The average heat flow is about, 2,4 cal/ cm^2 sec and this high heat flow causes high temperature gradients everywhere in the sediments of the basin. The observed gradients are generally between 50 and 70°C/km.

Intensive exploration for oil deposits in the Tertiary sediments of the Hungarian plain has revealed the topography of the subterranean surface
of the Paleozoic-Mesozoic bedrocks and
reliable figures on virgin rock tempera
Hungarian plain is in the center of the Ca
The Paleozoic-Mesozoic bedrock is elevate
SW-NE fracture line forming the mid-
Mountains which rise to 1000 m above se

These elevated, mostly Mesozoic strata
Hungarian plain into two basins, a smaller
northwestern direction and a greater on
southeast. The depressions are filled with
porous sediments; about half of their
consists of Lower Pliocene (Pannonian) st
maximum depth of the depressions is about
below sea level; the average depth of the
basins is about 3000 m. The porous and p
sandstone strata contain immense quant
water, and oil and gas deposits of commerc
have been found in about 50 traps.

The volume of Tertiary and younger rocks
160,000 km^3. The volume of porous roc
porosity over 10% is about 20,000 km^3. Mo
4,000 km^3 of hot water of 60 to 200°C is st
the pores of the rocks that are deeper than 1
most of it can be recovered by drilling wells w
water capacities of 1 to 2 m^3 /min.

If the temperature is dropped to 40°C
immense quantity of heat will amount to 2.
cal, which is about 50% of the calorific value
known petroleum deposits in the entire world
well of 1000 to 2000 m deep can produce 1
m^3 /min. of water at a temperature of 60 to
for decades. About half of the territory of Hung
potentially productive, as shown in Fig. 1.

It is of interest to note, that outside the C
thian arc, in the Vienna-basin, in Czechoslo
Poland and Ukraine, the value of terrestrial heat
is normal, less than half of the value withi
Carpathian basin. Consequently, the temper
gradient is also normal or less than normal
values between 35 to 10°C/km.

PRODUCTION METHODS

The standard procedure of opening up of
Upper-Pannonian reservoir is done by putting d
1600-2400 meters deep borehole with a sui
Rotary drilling rig.

According to the local stratigraphy, the first
m is usually drilled with 19-1/2" bit and cas
13-3/4" tube. After cementation the dri
continues with 12-1/4" bit down to about 80
After casing with 9-5/8" tube and cementi
8-1/2" bit goes down to 2000 m. Drilling proc
with bentonite based drilling mud with spe
gravities between 1,1-1,4.

After finishing the 8-1/2" hole, a suitable ele
logging sonde is lowered and resistivity and
SP logs, are made and porous and permeable la
are determined. Moreover, if necessary, gamm
and neutron logs are also made. For determinin
virgin rock temperature at the bottom, ca
temperature measurement is made, but most rel
values are obtained later, at the deepest inflo
hot water.

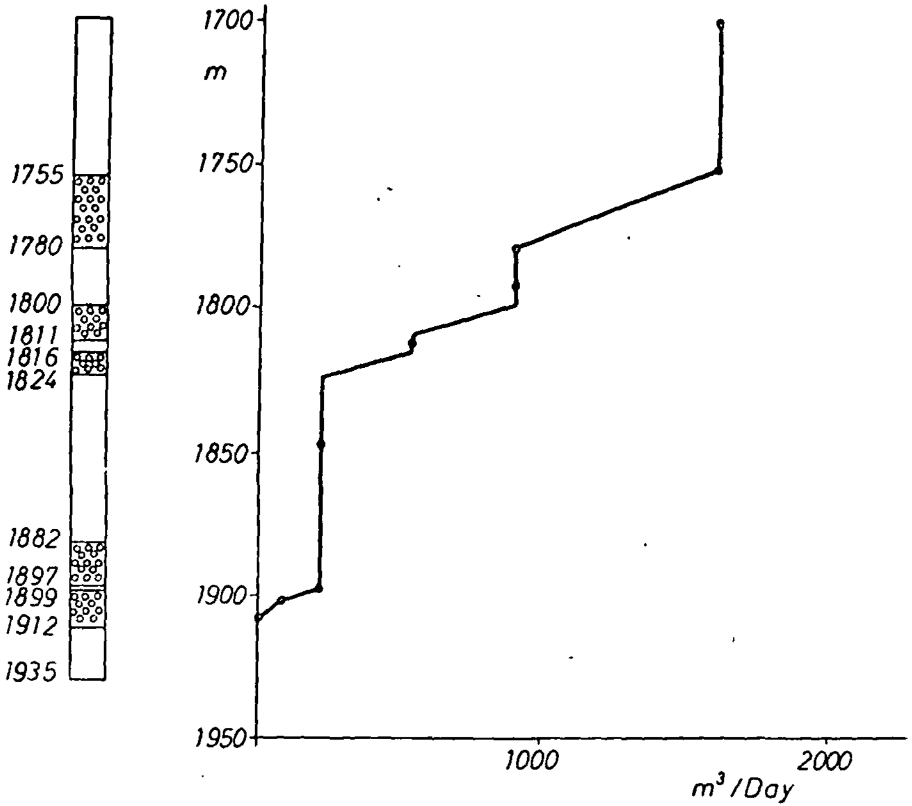

Fig. 2. Perforated sections and hot water production from a typical 1935 m deep well.

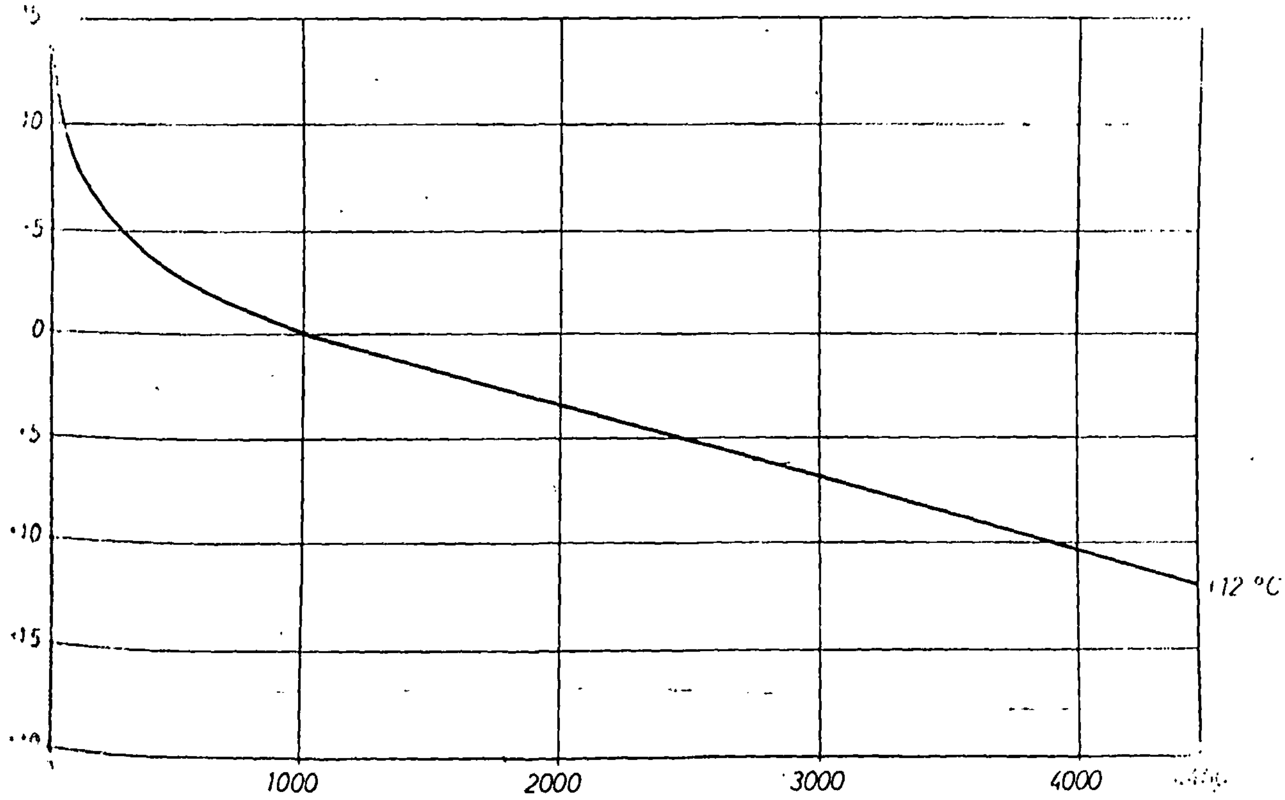

Fig. 4. Temperature — duration curve of the heating season in south Hungary.

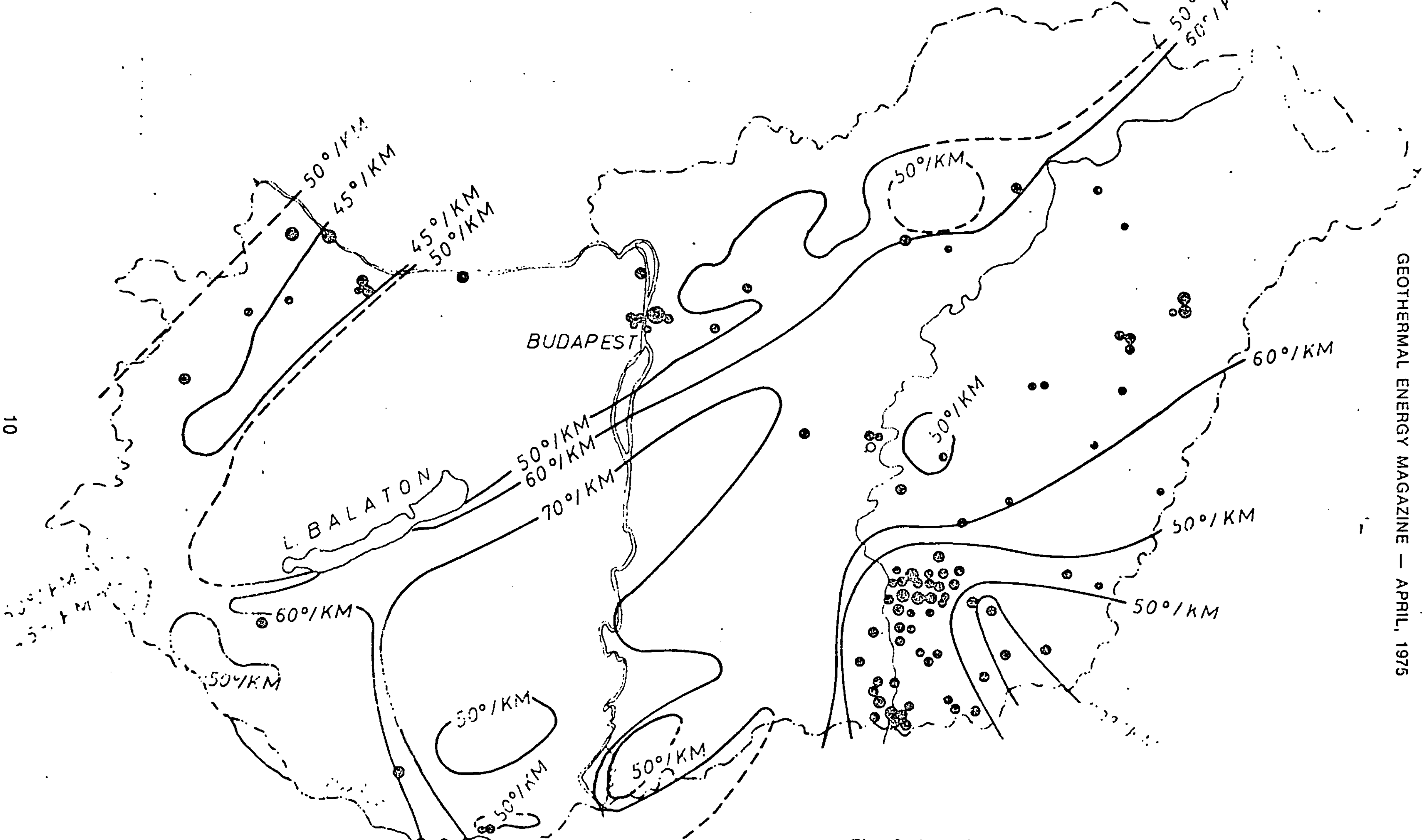

Fig. 3. Location of geothermal wells in Hungary.

The next step is to lower the 6-5/8" casing tube down to the bottomhole. After cementing, jet perforation follows. The depths of the perforated sections are determined according to the interpretation of the loggings. Usually 12 or 24 perforations per meter are made. Perforation is started at the first suitable permeable layer nearest to the bottom.

After perforating two or three layers, a production test is made. If the production rate is less than 1200-1500 liters/min. more layers are perforated and again a production test is made with all the perforated layers. Generally, 3-6 permeable sections are perforated, the overall thickness of the perforated sections are between 30 and 100 meters along a hole length of 100-200 m according to the given circumstances (Fig. 2).

The virgin rock temperature of the upper perforated layers is less than that of the deepest layer. Since the cooling of the water in the upper cold section is very sensitive of the volume rate, the increase of volume by perforating the cooler layer, up to a certain length, increases the outflow temperature.

The wells are equipped with a wellhead armature suitable for the production of 1-3 cu. meters per minute. The hot water, after flowing through a gas separator, is stored in a reinforced concrete tank, where CO_2 is separated and the $CaCO_3$ deposits as flakes. In the heating system, no scale deposit was observed. Corrosion is no problem, since the water is free of oxygen. Hot water production is controlled by four 6" gate valves.

After shutting down completely, it takes a certain time till the water column in the hole cools down to the geothermal temperature of the layers. After a long shutting down time, production cannot start by itself and an airlift is used to start production for which suitable connections to the 100 psi compressor are available.

Along the upper 30-80 meters scale may deposit on the casing. Yearly once or twice descaling is made by mechanical or acid treatments. The upper portion of the hole may be equipped with a plastic liner which can easily be exchanged.

The Upper-Pannonian hot waters are mainly alkali – hydrocarbonate waters of about 1800-2500 ppm soluble ions.

A typical chemical analysis at a well in Szentes

Ca	6,5 ppm
Mg	2,2
Na, K	594,8
HCO_3	1575,0
Cl	23,4
CO_4	23,0
others	2,0

Gas-water ratio is generally between 0,2-1,2 Nm^3 / Nm^3 at atmospheric pressure; mainly CH_4 and CO_2 can be found. In most cases the gas is combustible and after separation will be used in the geothermal project.

ECONOMIC CONSIDERATIONS

There are at present 131 geothermal wells in Hungary (Fig. 3). Total output all of them is 11.760 cu.m/hour with an energy capacity of 380. 10^6 kcal/hour. The average production of a well is about 80-90 cu.m/hour, the average energy about 4,4. 10^6 5,0. 10^6 kcal/hour. The energy of the wells is computed from the difference of outflow temperature and the off-flow temperature, latter is considered as 20°C.

Total energy production of the 131 wells amounts to about 770 MW, which is considered as the peak load. If heating of apartments, industrial and agricultural objects further warm water supply for washing, bathrooms are considered, only 30-35 per cent of the continuous heat output can be utilized, since in summer from May to October heating is unnecessary..

In summer months, warm water supply is needed, and the agriculture uses hot water to drying and cooling processes. In small towns municipal, industrial and agricultural uses can be coordinated and utilization may be higher than 35 per cent.

If one third of the full capacity is taken into account, the optimal useful production capacity of geothermal energy in form of hot water at present is about 260 MW. The geothermal energy production is expected to double within 6-8 years.

An average geothermal well produce 80-90 cu.m/hour hot water of about 85-95°C temperature. Such a well can supply a district heating for 1200 apartments and complimentary municipal and public buildings, swimming pools, schools, kindergartens including warm water supply for washing and bathrooms. The length of the severe peak heating load period is normally not more than two weeks. If the peak load is carried by complementary oil or gas overheating, the number of apartments supplied by one well can be increased to 1800.

The geothermal district heating plant in Szeged (Southern Hungary) comprising 1200 apartments each consisting of two living rooms, dining room, kitchen and bathroom, was economically a very successful project.

Heating costs are half those of coal-fired plants. Additional advantage is, that the geothermal hot water supply take off the load from the water works, since cold water is used in small amount only for drinking and cooking which amounts not more than 10 per cent of the domestic water consumption.

In agriculture, the use of geothermal energy is very economical. During the 6 month heating season, night air temperature are frequently under the freezing point and from the end of November to the beginning of March the soil is frozen. During cold spells in January and February air temperatures may sink frequently below minus 20°C.

Geothermal hot water is used for heating greenhouses, milking rooms, cattle stalls and pigsties, chicken houses, further all auxiliary rooms and premises (machine shops, garages, bureaus, service houses, etc.). In summer, drying and cooling

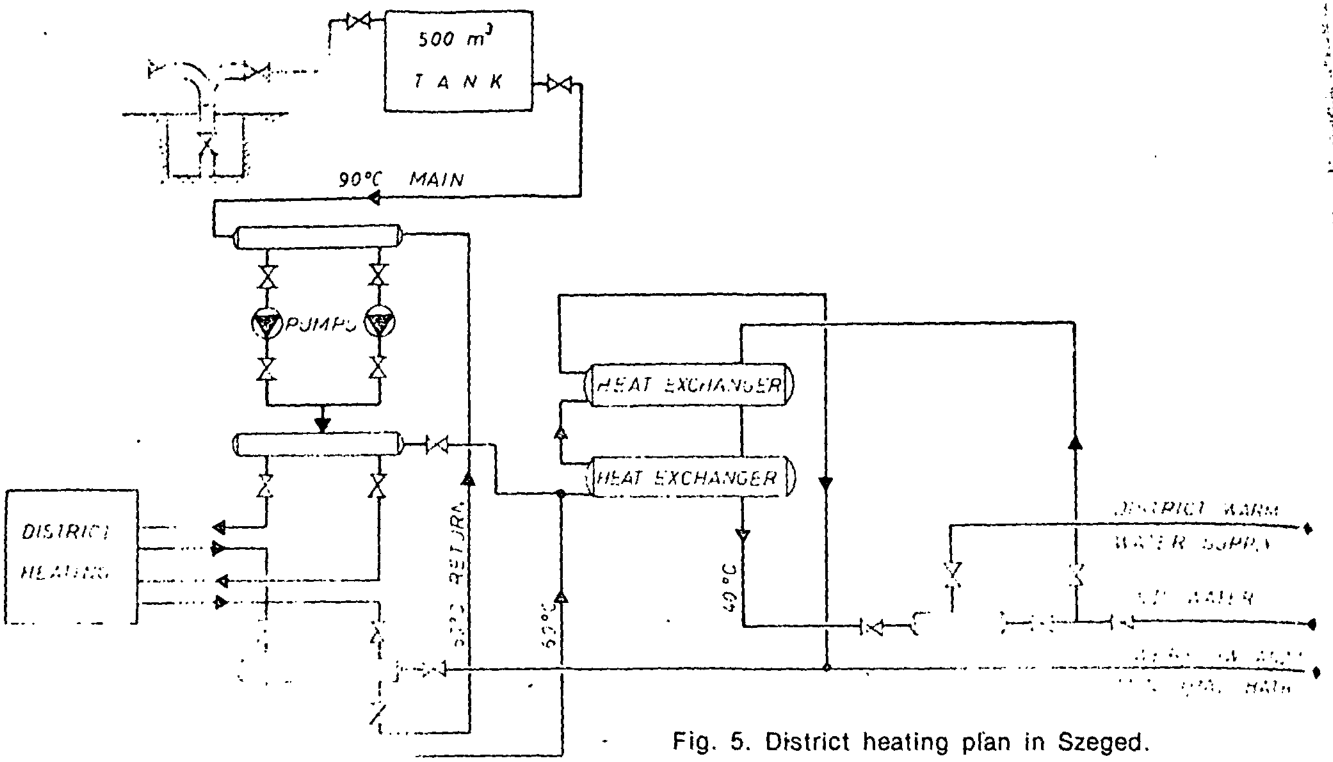

Fig. 5. District heating plan in Szeged.

pressures are important heat consumers. An average well can supply hot water to all installations of a modern 7000 acre farm. The price of the heat unit is 7 dollars/ 10^6 kcal with geothermal system, 17 dollars/ 10^6 kcal with coal or oil firing.

At the end of 1973, the geothermal greenhouse area was about 1,200,000 sq.m. Geothermal heating for animal husbandry projects is also increasing and from 1965 up to now 60 wells of about 6-8. 10^6 kcal/hours individual capacity were made for the cooperative agricultural units. The number of wells in the agriculture is increasing yearly by 10 or more wells.

Geothermal heating of hospitals, municipal buildings, factory premises and swimming pools in towns is also being made, but priority is given to agriculture because geothermal energy in agriculture increases the volume and variety of production. Geothermal heating of small towns and agricultural villages are being considered.

It should be mentioned, that in 1966, a geothermal borehole in Tape near Szeged discovered the biggest oil and gas field of Hungary. The well after perforation produced through the 6-5/8" casing 5400 bbl of oil a day. After shutting down, the oil and gas field has been developed by drilling an additional 300 production wells. This strike increased the Hungarian oil production capacity by a yearly amount of 7 million barrels and doubled the natural gas reserves of the country.

Cooling by geothermal hot water is possible by various processes and is very economical since the summer load is small or nil, and the hot water can be used to supply cooling plants. In Hungary geothermal cooling is used in the agriculture for food storage.

Drying of grain, haystock, tobacco, paprika and other products found successful application. Geothermal hot water supply heat to exchangers and the warm air of 50-60°C temperature is blown into the drying chamber by electrically driven ventilator.

EXAMPLES OF GEOTHERMAL HEATING

The average length of the heating season is 4460 hours per year. Fig. 4 illustrates the duration of the average daily outdoor temperature. The indoor temperature is +20°C. The ordinates are proportional to the heating load. The full capacity of the well can be used if the minimum heating load is equal to the heat capacity of the well. In this case, additional oil or gas-fired boilers are necessary.

Since, at the beginning of hot water production the district may be small, the first peak load is carried by the well. Later with the development of the district the number of apartments increases and either a new well will be drilled or a boiler installed. In most cases, the boiler plant will carry the peak load during 700-800 hours.

The daily variation of the outdoor temperature is equalized by hot water storage in concrete tanks. In any special case the proper solution is selected after economic considerations among various alternatives.

Fig. 5 shows the first district heating installation in Hungary. The well produced in 1962, 1500 liters/min hot water of 90°C temperature. This well nowadays supplies a district heating unit of 1800 apartments, several municipal buildings (schools, shops, and kindergartens). The off-flow gives warm water to the district and to the municipal swimming pool.

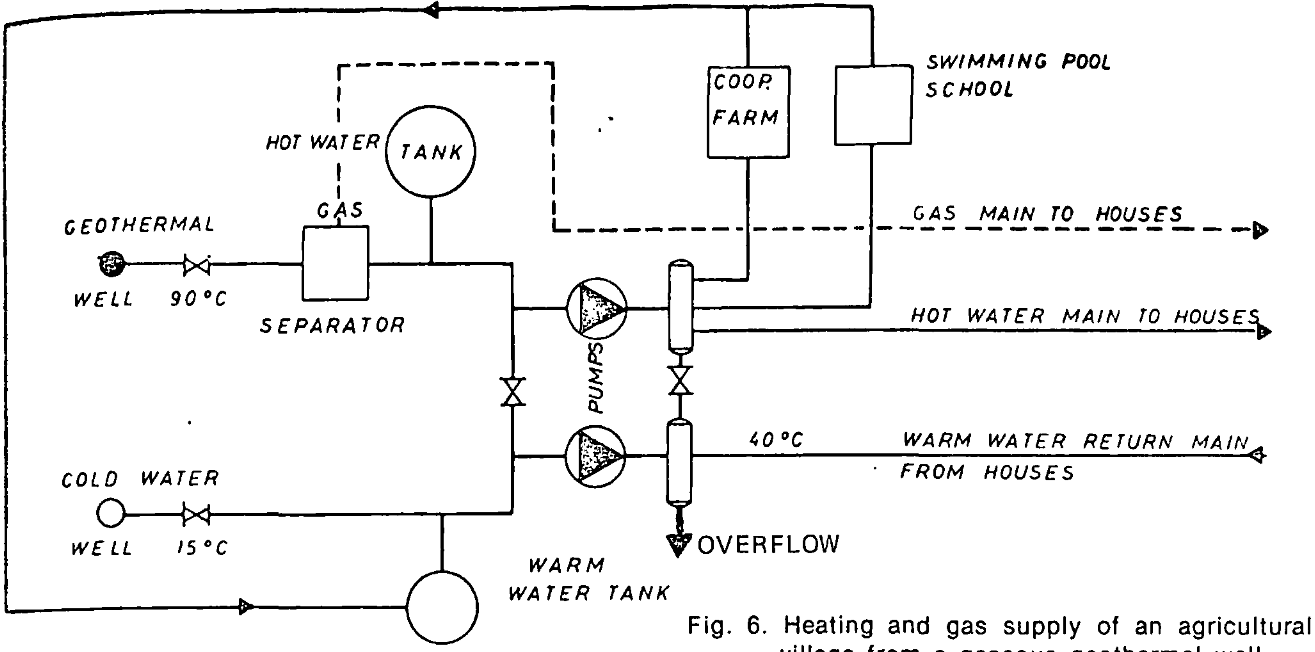

Fig. 6. Heating and gas supply of an agricultural village from a gaseous geothermal well.

The peak load is carried by a gas-fired boiler from the nearby gas field discovered by our geothermal exploration. Figure 5 shows the district heating before peak boiler installation as of 6 years ago. The 4-room apartment unit needs 5000 kcal/hours peak heat supply, and the yearly total heat required is 7 million kcal.

In Fig. 6 the use of a gaseous geothermal well is shown supplying a cooperative farm, swimming pool and village houses with methane separated from the hot water and with hot water. Methane is used in kitchens for cooking, hot water for heating and the 40-50°C hot water leaving the plant for warm water supply.

In Budapest, a thermal well supplies 5000 apartments in the central part of the town, with warm water. 600-700 m^3 thermal water of 69°C temperature is daily needed for discontinuous warm water supply of balneological quality.

Scaling takes place in the upper 30-80 m portion of the well and in the main line to the concrete tank, where CO_2 is separated and $CaCO_3$ deposits. Scaling can be prevented by using wellhead pressures more than 2.5 atmospheres.

This is being made by throttling. This procedure is simple and in the well no scaling takes place. Throttling diminishes hot water flow and this method can only be used with wells of high-shut-up pressures (more than 7-8 kg/cm^2) The average starting wellhead pressure is generally between 4-6 kg/cm^2 and by throttling the quantity at hot water is not enough in most cases. Moreover, throttling diminishes outflow temperature.

Scaling is removed generally by drilling out of $CaCO_3$ with roller-bits of the rotary drilling system, or by acid treatment. It is important, that by using acid treatment, a thin protecting stratum of 3-4 mm thickness should remain to prevent acid corrosion.

Both drilling and acid treatment is used in regular intervals depending on the amount of production. There are wells, where scaling must be removed weekly, and at some wells twice or once a month; at most of the wells a yearly treatment is enough, and in more than 50% of our wells requires no treatment at all. Generally, wells with the highest temperatures and higher dissolved solid present scaling problems. Hot water originated from mesozoic limestone and dolomite bottom rock causes more scaling difficulties than pliocene porous water.

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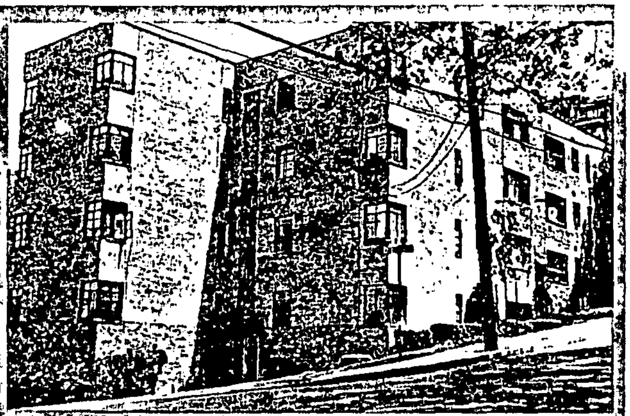


This 35-year old building was converted in 1967, and A.J. Buerkle says his company has not been called back once except for regular boiler inspections. He says boiler life is greatly extended when the heating system is converted to hot water, because of the elimination of corrosive condensate. Some conversions are operating with 50-year old boilers, and Buerkle says no boiler would last that long in this area on steam service.

CONVERTING STEAM HEAT TO HOT WATER PAYS OFF

☐ Long before the energy crunch, one Pittsburgh plumbing and heating contractor was proving energy could be saved — and a good business developed — by converting old-fashioned steam heating systems in apartment buildings and homes to hot water. Advantages: Better temperature control, more even heating and greater tenant comfort, silent operation, less maintenance and — most important — lower fuel consumption.

In thousands of steam-heated structures — mainly pre-dating World War II — rising fuel and maintenance costs are eating into profits. Tenants are usually either too hot or too cold. When they're hot, they open windows and waste energy. When they're cold, they complain.

A. J. Buerkle Plumbing and Heating Company in Pittsburgh has been successfully converting two-pipe steam systems to hot water for years. Buerkle's first conversion was done in 1936 to a building he owned himself. As a plumbing and heating contractor, Buerkle knows the shortcomings of old-fashioned steam heating — uneven heat, noise, and excessive maintenance due to the corrosiveness of steam condensate. He reasoned that hot water could be pumped through the existing radiatiors as readily as steam, and with greater efficiency.

His concept proved correct and in the intervening years his company has completed more than 50 such conversions of steam heated buildings — most of them originally constructed in the 1920's and 1930's. Buerkle claims callbacks because of problems are rare. What about economics?

Buerkle says cost is low enough so that a reasonable payback period can be expected. Average cost of systems he has converted is about $2,500, which varies with the number of radiators to be serviced and the need to replace any of the existing condensate piping. He says fuel bills are reduced by at least 10 per cent, a figure others consider conservative. But even with this saving, with an annual fuel bill of $5,000, the conversion cost would be paid back in five years. And this doesn't include reduced maintenance costs.

INSTALLATION SUMMARY

- Very little structural change is normally needed. Existing boilers, piping, and radiators are used if sound. Only minor modification is needed on radiators: A hot water valve and a key air vent to allow bleeding of air from the system are installed. The steam trap and, in some instances, steam vents are eliminated from each radiator. In some buildings, zone control valves are installed for thermostatically controlled heat in each apartment.
- Modification of the boiler is not extensive. Return piping is simplified so return water from the radiators flows directly into the boiler header. If the system is equipped with a boiler return trap and vent, these and associated piping including check valves must be removed up to the end of the return main. The opening at the boiler supply piping must be plugged. If the boiler is equipped with a condensation return pump, it must be removed.
- The steam boiler is converted to a hot water boiler simply by changing the trim. The safety valve, pressure gauge, water column and gauge glass are removed and replaced by a pressure gauge, thermometer, and an ASME relief valve properly sized for the gross output of the boiler.
- On the output side of the boiler an air separator should be installed to remove any air bubbles formed in the boiler, and a compression tank provided for expansion of the heated water in the closed system. A Bell & Gossett booster pump circulates hot water through the radiators in the system. In some buildings additional booster pumps can be added at critical points to enable the hot water to reach the farthest apartment.
- Circuit returns should be joined in a header at the boiler, which is connected to the return opening in the back section of the boiler. Each return line should be equipped with a balance valve.
- On a steam installation, radiation is sized at 240 BTU per square foot which is 215° average water temperature or 225° boiler temperature with a 20° temperature drop. (This 225° boiler temperature is only required when outdoor temperature is at the design condition.) Multiply the square feet of radia-

tion by 240 to arrive at the BTUH load for circuits and mains. Using the standard 20° temperature drop, divide total BTUH load by 10,000 to arrive at the GPM for the pump. Often in older systems, Buerkle oversizes the booster to compensate for buildup, particularly in return lines.

The circulating hot water provides a better heating medium than steam for two reasons. Water retains its heat and stays in the radiator when the boiler and pump shut down. This provides more even heating and greater overall comfort. When it starts up again, a steam boiler must raise the temperature over the boiling point, requiring more fuel than a hot water boiler which must raise the water temperature only a relatively few degrees. Also, when the hot water boiler starts up, warmed water immediately is force circulated through the radiators bringing instant heat.

One final advantage: Hot water preserves the life of the boiler. Buerkle has a number of boilers now operating as hot water boilers which are over 50 years old. He says they never would have lasted this long had they been producing steam. High temperatures and corrosion would have finished them long ago.

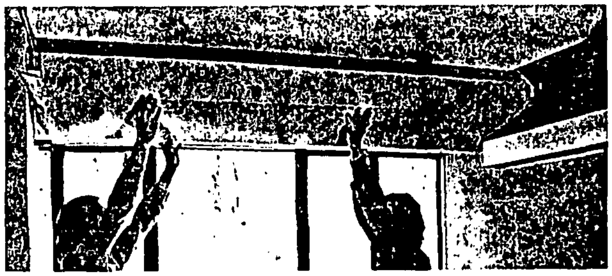
Buerkle began using bell and Gossett Company products for his conversions and has since been installing B&G pumps, valves and air control equipment supplied by Thermoflo Equipment Co., Inc., Pittsburgh, the Bell & Gossett representative in western Pennsylvania. In the early 1920's, Bell & Gossett, now a part of the ITT-Fluid Handling Division, did pioneering work in the science of hydronics and developed equipment for hot water systems. Bell & Gossett engineers have prepared instruction manuals for plumbing and heating contractors to use in making conversions of both two-pipe and single-pipe systems. Manuals showing typical examples are also available. B&G representatives nationwide will help in the selection and sizing of proper equipment. **For more information, Circle No. 71.** ☐ ☐

The convent of St. Bernards Church in Mt. Lebanon, Pa., was converted from steam to hot water heating in 1965. The building includes 52 rooms, each heated by a single radiator, as well as meeting rooms, reception rooms, and a dining room. Prior to converting to hot water heating, the farthest rooms in the steam system were continually cold, while those nearest the boiler were excessively hot. Hot water heating has changed that, and even temperatures are maintained throughout the building.

VALENCE AIR CONDITIONING PROVIDES COMFORT AND LOW COST IN HEALTHCARE FACILITY

☐ Administrators of the Lake County T.B. Sanatorium in Waukegan, Ill., wanted to add air conditioning to their 40-year old facility as part of a general interior remodeling and modernization. They had problems: Patients could be moved from the premises only with the greatest difficulty, setting limits on the amount of remodeling work. The facility is monolithic concrete and ductwork would incur extra construction time, and labor costs. Concealing ducts would require mechanical ceilings in each room. Fan-coil units would require cutting through the concrete walls, greater expense for equipment, and continuing maintenance.

Mechanical engineers recommended the use of a valance cooling system manufactured by Edwards Engineering Corp., employed in many healthcare facilities. The system requires no ducts because it cools by natural convection, with no blowers. The only modification needed to the concrete: Two small holes drilled through the wall in each room to allow the entrance of supply and return copper water piping. The system is designed to be exposed.



Typical room installation in the Lake County TB Sanatorium. Unit, mounted across the wall above window, does not need to be concealed or disguised.

The Valance System is a hydronic finned coil, housed in an enclosure that looks like a decorative valance, mounted on the wall where it intersects with the ceiling. The finned coil encloses copper tubing for supply and return cool water lines. The system is installed by the placement of two end brackets mounted at each end of the room. The brackets are placed in the corner formed by the wall and ceiling with no measuring for positioning required. They are usually 3"-6" from the ceiling. A condensate drain is snapped in place.

Chilled water mains were brought into the structure through the corridor areas and connected in each room. The entire installation took ten weeks. In operation, chilled water circulates through the valance coils, cooling the room air next to the fins. The heavier cool air falls to the floor, spreading outward through the room by convection. Moisture in the air condenses out on the coil and is drained away. Cool water is provided by a packaged chiller. **For more information on the Edwards system, Circle No. 74.**

How steam is produced and handled at The Geysers

Illustrated tour of the only commercial U.S. geothermal development shows typical field operations from geology to electrical output

Robert E. Snyder, Engineering Editor

10-second summary

Unique properties of superheated steam dictate field development by well clusters around a plant site. Here's how operators plan such developments, how they deliver steam to the utility for power generation and how they get paid for their production.

EXPLORATION AND DEVELOPMENT is continuing in the world's largest geothermal project—California's Geysers area, 90 miles north of San Francisco. Five rigs are active for several operators and clusters of new wells are being completed to serve as sites for additional power plants. However, only Union Oil Co. of California, the company most responsible for modern development at The Geysers, has commercial production.

Including active locations and abandoned sites, over 150 wells have been drilled in a roughly rectangular, 4-mile-wide, 7-mile-long area extending southeastward to include the latest Castle Rock Springs development. There are perhaps some 100 wells in this area capable of commercial production.

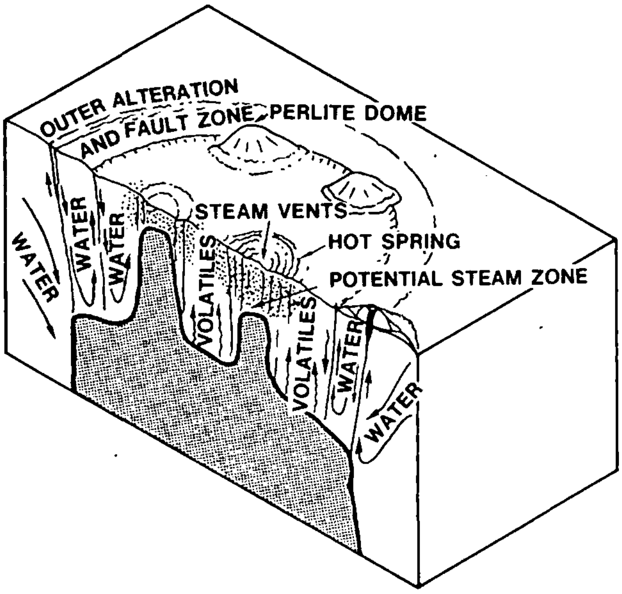
Eleven generating units presently in operation are producing a total net output of 502 megawatts (mw). In perspective, this would be enough electrical power, at a rule-of-thumb of one kw per person, to supply the needs of a city of 500,000. In terms of fossil fuel to produce the same output, it is equivalent to about 19,000 barrels of oil per day.

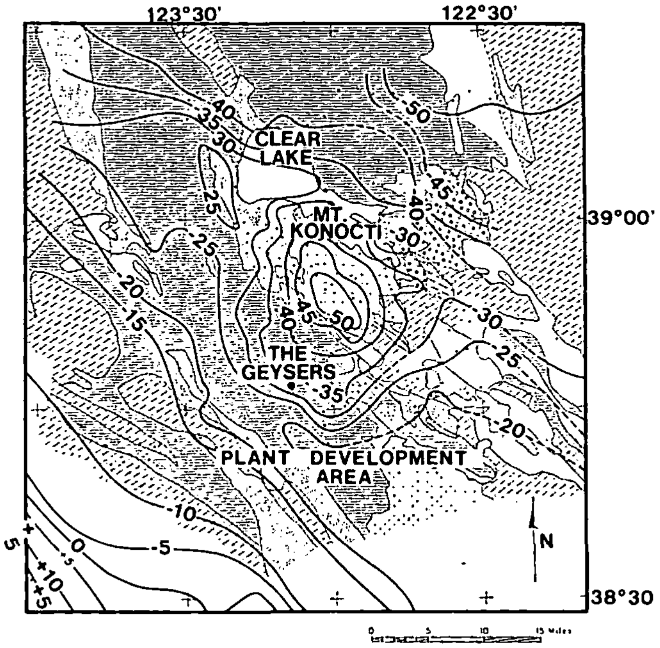
Plants 12, 13, 14 and 15, tentatively scheduled pending application approval by the regulatory agency, will bring total net output to 897 mw.

The most common figure mentioned for future potential of The Geysers is 1,500-2,000 mw, and theoretical studies place possible capacity of the 100-square-mile surrounding Geysers KGRA (Known Geothermal Resource Area) even higher. But all operators emphasize that the short production history of wells and the early state of the art in geothermal reservoir analysis make practical "reserve" estimations nearly impossible.

Well production is measured in pounds per hour (pph) of dry, superheated steam. Operators look for 150,000-

Power plant in The Geysers field contains two 55-megawatt turbine generator units. Note two steam lines entering from right. Huge cooling tower system cools turbine exhaust condensate and auxiliary systems to 80°F. Nearly 80% of the condensate is evaporated. (Courtesy PG&E)





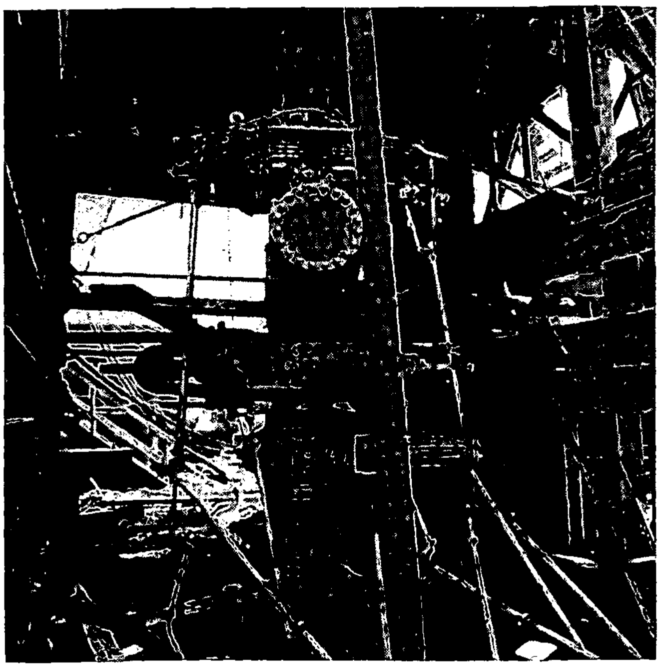
Underlying heat source for The Geysers field and surrounding 100-square mile geothermal area is likely a deeply buried magma intrusion, with local geothermal cells, illustrated schematically at left. Negative gravity anomaly, right, shows probable center of main magma body, some 10 miles northeast of The Geysers. (After Austin et al.[1])

200,000 pph from a new completion. Rates of 380,000 pph have been tested.

Turbine units now being installed require about 1 million pph. New plants with two such units would require 14-16 typical wells.

Because of energy losses in gathering lines, it is desirable to have wells as close as possible, generally within ½ mile, to the plant site. This requirement is the basis for the cluster system under which plants and wells are developed.

Operating conditions do not involve particularly high pressures or extreme temperatures, as might be expected.



BOP stack of Geysers well drilling in mud phase above steam zone shows 13⅜-inch wellhead and wing valves, master valve, steam gate, BOP, banjo box, top BOP, bell nipple and flowline. Bell nipple is replaced by rotating head for steam drilling and banjo box is connected to blooey line and muffler.

Reservoir pressures of 450-500 psig are reduced to 125 psig at the wellhead by expansion and cooling of the flowing steam. Reservoir temperatures are generally less than 500°F. Corresponding wellhead temperatures would be about 370°F, considering a typical super heat condition of less than 20°F. And turbines are designed to handle dry, 355°F, 114 psia steam at the inlet.

However, operators and equipment handlers must be constantly aware of the tremendous energy inherent in the nonconventional product they produce and deliver.

Between reservoir and generating plant, erosion by entrained particles and dust in the dry vapor is more significant than corrosion. After condensation within plants, or at any venting spot, associated gases and liquids may release small amounts of corrosive and noxious elements. Most noticeable is the minor concentration of H_2S in the atmosphere, which accelerates corrosion of bare steel such as racked drill pipe and, of course, any exposed copper cables and electrical contacts.

Development history. After The Geysers was discovered in 1847 and its hot mineral water first used in a resort and spa for adventurous Californians making the long, tortuous journey into the rugged area, shallow wells were drilled in the 1920s to power a small steam engine driven generator.

Magma Power Co. obtained several leases in 1955 and Magma and Thermal Power Co. then drilled six successful wells. Pacific Gas and Electric Co. (PG&E) installed the first 12-mw plant in 1960. Earth Energy Co., a Pure Oil Co. subsidiary, obtained adjacent leases in 1965 in the course of the Pure-Union Oil Co. merger. In 1967, Union-Magma and Thermal formed a joint venture which now controls some 15,000 acres in The Geysers with Union as operator.

Union will supply steam to all but two of the existing and proposed plants. Pacific Energy Corp. will supply 55-mw Plant 15 from a well cluster being developed just

The predominant heat source for geothermal activity is believed to be a large magmatic body buried 10-40 miles below the surface

southwest of the main field complex. Burmah Oil & Gas (formerly Signal) will support PG&E's $17½-million, 135-mw Plant 13 from 15-20 wells located in the Castle Rock area, 5 miles to the southeast.

Geology. The reservoir consists of highly fractured, slightly metamorphosed sedimentary and igneous rocks of Cretaceous and upper Jurassic age, known locally as the Franciscan graywake.

The predominant heat source for geothermal activity is believed to be a large magmatic body buried perhaps 10 miles or more below the surface. A closed negative gravity anomaly centered 10-15 miles northeast of The Geysers may generally define this large, relatively less-dense magma intrusion.[1,2]

The government now has designated this general area as a Known Geothermal Resource Area, and under provisions of the Geothermal Act of 1970, leasing within such areas must be done by competitive bidding.

Smaller intrusions from the main chamber result in characteristic elliptical patterns on the surface which can be identified in aerial photographs. Extinct volcano cones are visible from high points in the field.

Conditions for producing dry steam that can be used directly are fairly rare. Besides the underlying heat source, the steam zone must have a high fracture permeability that is, or once was, connected to a surface water source. At The Geysers, these surface connections have long been nearly sealed by secondary mineral deposits.

To generate dry steam *in situ*, the fractured rock must not be completely flooded and an excess ratio of heat to water must be maintained.

Steam plants are also operational in Italy, New Zealand, northwestern Mexico, Japan and Russia. In the United States, geothermal exploration continues at a strong pace in many areas, including The Geysers, but no other type of system—hot water, dry rock, etc.—is operational. The next largest area of interest is in the Imperial Valley, where experiments are under way with heat exchange or "binary" systems to utilize the hot, corrosive underground brines found in one area, and other lower temperature fluids.

Steam production does decline in Geysers wells, contrary to early beliefs that the supply is inexhaustible. But well life is dependent on many variables such as spacing, depth, natural permeability and completion design. One example well on 5-acre spacing declined to 70,000 pph from 140,000 pph in five years.[3] Pressure buildup tests indicated that a major factor was reservoir pressure depletion, not well bore plugging. Wider spacings, of course, cut this decline significantly.

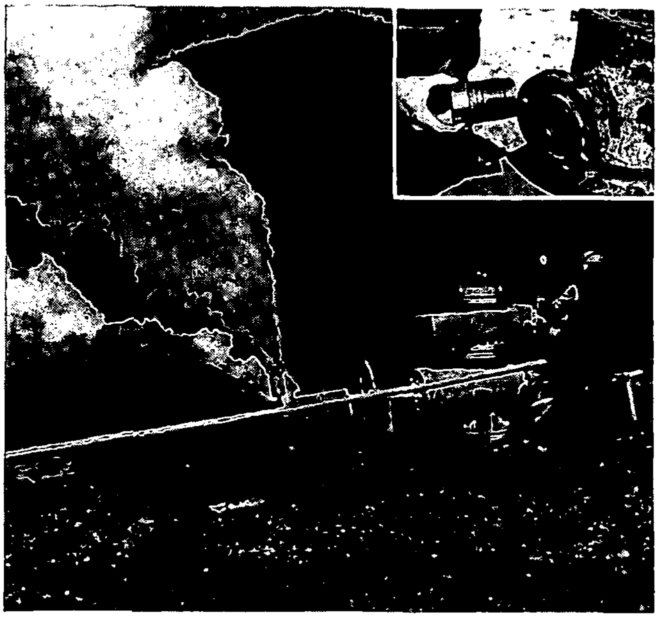
High velocity dry steam and entrained particles can damage drilling equipment. Top photo shows severely eroded tool joint shoulders. Lower photo shows typical hard band protection used to minimize erosion. Softer band is used on box OD to prevent casing wear. Harder material on shoulder takes direct force of flowing steam. Note that racked pipe is coated with a protective material to minimize atmospheric corrosion.

Some recharging may be possible with controlled injection but no quantitative evaluations of this effect are available. Presently, the remaining 20% of the condensed liquid from generating plants is reinjected. Too much water injected on close spacings may also flood-out nearby wells by temporarily altering the *in situ* super heat environment.

Pressure increases with depth but drilling costs also increase rapidly and rate of flow decreases due to the longer steam conduit to surface. A well at 10,000 feet, for example, may deliver 20% less than a comparable completion at 5,000 feet. These are major factors in designing completion systems.

Well and plant siting. Commercial operation generally follows exploratory and confirmation drilling by five years due to plant application lead times, delays for pipe line

Two types of banjo boxes. One style, utilizing a heavy BOP body, top, has double flanges for blooey line. When one side wears, the other flange can be used, to double life. Another style BOP body, bottom, is modified with addition of extra heavy welded box to serve as a vortex chamber for steam flow.



Wellhead on new completion not yet tied to gathering system has two ANSI 300 series, 500 psi 12-inch gate valves. As per common gas well practice, the lower valve is never opened or closed under differential pressure, to protect its sealing capability. Inner thread in wing valve outlet, inset, and hardened protector allow plug to be installed through a lubricator assembly for changing bad valves under pressure.

construction and operator evaluation after discovery.[3]

Plants can be sited after a discovery well and confirmation wells prove a significant "block of power." This has been done with as few as two wells. Then the required number of wells are completed to guarantee adequate steam supply, and the utility proceeds with plant design and construction. As output declines, additional wells are drilled.

Operator planning centers around plant capacity and its expected life. Sufficient acreage must be set aside within the "block" to accommodate additional wells.

With four new plants proposed and much exploratory area to be investigated, this general operational procedure indicates that significant drilling and completion activity will likely continue for several years.

How wells are drilled. Basic problems facing drillers are the steep terrain, hard abrasive formations from surface to TD and erosional effects of near sonic fluid velocities.

In narrow, grass-covered canyons between 2,500-3,000-foot mountain ridges, hillsides are very steep with 1,000-foot elevation changes per one-half mile, in some places. Often surface site economics dictate well locations and the hole may have to be deviated to reach a desired target.

A typical well may be 6,000-7,000 feet deep. Such a well may have 20-inch conductor to 150-200 feet, $13\frac{3}{8}$-inch to 2,000-2,500 feet, and a $9\frac{5}{8}$-inch liner to 6,000 feet (or higher), overlapping the $13\frac{3}{8}$-inch by 200-250 feet. The steam zone is completed open hole using compressed air as the bit cooling medium.

Hole sizes for this program are $17\frac{1}{2}$-inch opened to 26-inch, $17\frac{1}{2}$-inch, $12\frac{1}{4}$-inch and $8\frac{3}{4}$-inch. One operator has dense graywake from top to bottom, and hard formation rock bits of the non-sealed bearing type are used. Another area contains a problem serpentine section that is cased off.

Mud programs generally specify fresh water and gel, with lime viscosifier in the surface hole. The 12-inch hole is drilled with water, gel and a gel extender, and lignite. High temperatures may dehydrate and thicken mud, making additional treatment necessary.[4]

Water loss is no problem in the dense rock. Solids must be kept low with screens, desanders and desilters. For lost circulation, an inexpensive initial plug may be used followed by cement-type plugs.

Deviated holes may be desirable for economic location selection, as noted above. A controlled natural drift also

Geysers power plant development

Year	Unit no.	Supplier	Output, megawatts		
			Gross	Net	Cum.
1960	1	G. E.	12	11	11
1963	2	Elliot	14	13	24
1967	3	Elliot	28	27	51
1968	4	Elliot	28	27	78
1971	5	Toshiba	55	53	131
1971	6	Toshiba	55	53	184
1972	7	Toshiba	55	53	237
1972	8	Toshiba	55	53	290
1973	9	Tosoiba	55	53	343
1973	10	Toshiba	55	53	396
1975	11	Toshiba	110	106	502
	12	Toshiba	110	106	608
	13	G. E.	135	130	738
	14	Toshiba	110	106	844
	15	G. E.	55	53	897

Steam handling systems must be designed to deliver only superheated, particle-free steam to the turbine inlet at 350°F, 114 psi

may be allowed to cause the hole to cut as many fault planes as possible to expose maximum fracturing.

Heavy assemblies are used in the 17½-inch hole. In one well, three 9⅝ and seven 8-inch collars, and 10 joints of heavy weight drill pipe were used. Drill pipe may be 4½-inch, 20 pound, or 5-inch, 19.5 pound. With less prominent shoulders to erode, the larger diameter pipe may be preferable. In 8¾-inch hole, six 6½-inch collars and heavy weight pipe are commonly used.

Prior to drilling into steam zones, the system is converted to air. Rates of 3,000-4,000 cubic feet per minute are common, supplied from commercial compressor units. Pressures may be 140-150 psi initially, increasing to 450-600 psi as large volumes of steam are penetrated.

When air is connected, the BOP stack is modified by replacing the bell nipple with a rotating head and connecting up the "banjo box," a heavy walled erosion resistant chamber that diverts high velocity steam and particles into the blooey line to the muffler.

Old style mufflers have been replaced with a new style, vertical centrifugal unit of Union Oil Co. design into which steam and drilling particles flow tangentially, partially cushioned by an injected stream of water. This system promises to greatly cut potentially harmful and annoying noise, and extend muffler life.

The BOP stack, in the mud phase, is mounted on the 13⅜-inch head and 12⅜-inch bore master gate valve. A wear ring protects this valve during drilling. The stack then consists of a steam gate (with blank steel ram), a 12-inch, single gate BOP, the banjo box, a 12-inch double gate BOP (with DP and collar rams) and the bell nipple. Wing valves on the head are connected to kill and choke lines.

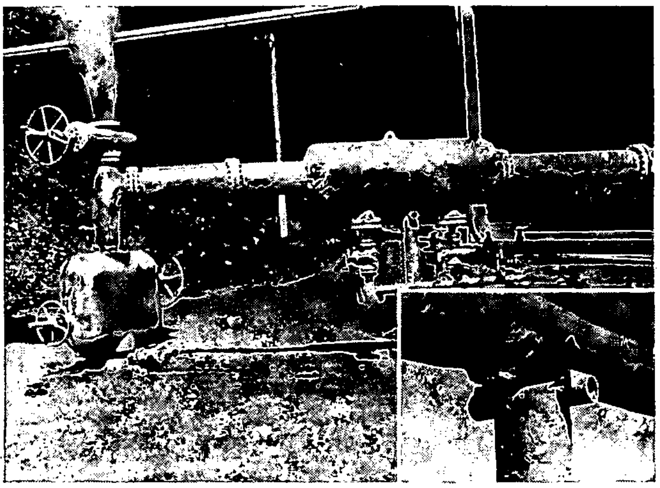
The 13⅜-inch is cemented with 100% excess 50/50 Pozmix, 35-40% silica flour. Liner is cemented with 50/50 Pozmix, 35% silica flour, friction reducer and retarder as needed. Neat cement is usually tailed in.

In the drill string, a metal-metal lower float valve is used to withstand 400°-500°F temperatures.

An average well now costs $500,000-$550,000, with 20-25% tangibles, including the wellhead. A rig may be on the hole 40-60 days.

Well capacity is first estimated using an orifice in the blooey line and flowing temperature. With the rig off, isochronal back flow tests similar to those used for gas wells give better evaluations of sustained flow rates.

Surface equipment consists of the 13⅜-inch wellhead



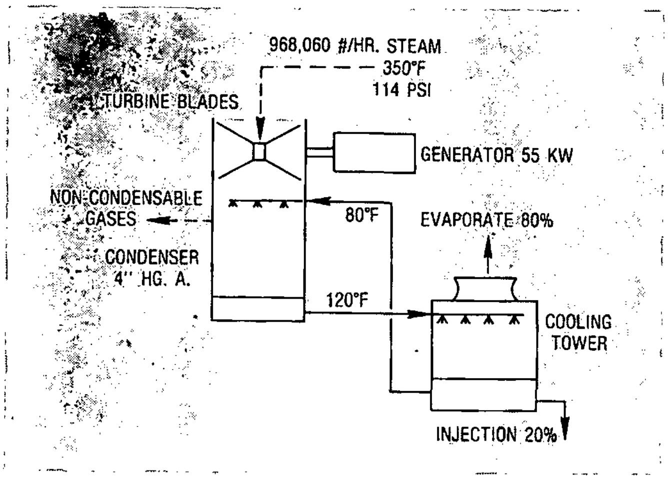
Producing well covered with fiber glass insulation has top access valve and centrifugal horizontal particle separator in the flowline. Two dirt legs under separator, vent small amounts of steam to blow out residue. All lines have expansion joints and flexible restraining mounts, inset, to permit movement with temperature changes.

During temporary plant shutdown, steam is vented through large mufflers to keep gathering system and wells at proper temperature. Intermittent operation is avoided as wells are sensitive to shut in and start up. Occasional system shutdown gives opportunities for reservoir pressure build-up tests.

with wing valves, two master valves, the tee, a top access valve (used almost exclusively to clean out the well after long shutdowns), and in the flowline: a centrifugal dust and particle remover and a differential pressure meter. All equipment is insulated with compressed 3-inch fiber glass pad and covers dyed an aesthetic green color.

Great care is taken to keep the dry steam particle free. The centrifugal horizontal particle trap mentioned above has a cone shaped nose facing the flow, with spiral vanes that create a high speed whirl to throw particles into the dirt leg. Units are reportedly 99% effective in removing 10-micron or larger particles. Dirt legs and other traps located at changes of direction are vented slightly to blow particles out of the line.

Gathering systems must be carefully sized to assure proper productivity at least cost. Depending on conditions, lines may be 10-16 inches at the well, increasing to 24 inches, 30 inches and finally 36 inches at the plant entry. Too-large lines may not be desirable, as cooling effects may counteract increased productivity from lower pressures.



Simplified power plant schematic shows flow of dry steam through turbine blades, condenser and cooling tower. Portion of steam is diverted through ejectors that maintain vacuum on condenser to draw off gases. Other systems use 2 kw of output leaving 53 kw net. Operating voltage is primarily 115 or 230 kv.

Plant Superintendent Bill Pearce, left, discusses operations of PG&E's Plants 5 and 6 with *World Oil's* Robert E. Snyder during recent visit to The Geysers.

Control valves at the plants, regulate line pressure, venting the system at the plant during shutdown. Wells are not normally shut in except for extended downtime as cooling and startup introduce liquids into the system, shock the well and loosen rock particles. Back-up rupture discs along the line set at about 180 psi are final protection against pressuring the system to 400-500 psi reservoir pressures.

How plants operate. Turbines are designed to accept 350°F, 114 psia dry steam. Liquids and particulate matter may damage the system.

Steam strikes the double sided turbine and converts its heat energy to rotational velocity which is transferred directly to the generator. The steam discharges into a chamber kept at 4 inches of mercury absolute pressure. Steam is condensed in this chamber, and hot water at 120°F is pumped to a large cooling tower.

From the first chamber, noncondensable gases are also drawn off, then cooled in additional condenser units before venting. Steam generally contains less than 1% noncondensable gases, in the following proportions:[5]

Carbon dioxide	79%
Hydrogen sulfide	5%
Methane	5%
Ammonia	7%
Nitrogen	3%
Hydrogen	1%
Ethane	trace

Tower water at 80°F is also used to cool lubricating oil and the turbine blade hydrogen cooling system.

In the over-all process, some 80% of the steam condensate is evaporated. The remaining 20% is reinjected into the producing reservoir. Liquids are not discharged into streams of the area.

Some H_2S is returned to the reservoir in injected fluid; the output to the atmosphere from a geothermal plant is estimated to be one-fourth that of a coal plant. And total CO_2 discharge from the comparable sized fossil fuel plant is 20 times that of a geothermal plant.[5]

Still, released gases give the area a sulfur odor typical of that around any large hot mineral spring. And protective coatings must be used on exposed steel where surface corrosion would be a problem.

How operators are paid for steam. All steam is purchased by PG&E according to a lengthy, negotiated formula that considers PG&E's cost of power generation by fossil and nuclear fuels.[6] The price is revised each Jan. 1, using the previous year's data. The formula considers the following:

1. A constant 2.11 mills/kwh
2. PG&E's fossil fuel costs for preceding year
3. Fossil fuel costs for 1968 (31.66 cents/million Btu)
4. Lowest operating net heat rate, Btu/kwh, of the most efficient fossil fuel unit (8,274 Btu/kwh to date). And the comparable value for 1968 (same)
5. Average net cost of fuel for PG&E's nuclear plants for previous year, and
6. Total output from fossil and nuclear plants in previous year.

In 1974 and 1975, PG&E's base price, excluding 0.50 mills/kwh effluent disposal payment, was 3.23 and 6.89 mills/kwh, respectively. One independent report presented estimates of prices more than double that amount by 1985.[6]

ACKNOWLEDGMENT

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