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DETERMINATION OF THE 5 MW GROSS NOMINAL DESIGN CASE BINARY CYCLE FOR POWER GENERATION AT RAFT RIVER, IDAHO

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MASTER

December 1976

EG&G Idaho, Inc.

IDAHO NATIONAL ENGINEERING LABORATORY

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EG&G Idaho, Inc.

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ABSTRACT

This report documents a series of Rankine Cycle studies for power generation utilizing geothermal fluid as the heat source and isobutane as the working fluid. To find the plant configuration which would most effectively utilize the available energy, a parametric study was performed. The study considered the desirability of supercritical, single boiler or double boiler cycles, and the relative boiler temperatures and percentage isobutane flow split between the boilers in the double cycles for geothermal fluid temperatures of 260°F to 360°F. This study was designed to discover thermodynamic trends which would point to an optimum isobutane cycle for geothermal fluid temperatures in this temperature range. The results of the parametric study were applied to derive a Nominal Design Case for a demonstration plant at Raft River, with a geothermal fluid resource at 290°F. In addition, plant variations due to tolerances applied to thermodynamic properties and other key factors are included.

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INTRODUCTION

This report documents a series of Rankine Cycle studies for power generation utilizing geothermal fluid as the heat source and isobutane as the working fluid. The end purpose of this study was to determine the nominal configuration and steady state operation characteristics for a 5 MW gross plant operating from the Raft River Idaho Geothermal Resource. To find the plant configuration which would most effectively utilize the available energy, a parametric study was performed. The study considered the desirability of supercritical, single boiler or double boiler cycles, and the relative boiler temperatures and percentage isobutane flow split between the boilers in the double boiler cycles for geothermal fluid temperatures of 260°F to 360°F. This study was designed to discover thermodynamic trends which would point to an optimum isobutane cycle for geothermal fluid temperatures in this temperature range. Optimum was defined as the case which utilized the greatest amount of available geothermal fluid energy, and was indexed as a variable called effectiveness (net power output per pound of geothermal fluid circulated through the plant). The results of the parametric study were applied to derive a Nominal Design Case for a demonstration plant at Raft River, with a geothermal fluid resource at 290°F.

RESULTS

The Nominal Design Case was defined for the Raft River geothermal fluid resource at 290°F. The optimum combination for that temperature is a cycle with two boilers operating at 240°F and 180°F with the isobutane flow split so that there is approximately twice as much flow going through the high pressure boiler as through the low pressure boiler. The effectiveness for this system is 3.2 watt - hrs/lb of geothermal fluid. The net thermal efficiency is 7.5%. Parasitic losses, including geothermal fluid supply pumping and reinjection, are on the order of one third of the gross power. Thus, the Raft River plant, which is to be rated at 5 MW gross electrical power output requires about 40 MW thermal input, will produce a net power of 3.35 MW (e), and requires approximately 1×10^6 lb/hr of geothermal fluid. The parametric study yielded several thermodynamic behavioral patterns related to the binary Rankine Cycle. These are summarized in Section 2.4 and discussed more fully in Sections 2.2 and 2.3.

1.0 Definition of Terms

Brine: A short term used to refer to the geothermal fluid. This usage does not imply that the geothermal fluid has a significant saline content; it is only used for abbreviation and convenience.

Effectiveness: The effectiveness is a measure of brine utilization. It is defined as the net power output of the plant per pound of brine circulated (Btu/lbm brine). The brine wells are a major plant cost, therefore it is important to maximize the effectiveness, resulting in a minimum brine flow rate.

Flow Split: ($WF2/WF1$) For a two boiler system, the flow split is the ratio of the mass flow in the low pressure (LP) path to the flow in the high pressure (HP) path. A flow split of 0.0 indicates a single boiler system.

Pinch Point: The pinch point is a hardware - based parameter which is the minimum difference between the isobutane temperature and the brine temperature in the system. It occurs at the brine outlet of the boiler.

Pinch Point Control: In a two-boiler system, the pinch points and the flow split are closely related parameters. The minimum pinch points for both boilers are input, as well as the flow split. There is a unique flow split value at which both pinch points are minimized. For any other flow split, one of the pinch points will exceed the minimum value. The pinch point which is minimized is said to control, because it is from this minimum temperature difference that the brine flow requirement is calculated.

Raft River: Refers to the location of the geothermal resource in the Raft River Valley about 15 miles south of Malta, Idaho.

2.0 Parametric Study

In order to determine the boiler temperature(s) for a geothermal isobutane binary cycle, at which brine utilization is the highest, a parametric study was performed, using a modified version of the computer program GEOSYS.⁽¹⁾ The basic model was documented in Reference 1, and current modifications are documented in Appendix A of this report. The GEOSYS model used is shown schematically in Figure 2.0-1 and consists of two boilers, two preheaters, two turbines, a condenser and several pumps.

The parametric study considered single boiler cases and combinations of boiler temperatures and flow splits in two boiler cases for high and medium temperature brine. Brine temperature was varied in 20°F increments from 260°F to 360°F and included a 290°F case corresponding to brine temperatures encountered at Raft River. For brine temperatures of 260°F to 300°F, several high pressure (HP) boiler temperatures were chosen, and for each of these several low pressure (LP) boiler temperatures were chosen. Then for each combination of boiler temperatures, the flow split was varied from zero (single boiler case) to a value at which the effectiveness reached its peak. For the high temperature brine cases, 320°F to 360°F, supercritical cycles were run in addition to the boiling cycles described above.

For all cases, the condenser temperature, and therefore turbine back pressure, were fixed at a value previously determined by cooling tower capabilities and atmospheric conditions.

Superheat and regeneration were not considered in this study for two reasons: First, the main purpose of this plant is to gain experience with various operating modes so that larger power plants may be designed with more certainty. Therefore, the plant must be able to produce power, and at the same time, be flexible enough to allow experimental operating procedures and hardware. Superheaters and regenerators are not essential components

Figure 2.0-1 Double Boiling Isobutane Binary Cycle Diagram

for this plant and working fluid (turbine exhaust occurs near the dome) and may be added in a future phase of development. Second, previous studies⁽¹⁾ have shown that although superheaters and regenerators improved the cycle thermodynamically, the improvement in cycle performance did not offset the accompanying cost increase for an experimental plant.

2.1 Assumptions Used for the Parametric Study of the Geothermal Binary Cycle

The basic assumptions were as follows:

1. All pump efficiencies were assumed to be 80%. Turbine efficiency was assumed to be 85% and electrical efficiency was assumed to be 95%.
2. The limiting boiler pinch point was assumed to be 10°F .
3. The overall pressure drop for each leg for the isobutane flow was set at 40 psid. Three psid was assumed across the isobutane condenser.
4. The total brine pump pressure rise was set equal to 480 psid due to system design requirements. This figure includes the pumping requirements for the down-hole pumps, the reinjection pumps (at 300 psia), line losses and elevation head requirements.
5. Cooling water system power consumption was assumed to be a 10 psid pressure drop in the condenser, the line pressure drops, a 40-ft head rise required by the cooling tower, and tower fan power requirements.
6. The condenser water temperature inlet was set at 75°F . This was obtained from cooling tower performance curves and the worst climatic conditions existing at Raft River. The water outlet of the condenser was set at 95°F . Allowing 10°F terminal difference for the heat exchanger, the isobutane condensing temperature was therefore set at 105°F . Four degrees of subcooling were added to protect the isobutane circulating pump.
7. The overall heat-transfer coefficients (U's) were derived from manufacturers data⁽²⁾ corresponding to a fouling factor of $0.003 \frac{\text{hr-ft}^2}{\text{Btu}} - ^{\circ}\text{F}$. These are listed in Table I.

TABLE I

Overall Heat Transfer Coefficients Used for Heat Exchanger Calculations

<u>Heat Exchanger Description</u>	<u>Fouling Factor = 0.003 (Btu/hr-ft²-°F)</u>
HP Boiler	157
HP Preheater	120
LP Boiler	145
LP Preheater	110
Condenser	133

2.2 Medium Temperature Brine Cases

2.2.1 Single Boiler Cycles

A plot of effectiveness vs boiler temperature for the single boiler system is found in Figure 2.2.1-1 for brine temperatures of 260°F, 280°F, 290°F, and 300°F. For a given brine temperature, effectiveness increases as boiler temperature increases due to the increased turbine pressure ratio. The curve turns down for two reasons: As turbine inlet pressure increases, pumping requirements also increase, reducing usable power, and, as the boiler temperature approaches the brine temperature, the boiler pinch point limitations require increased brine flow, and effectiveness drops.

Figure 2.2.1-2 represents a cross-plot of effectiveness vs brine temperature for the most effective single boiler temperature at a given brine temperature. As brine temperature increases, effectiveness increases due to the higher temperature heat source. There is more energy available from the brine and therefore less brine flow is required. Since the boiler pinch point controls the brine flow rate as brine temperature increases, there is a larger log mean temperature difference for the preheater, allowing better heat transfer and a smaller preheater.

2.2.2 Double Boiler Cycles

Typical flow split variation curves for the 300°F, 290°F, 280°F, and 260°F cases are shown in Figures 2.2.2-1 through 2.2.2-4. A complete set of curves can be found in Reference 3. Figure 2.2.2-1 shows the effect of varying the flow split for a brine inlet temperature equal to 280°F, an HP boiler temperature of 240°F, and an LP boiler temperature of 140°F. This case is representative of those cycles in which the HP and LP boiler temperature difference and the HP boiler and brine inlet temperature difference are relatively large (40°F). The graph actually shows two curves: The first, starting from a flow split of zero, is the effectiveness curve obtained while the HP boiler pinch

Figure 2.2.1-1 Effectiveness vs. Boiler Temperature for Various Brine Temperatures, Single Boiler Case

Figure 2.2.1-2 Maximum Effectiveness vs. Brine Inlet Temperature for Single Boiler Case

point controls. The second curve, which intersects the first, is indicative of cycle performance when the flow split becomes large enough to shift control to the LP boiler pinch point. The intersection of the curves occurs at the point of maximum effectiveness, where both pinch points are equal to 10°F . In almost all cases, it was found that the maximum effectiveness occurred at a flow split corresponding to both pinch points minimized at 10°F . When the HP boiler pinch point controls, the brine temperature at the entrance to the HP preheater is fixed, thereby fixing the brine flow rate. The LP pinch point floats, depending upon the amount of brine energy remaining after the HP preheater and the LP boiler. As more isobutane flow is channeled to the LP flow path (flow split is increased), the LP pinch point decreases to the minimum value, and both pinch points are minimized. If the flow split is further increased, the control shifts to the LP boiler pinch point. The brine temperature at the entrance to the LP preheater is fixed and brine flow must increase to maintain that temperature as the LP boiler energy demands increase. Then, the HP pinch point increases due to the decrease in HP boiler requirements (less isobutane flow) and the increased brine flow rate.

There appears to be a point of higher effectiveness, as the curve bends backwards, with increasing effectiveness at a flow split of about 1.15. This is on the LP pinch point controlling curve, in the portion where the LP boiler pinch point is 10°F , and the HP boiler pinch point is allowed to drop below 10°F . Decreasing the pinch point allows more energy to be extracted from the brine, thereafter effectiveness increases. However, so does the heat exchanger area, and therefore plant cost. A pinch point of 0.0°F , requiring infinite heat exchanger area, would result in the most effective cycle. Since the minimum allowable pinch point is 10°F for this study, the higher effectiveness point is not included.

MEDIUM TEMPERATURE BRINE

Figure 2.2.2-1 Sensitivity Study for Double Boiler Cycle - Flow Split vs. Effectiveness

MEDIUM TEMPERATURE BRINE

Figure 2.2.2-2 Sensitivity Study for Double Boiler Cycle - Flow Split vs. Effectiveness

Figure 2.2.2-2 illustrates a cycle in which the boiler temperatures are closer together and closer to the brine inlet temperature. For this case there is a brine inlet temperature of 260°F , and HP boiler temperature of 230°F and the LP boiler temperature of 210°F . The curves are similar to those in Figure 2.2.2-1, but the curve which indicates LP boiler pinch point control is flatter. This means the effectiveness is less sensitive to increases in flow split after the shift point (flow split = .66). In other words, since the two boiler temperatures are relatively close together, the effect of shifting flow to the LP path is less pronounced than in Figure 2.2.2-1, where the LP boiler temperature is significantly lower than the HP boiler temperature.

This flattening effect is more pronounced in Figure 2.2.2-3 which shows the case of brine inlet temperature equal to 300°F , with an HP boiler temperature of 230°F , and an LP boiler temperature of 210°F . In this instance there are two factors which contribute to producing a system which is quite insensitive to flow split increases: The brine temperature is significantly higher than the HP boiler temperature, and the two boiler temperatures are close together. The large temperature difference between the brine and the HP boiler causes the pinch point control shift to occur early (flow split $<.1$). The fact that the difference between the HP and LP boiler temperatures is small makes the curve flat, since the system sees little difference in specific power output or specific pumping power requirement between the two boilers. See Section 2.2.3 for a more complete discussion of this phenomenon.

Figure 2.2.2-4 is an illustration of the exception to the rule that effectiveness is maximized where both pinch points are minimized. In this case, the brine temperature is 280°F , the HP boiler temperature is 260°F , and the LP boiler temperature (110°F) is very close to the condensing temperature (105°F). This results in a pressure ratio of only 1.07 across the LP turbine, producing

MEDIUM TEMPERATURE BRINE

Figure 2.2.2-3 Sensitivity Study for Double Boiler Cycle - Flow Split vs. Effectiveness

MEDIUM TEMPERATURE BRINE

Figure 2.2.2-4 Sensitivity Study for Double Boiler Cycle - Flow Split vs. Effectiveness

very little power per pound of isobutane. In fact, the parasitic losses for the LP loop are greater than the turbine output, resulting in a negative net power out of the LP turbine. Therefore, any increase of flow to the LP loop would decrease effectiveness.

Figures 2.2.2-5 through 2.2.2-8 are plots of effectiveness vs LP boiler temperature for several HP boiler temperatures at brine temperatures of 260°F, 280°F, 290°F, and 300°F. The points on these curves represent the most effective case for each pair of boiler temperatures, as found from the flow split curves. At the maximum effectiveness, both boiler pinch points are minimized at 10°F. Figures 2.2.2-9 through 2.2.2-11 are cross plots of the above curves, showing effectiveness vs HP boiler temperatures. The 260°F brine cases were not cross plotted because only two LP boiler temperatures were studied.

Figure 2.2.2-12 is a plot of effectiveness vs brine temperature. The effectiveness is that for the most effective boiler combination for each brine temperature. As in the single boiler case, the effectiveness increases with brine temperature.

2.2.3 Results of the Medium Temperature Brine Cases

All of the flow split plots for the double boiler cases include a point of flow split equals zero, or the single boiler case at the HP boiler temperature. With the exception noted in Section 2.2.2, at a given brine temperature, the maximum effectiveness for each two-boiler combination was found at the flow split where both pinch points were minimized at 10°F, and the single boiler cases were less effective than any two-boiler temperature. The boiler pinch point controls the brine temperature at the boiler exit, and the brine is rejected from the system at elevated temperatures. The LP boiler and preheater utilize the previously wasted energy, and the cycle becomes more effective. A

MEDIUM TEMPERATURE BRINE

Figure 2.2.2-5 Effectiveness vs LP Boiler Temperature for Varying HP Boiler Temperatures

Figure 2.2.2-6 Effectiveness vs LP Boiler Temperature for Varying HP Boiler Temperatures

MEDIUM TEMPERATURE BRINE

Figure 2.2.2-7 Effectiveness vs LP boiler Temperature for Varying HP Boiler Temperatures

Figure 2.2.2-8 Effectiveness vs LP boiler Temperature for Varying HP Boiler Temperatures

Figure 2.2.2-9 Effectiveness vs HP Boiler Temperature for Varying LP Boiler Temperatures

MEDIUM TEMPERATURE BRINE

Figure 2.2.2-10 Effectiveness vs HP Boiler Temperature for Varying LP Boiler Temperatures

Figure 2.2.2-11 Effectiveness vs HP Boiler Temperature for Varying LP Boiler Temperatures

Figure 2.2.2-12. Maximum Effectiveness vs. Brine Inlet Temperature - Double Boiler Case

third boiler would further increase the cycle effectiveness, but the increase is marginal compared to the cost of heat exchangers, pumps, turbines, etc. For purposes of comparison, the maximum effectivenesses obtainable for a brine temperature are plotted in Figure 2.2.3-1 for the single and double boiler cases. This is a combination of Figure 2.2.1-2 and Figure 2.2.2-12. The double boiler combinations run between 20-25% more effective than the single boiler cases for a given brine temperature.

The point of maximum effectiveness, where both pinch points are minimized, occurs at the flow split at which pinch point control shifts from the HP boiler pinch point to the LP boiler pinch point. This "shift point" is dependent upon the relationship between the brine inlet temperature (TBI), HP boiler temperature (TF1), and LP boiler temperature (TF2). Figure 2.2.3-2 illustrates the "shift point" dependency upon boiler temperatures for a given brine inlet temperature of 300°F. As TBI-TF1 increases, the "shift point" moves toward a flow split of zero, or the single boiler case. But for a given TBI-TF1, as TF1-TF2 increases, the "shift point" also increases. Therefore, for a set TBI, the "shift point" approaches zero as TF1-TF2 approaches zero and as TBI-TF1 gets large.

The "shift point" also appears to be dependent upon the value of brine inlet temperature. Figure 2.2.3-3 shows the relationship between brine temperature and shift point for two values of TBI-TF1, 20°F and 30°F. As previously noted, the "shift point" decreases as TF1-TF2 decreases. Also, as TBI increases the "shift point" decreases. Therefore, for a set TBI-TF1, the "shift point" approaches zero as TF1-TF2 approaches zero and as TBI gets large.

Combining these trends, then, as the brine temperature increases, and as TBI-TF1 increases, and as TF1-TF2 decreases, the "shift point" approaches

Figure 2.2.3-1 Comparison of Maximum Effectiveness vs Brine Inlet Temperature for Single and Double Boiler Cases

zero, or the single boiler case. At the "shift point" neither pinch point controls, both pinch points are minimized and effectiveness is maximized.

Physically then, the "shift point" approaches zero when the brine temperature is relatively high, the LP boiler temperature is comparatively low, and the LP boiler temperature is very close to the HP boiler temperature.

MEDIUM TEMPERATURE BRINE

Figure 2.2.3-2 Flow Split at which pinch point control shift occurs vs the temperature difference between the HP and LP boiler for several temperature differences between the brine and HP boiler. Brine inlet temperature = 300°F

Figure 2.2.3-3 Flow Split at which pinch point control shift occurs vs the temperature difference between the HP and LP boilers for various temperature differences between the brine and HP boiler

2.3 High Temperature Brine Cases

2.3.1 Single Boiler Cycles

Single boiler cases were run for brine temperatures of 320, 340, and 360°F. Figure 2.3.1-1 is a plot of effectiveness vs boiler temperature for those brine temperatures. As expected, effectiveness increases with boiler temperature due to the increased turbine pressure ratio. The effectiveness values themselves are high compared to the medium temperature brine cases. This effect is caused by the fact that less high temperature brine flow is required to supply the same amount of energy at a given medium temperature flow rate.

The effectiveness curve of the 320°F brine case makes a sharp bend at a boiler temperature of about 250°F and continues to rise instead of laying over like the 340°F and 360°F brine cases. The reason for this is found in the relationship between boiler pinch point, boiler latent heat of vaporization, and preheater energy requirements. Several things happen simultaneously as boiler temperature increases:

1. Isobutane flow decreases, because of the increased turbine output. This decreases the brine flow requirement.
2. The boiler pinch point fixes the brine temperature at the boiler exit.
3. The preheater requirement increases because the isobutane must be heated to a higher temperature.
4. The latent heat of vaporization decreases. This means that brine flow further decreases due to the smaller energy requirement. In fact, the rate of decrease of the latent heat is very rapid near the top of the dome. It is down 30% from 260°F to 270°F as opposed to less than 10% per 10°F for boiler temperatures up to 250°F.
5. It should be noted that at boiler temperatures of 250°F, 260°F and 270°F, the turbine expands through the dome but exhausts into the superheat region. However, the maximum percentage liquid is less than 3% by volume, not a significant amount. Any degradation in turbine efficiency would be negligible, therefore no superheat was added to clear the dome.

For the 320°F brine case, the decrease in latent heat is so rapid from 250°F to 270°F that the effectiveness climbs dramatically. The brine flow is great enough, however, that the brine energy remaining after the boiler demands is sufficient for preheating.

For the 340°F and 360°F brine cases, the latent heat at high boiler temperatures is small enough, and the brine temperature is high enough, that the brine flow is too low to provide energy for the increased preheater load when the boiler pinch point is fixed at its minimum, 10°F. Therefore, the pinch point must be raised and brine flow must increase to accomplish the preheating. In fact, it is the preheater terminal difference which controls the brine flow rate instead of the boiler pinch point, and, because of the elevated pinch point, the 340°F and 360°F brine effectiveness curves lay over at high boiler temperatures.

Figure 2.3.1-1 Boiler Temperature vs Brine Inlet Temperature for High Temperature Brine, Single Boiler

2.3.2 Supercritical Cycles

For the supercritical cases, there is no discrete preheater or boiler, but a single heater. Since there is no boiler (no latent heat of vaporization), there is no pinch point defined. Several checks are made to ensure that there is no temperature overlap in the heater, but the pinch point limitations inherent in the boiler systems do not exist. The disadvantages of the supercritical cycles are the high operating pressures (critical pressure is 529 psia) which significantly increase the isobutane pumping power requirements.

Figures 2.3.2-1 through 2.2.2-3 show effectiveness vs turbine inlet temperature for brine temperatures of 360°F, 340°F, and 320°F. The turbine inlet pressures and temperatures were chosen such that an isentropic expansion would exhaust at the saturation line. The 360°F and 340°F brine cases exhibit increasing effectiveness with turbine inlet temperature until a maximum point is reached and the curve turns downward. This behavior is due to the fact that pressure is not a linear function of temperature, and pressure increases faster than temperature. The temperature increase causes a rise in thermodynamic efficiency. The pressure increase causes an increased pressure ratio across the turbine, and a larger gross power output. However, the pressure increase also builds up the pumping losses. At a trade-off point (maximum effectiveness) the pumping losses overshadow the thermodynamic efficiency increase, and the effectiveness drops.

Figure 2.3.2-3, the 320°F brine case, does not show a maximum effectiveness point at this lower brine temperature, the effect of raising turbine inlet temperature is less pronounced, and only the effect of the pumping power increase is seen.

Figure 2.3.2-1 Turbine Inlet Temperature vs Effectiveness for the Supercritical Case
TBI = 360°F

Figure 2.3.2-2 Turbine Inlet Temperature vs Effectiveness for the Supercritical Case
TBI - 340°F

Figure 2.3.2-3 Turbine Inlet Temperature vs Effectiveness for the Supercritical Case
TB1 - 320°F

2.3.3 Double Boiler Cycles

Double boiler cases with HP boiler temperatures of 270°F, 260°F and 240°F were run for the high temperature brine cases. The flow split curves were typified by those in Figures 2.3.3-1, 2.3.3-2, and 2.3.3-3. Figure 2.3.3-1 is the typical flow split curve for a brine temperature of 320°F, with HP and LP boiler temperatures of 260°F and 160°F, respectively. The maximum effectiveness occurs at a flow split of about 0.14 (both pinch points equal to 10°F), with the effectiveness dropping rapidly as more flow is directed to the LP boiler. This rapid dropoff is caused by the fact that the LP boiler pressure is low enough that the reduction in specific turbine power penalizes the system severely. Figure 2.3.3-2 presents an interesting phenomenon: The maximum effectiveness is found in the single boiler case. Brine temperature is 360°F, with HP and LP boiler temperatures of 270°F and 240°F, respectively. At the high brine temperatures, the pinch point limitation inherent in medium temperature brine single boiler operation is no longer a problem.

For the medium temperature brine single boiler cases, the brine flow was increased to provide the needed brine energy in the boiler, thereby reducing effectiveness. A second boiler was added to capture the energy rejected at exit of the preheater. More and more flow was diverted to this LP boiler until maximum effectiveness was achieved. For the high temperature brine cases, the controlling factor is not the boiler pinch point, but the LP preheater exit temperature. The pinch point must be increased in order to provide enough energy for the preheater. Therefore, the addition of a second

EFFECTIVENESS (Btu/lbm of Brine)

Figure 2.3.3-1 Sensitivity Study for Double Boiler Cycle - Flow Split vs. Effectiveness

Figure 2.3.3-2 Sensitivity Study for Double Boiler Cycle - Flow Split vs. Effectiveness

Figure 2.3.3-3 Flow Split vs Effectiveness -

boiler would accentuate this problem, requiring more brine flow, and lowering effectiveness. For the high temperature brine cases, the LP boiler pinch point defines the brine flow rate, but it must be increased to provide enough brine energy for the LP preheater, which really is the controller. This in turn increases the HP pinch point, indicating that energy is being wasted in that portion of the cycle, too.

Figure 2.3.3-3 is a typical family of flow split curves, produced for the 340°F brine temperatures, and 240°F HP boiler temperature cases.

Figures 2.3.3-4, 2.3.3-5, and 2.3.3-6 are plots of LP boiler temperatures vs effectiveness. The maximum effective flow split cases for each of three HP boiler temperatures at each brine inlet temperature are plotted. The 340°F and 360°F brine temperature cases show that the most effective boiler combination is the single boiler case, as discussed above. The 320°F brine case curves retain the characteristic shape of the medium temperature brine cases, although the curves are much flatter.

HIGH TEMPERATURE BRINE
Brine Inlet Temperature = 360°F

Figure 2.3.3-4 LP Boiler Temperature vs Effectiveness

HIGH TEMPERATURE BRINE
Brine Inlet Temperature = 340°F

Figure 2.3.3-5 LP Boiler Temperature vs Effectiveness

HIGH TEMPERATURE BRINE
Brine Inlet Temperature = 320°F

Figure 2.3.3-6 LP Boiler Temperature vs Effectiveness

2.3.4 Results of the High Temperature Brine Cases

For the 360°F and 340°F brine cases, the single boiler cases were more effective than any of the double boiler combinations for the same HP boiler temperature. The 320°F brine cases showed maximum effectiveness at a double boiler cycle, although the curves are very flat. The single boiler cycles were also more effective than the supercritical cycles for each brine temperature. Figure 2.3.4-1 is a comparison of the single boiler vs supercritical cycles on the basis of turbine inlet temperature. The same data is plotted in Figure 2.3.4-2 on the basis of turbine inlet pressure. The second graph is a good indicator of the pressure range involved. It is the pumping losses at the higher pressures which kill the cycle efficiency. Figure 2.3.4-3 illustrates the increase of isobutane pumping power as turbine inlet temperature increases. Therefore, although the supercritical cycle looks attractive from the standpoint of simplicity, the single boiler cycle is more effective at the high brine inlet temperatures.

Figure 2.3.4-2

Figure 2.3.4-3 Turbine Inlet Temperature vs Percentage of Gross Power that is Required for the Isobutane Circulating Pump

2.4 Results of the Parametric Study

In general, five new trends were noted:

1. For the medium temperature brine double boiler cases, the optimum effectiveness was obtained corresponding to a flow split at which both pinch points were minimized. This indicates that, from a thermodynamic availability standpoint, both boilers are working equally hard. As the brine inlet temperature increases, the point of maximum effectiveness moves to a lower flow split, indicating that, for the best brine utilization, as the brine temperature increases, more isobutane flow should be directed to the HP boiler. The reason for this effect is found in the pinch point limitations of the boilers. At the lower brine temperatures, the pinch point requirement dictates high brine flow to accommodate one boiler. This results in an elevated brine exit temperature, which reduces effectiveness. If the brine is then cycled through a lower temperature boiler and preheater, this "leftover" energy can be utilized, and effectiveness increases.

2. At high brine temperatures, the point of maximum effectiveness is located at a flow split of zero. In other words, the single boiler case is more effective than any double boiler combination, where the HP boiler is set at the single boiler temperature. This happens because, for a given single boiler energy requirement, the brine flow rate is reduced at high brine temperatures. The pinch point restriction encountered at the medium brine temperatures is no longer a problem, and brine is not exhausted at elevated temperatures. In fact, the brine flow must be substantially increased in order to accommodate a second boiler.

Since any lower temperature (and pressure) boiler will produce less specific power than the first boiler, effectiveness decreases. Figure 2.4-1 is a graph of the flow split values at which the maximum effectiveness occurs vs brine inlet temperature. The curve indicates that the high temperature brine cases are really a logical extension of the trend noted in the medium temperature brine cases: As brine temperature increases, the point of maximum effectiveness moves to a lower flow split until a flow split of zero (the single boiler case) is reached for the 340°F and 360°F brine cases. In short, the second boiler is useful only at brine temperatures when pinch point limitations cause wasted brine energy in the single boiler system.

3. Furthermore, at high brine temperatures, the single boiler cycle runs into pinch point problems of a different type. In this case, the brine flow as dictated by the boiler pinch point decreases to the point that there is not enough brine energy to accomplish the preheating. The terminal difference on the preheater actually determines minimum brine flow, the boiler pinch point is increased, and the effectiveness drops.

4. Although brine temperature has a major effect upon the value of the flow split at which maximum effectiveness occurs, there are other factors which also enter the picture. The flow split at which the pinch points are both minimized and control shifts (maximum effectiveness), or the "shift point" is also dependent upon the temperature difference between the brine and the HP boiler and upon the temperature difference between the two boilers. As the temperature difference between the brine and the HP boiler increases (the HP boiler temperature is low relative to the brine temperature), the "shift point" decreases. As the temperature difference between the two boilers decreases, the "shift point" decreases. Therefore, there are three factors

which affect the flow split value at which effectiveness is optimized; the brine inlet temperature, the temperature difference between the brine and the HP boiler, and the temperature difference between the two boilers.

5. The supercritical cycle was not as effective as the single boiler cycle for the high temperature brine cases. The high pressures required for the supercritical cycle require a large parasitic loss in the form of isobutane pumping power. The increase in turbine output due to the increased pressure ratio is not large enough to offset the loss when the cycle is compared to the lower pressure single boiler cycle. It may be possible to develop a better cycle using regeneration, but for this study, all cycles were formulated to minimize the amount of superheat remaining after the turbine expansion. At any rate, it would appear that for the high temperature brine, another working fluid or fluid mixture may be the answer for a supercritical cycle.

MAXIMUM EFFECTIVE CASES FOR EACH BRINE TEMPERATURE

Figure 2.4-1 Brine Inlet Temperature vs Flow Split at which Maximum Effectiveness is Achieved.

3.0 Determination of the Nominal Design Case (NDC)

The parametric study (Section 2.2) for the 290°F brine temperature case was used to determine the optimum thermodynamic cycle for the Nominal Design Case. The 290°F brine case was chosen because the wells at Raft River, Idaho are producing brine at that temperature, and one of the purposes of this study was to determine optimum boiler temperatures for an isobutane cycle power plant to be built at that site.

The Nominal Design Case state point is shown in Figure 3.0-1. The plant is a two boiler system, at 240°F and 180°F, condensing at 105°F and producing 5 MW gross or 3.35 MW(e) net. The two boiler system was chosen to alleviate the pinch point problems discussed in Section 2.0. The NDC operates with a flow split of 0.524 at an effectiveness of 10.97 Btu's per pound of brine.

Binary Cycle, Dual Boiling Geothermal Power Plant

State Point	Temp. (°F)	Flow Rate lbm/hr
1	105	9.34×10^5
2	180	6.13×10^5
3	240	6.13×10^5
4	240	6.13×10^5
5	130	6.13×10^5
6	128	9.34×10^5
7	101	9.34×10^5
8	180	3.21×10^5
9	180	3.21×10^5
10	123	3.21×10^5
11	290	1.04×10^6
12	250	1.04×10^6
13	222	1.04×10^6
14	190	1.04×10^6
15	144	1.04×10^6
16	75	6.72×10^6
17	95	6.72×10^6

Net Power = 3.35 MW(e)

Gross Power = 5 MW

Pumping Power

Brine = .59 MW

Isobutane = .54 MW

Coolant Water = .52 MW

Plant Cost = 31.15 mils/kwh

Effectiveness = 10.97 BTU/lb of Brine

Brine Inlet Temp. = 290°F

Brine Reinjection Press. = 300 psia

Boiler #1 Pressure = 381.57 psia

Boiler #2 Pressure = 203.04 psia

Flow Split (W_2/W_1) = .524

4.0 Tolerance Study of the Nominal Design Case

Several of the parameters input into the computer model are not known exactly. Therefore a study was performed to determine the effect on plant performance due to the tolerances in the input by using the "floating power" option of GEOSYS. The boiler temperatures and pressures and the heat exchanger areas of the NDC were held constant to simulate the actual plant configuration while each input parameter was varied separately by its tolerance values. This produces a new steady-state case with different effectiveness, power output, flow rates, and brine temperatures. There were four major areas of uncertainty: brine temperatures, condensing temperature, brine-side fouling factor, and specific heats (C_p) of the isobutane. Additionally, a separate condenser study was run to determine the effect on plant performance of further lowering the condensing temperature to account for the possibility of lower temperature cooling water being available from the cooling tower during the colder months of the year. Since the tolerance study functions to bracket the normal plant operating regime, and these studies describe another operating condition, they are not actually a part of the NDC tolerance study, but the analysis was performed in the same manner, and therefore is included in this portion of the report.

4.1 Brine Inlet Temperature

The NDC is based upon brine supplied at 290°F. Since the geothermal wells have not all been drilled, and since they are a fairly new and untried resource, the tolerance on brine temperature was estimated at $\pm 10^{\circ}\text{F}$ or $\pm 3.5\%$. Running a case at 280°F, net power was down 4.2%, with effectiveness down 16.4%. Although the total isobutane flow increased by only 4.5%, the flow split shift required to minimize both boiler pinch points increased LP flow 39.9% and decreased HP flow by 15%. Brine flow is up 15.4% with a resulting increase in brine pumping power of 14.8%. The brine temperature at the exit of the HP preheater decreased 3.2%, and the brine temperature at the LP preheater exit decreased 2.8%. The reason for these temperature drops is that, for the higher temperature heat source, less brine flow is required, yet the brine temperature at the exit of the boilers remains fixed by the pinch points. This means the brine temperature must be decreased at the heat exchanger exits in order to provide sufficient energy to the isobutane.

Increasing the brine supply temperature to 300°F results in a 2.1% increase in net power with a 16.3% increase in effectiveness. Total isobutane flow is down 4.6%, with a slightly less severe flow split shift of -31.5% on the LP path and +9.5% to the HP flow stream. Brine flow is down 12.1%, with an accompanying decrease in brine pumping power of -12.3%. The brine temperature at the exit of the HP preheater increased 3.2%, and the brine temperature at the exit of the LP preheater is up 2.9%. Both of these effects are caused by the increased brine flow and increased isobutane flow. The higher flow rate and fixed boiler exit temperatures provide "extra" brine energy at the preheater exits.

4.2 Condensing Temperature

Nominal condensing temperature is 105°F. Because of uncertainties in cooling tower performance, a tolerance of $\pm 10^{\circ}\text{F}$ or $\pm 9.5\%$ was placed upon condensing temperature. This indicates a -13.7%, +15.3% in turbine back pressure. For a condensing temperature of 115°F, net power decreased 8.7%, and effectiveness went down 10.8%. Total isobutane and brine flow rates were up 2.1% and 2.9% with less than 0.1% change in isobutane flow split. Cooling water flow rate is down 0.7%, with a corresponding 1% decrease in pumping power requirements. The isobutane pumping requirement is down 0.7% because the condensing pressure has been raised. Brine pumping power is increased 2.2%, corresponding to the brine flow rate increase. The brine temperature at the exit of the HP preheater is unchanged, but the temperature at the exit of the LP preheater has increased 3.8% because of increased brine flow.

Condensing at 95°F results in a 14.0% net power increase and a 16% effectiveness increase. Brine temperatures and all flow rate and pumping power shifts were less than 2%.

4.3 Brine Side Fouling Factors

The NDC brine side fouling factor was $0.003 \frac{\text{hr} - \text{ft}^2 - ^\circ\text{F}}{\text{Btu}}$. Lack of experience with geothermal brine requires tolerances of $\pm 0.002 \frac{\text{hr} - \text{ft}^2 - ^\circ\text{F}}{\text{Btu}}$ or $\pm 67\%$.

The overall heat transfer coefficients recalculated corresponding to the minimum and maximum brine-side fouling factors are shown in Table II. The effect of running the plant with a reduced fouling factor of 0.001 is to increase net power by 34.9%. All of the flow rates and pumping power losses are up by approximately the same amount. Effectiveness and brine temperatures remain unchanged since changing the fouling factor only impacts the rate of heat transfer in the heat exchangers and therefore, the amount of flow that can be handled in a heat exchanger of fixed area, with fixed thermal temperature

TABLE II

Overall Heat Transfer Coefficients (U's) Used for the Tolerance Study

Heat Exchanger Description	NDC U's (Btu/hr-ft ² -°F) Brine-side Fouling Factor = 0.003	Minimum U's (Btu/hr-ft ² -°F) Brine-Side Fouling Factor = 0.005	Maximum U's (Btu/hr-ft ² -°F) Brine side Fouling Factor = 0.001
HP Boiler	157	97	229
HP Preheater	120	120	158
LP Boiler	145	90	204
LP Preheater	110	112	141
Condenser	133	133*	133*

*Since the condenser does not see the brine, changing the brine-side fouling factor does not affect the U value.

differences. Increasing the brine-side fouling factors to $0.005 \frac{\text{hr-ft}^2\text{-}^\circ\text{F}}{\text{Btu}}$

decreases net power by 20.3%, with equivalent decreases in flow rates and pumping power requirements.

Condensing at 95°F results in a 14.0% net power increase and a 16% effectiveness increase. Brine temperatures and all flow rate and pumping power shifts were less than 2%.

4.4 Isobutane Specific Heats

Specific heat at constant pressure (C_p) for isobutane is an input to the program. Without a definitive properties deck, the C_p values can vary as much as $\pm 5\%$. The main impact of this tolerance comes with the results of the parametric study. If the C_p 's were all input with a consistent bias, the trends produced by the parametric study would still be valid, and the NDC is indeed the optimum operating statepoint. Therefore, the minimum and maximum values of C_p were input into the NDC to determine if the effect of varying C_p is significant.

Since C_p varies considerably with pressure and temperature, the input was split into five regions and an average value for each region was used. The five areas are: C_{p1} in the HP superheat region, C_{p2} in the LP superheat region, C_{p3} in the turbine exhaust region, C_{p4} in the condenser region, and C_{p5} in the HP preheater region. Since superheaters are not being used, C_{p1} and C_{p2} do not impact the cycle. With a constant condensing pressure and temperature, C_{p3} , and C_{p4} do not vary significantly. Therefore, with the HP and LP boiler temperatures varying C_{p5} is the parameter which will cause the largest impact, and it was C_{p5} which was varied to the tolerance levels.

The effect of varying C_{p5} is small and not significant compared to the other, larger uncertainties already present. For $C_{p5} \pm 5\%$, net power is $\mp 0.6\%$. All of the other plant parameter changes are less than 3%, with the largest being 2.8% for the LP isobutane flow rate, due to the flow split shift.

TABLE III

NOMINAL DESIGN CASE TOLERANCES (PERCENTAGES)

	Brine Temperature		Condensing Temperature		Brine Side Fouling Factor		Isobutane Specific Heat		Total + Tolerances (%)	Total - Tolerances (%)
	+3.5%	-3.5%	+9.5%	-9.5%	+67%	-67%	+5%	-5%		
Effectiveness	+16.3	-16.4	-10.8	+16.0	0	0	-1.3	+1.2	+22.9	-19.7
Net Power	+ 2.1	- 4.2	- 8.7	+14.0	+34.9	-20.3	-0.6	+0.6	+37.67	-22.5
Isobutane HP Flow Rate	+ 9.5	-14.0	+ 2.1	- 1.8	+34.7	-20.6	+1.6	-1.8	+36.2	-25.0
Isobutane LP Flow Rate	-31.5	+39.9	+ 2.2	- 1.9	+34.9	-20.6	+0.1	+2.5	+53.1	-37.8
Total Isobutane Flow Rate	- 4.6	+ 4.5	+ 2.1	- 1.8	+34.8	-20.6	+0.1	-0.3	+35.2	-21.2
Brine Flow Rate	-12.1	+15.4	+ 2.9	- 1.9	+35.6	-20.2	+1.9	-1.0	+38.9	-23.6
Coolant Water Flow Rate	- 4.2	+ 4.5	- 0.9	+ 1.0	+35.1	-20.3	+0.4	-0.1	+35.4	-20.7
Isobutane Pumping Power	+ 1.3	- 3.2	- 0.7	+ 0.4	+34.8	-20.4	+0.7	-0.9	+34.8	-20.9
Brine Pumping Power	-12.3	+14.8	+ 2.2	- 1.7	+34.9	-20.3	+1.9	-1.7	+38.0	-23.9
Coolant Water Pumping Power	- 4.4	+ 4.2	- 1.0	+ 1.0	+34.9	-20.4	+0.2	-0.4	+35.2	-20.9
Brine Temp. @ HP Preheater Outlet	-3.2	+ 3.2	0	0	0	0	-0.6	+0.7	+ 3.3	- 3.3
Brine Temp. @ LP Preheater Outlet	- 2.8	+ 2.9	+ 3.8	- 3.8	0	0	+1.5	-1.5	+ 5.0	- 5.0

4.5 Results of the Tolerance Study

Table III is a summary of the results of the tolerance study. The total tolerance swings on the system were computed by computing the square root of the sum of the squares of the individual component tolerances. All of the positive swings were in one group, and the negative swings in another, regardless of the sign of the input parameter tolerance which caused the plant parameter change.

The total tolerances are dominated by the brine-side fouling factor tolerances, with brine temperature variations also affecting the outcome. Total swing on effectiveness is +22.9%, -19.7%, and +37.67%, -22.5% for net power. Isobutane LP flow rate exhibited total tolerance of +53.1%, -37.8% resulting from the variation in flow split necessary to maintain the minimum pinch points. The other flow rates and pumping requirements varied on the order of +35 to 39%, -20 to 25%. Brine temperature variations were small, on the order of +5%. Note these total system tolerances do not define additional state points, but the worst combination of tolerance regardless of any interaction effects which may occur if two or more variations happen simultaneously. The NDC state point, with tolerances is shown in Figure 4.5-1.

4.6 Additional Condenser Study

A study was performed to determine plant performance in case the condensing temperature is dropped below the limits of the tolerance study. The 105°F NDC condensing temperature is defined by the minimum cooling water temperature which can be guaranteed year-round (75°F). This includes the hottest days of the year however, and lower temperature cooling water can be supplied in colder months and at night. Therefore, the NDC was run with condensing temperatures of 95°F, 85°F, 75°F, and 65°F, corresponding to cooling water supply temperatures of 65°F, 55°F, 45°F, and 35°F, respectively. The floating power option of GEOSYS was utilized, holding ASUM, the sum of the boiler and preheater areas in both loops, constant. In all cases the pinch points were minimized and the flow split remained the same.

Figure 4.6-1 illustrates the variation in the individual heat exchanger areas for the sum of the areas, less the condenser area, held constant. The areas of the LP boiler, of the HP boiler, and of the HP preheater drop 6% as condensing temperature is lowered from 105°F to 65°F. However, over the same range the area of the LP preheater increases 10%. The decrease in the areas of the two boilers and the HP preheater is due to the decrease in isobutane flow (6%) and the corresponding decrease in brine flow (5%). Isobutane flow decreases because more specific power is produced from each turbine, since the back pressure has been lowered by 47%. The LP preheater area increases, however, because more preheating is necessary to reach the LP boiler temperature from the lowered condensing temperature. Realistically, however, since the areas vary by 10% or less, they can be considered constant. The condenser area itself is down 26%, because the log mean temperature difference on the condenser has increased from 29°F to 41°F.

Figure 4.6-2 shows the effects of lowering condensing temperature upon effectiveness and net power output. Net power increases because turbine pressure ratios increase from 4.9 and 2.6 to 9.2 and 4.9. Therefore more power is produced per pound of isobutane circulated. Effectiveness increases at a faster rate since, at the same time, the brine outlet temperature has decreased from 144⁰F to 122⁰F and more brine energy is utilized. The brine flow is down by 5%. There are three factors which determine the brine flow change. First, total isobutane flow has decreased 6%, therefore there is less working fluid to be heated. On the other hand, as condensing temperature decreases, the isobutane must be heated from a lower temperature, therefore there is an increase in brine energy requirement. Simultaneously, however, since the system sink temperature has been lowered, some of the additional energy requirement can be extracted from brine energy which was previously wasted. The net effect, then, is to reduce brine flow. Since net power is up, and brine flow is down, effectiveness increases a factor of 65% for a 56% increase in net power.

Figure 4.6-1 Heat Exchanger Area Variation for NDC Condensing Temperature Study

5.0 Plant Cost Studies

The equations used for determining plant cost were defined in Reference 4. Cost estimates were performed for 10 MW (e) and 50 MW (e) plants. These were documented in Reference 5. The coefficients and exponents applicable to the 3.35 MW (e) or NDC plant were determined approximately by applying a scaling factor based upon the relationship between the 10 MW (e) and 50 MW (e) plant costs.

The cost of the complete system, TOTSYS, was determined as follows:

$$\text{TOTSYS} = 1.68 (\text{EQCOS}) + \text{SPYLCO}$$

EQCOS is the equipment cost, and SPYLCO is the energy supply cost.

$$\text{EQCOS} = \text{HEXCOS} + \text{CDCOS} + \text{ELCCOS} + \text{SECCOS} + \text{TRBCOS}$$

HEXCOS = heat exchanger cost

$$= 10.56 (\text{AB1} + \text{AB2}) + 6.91 (\text{APH1} + \text{APH2} + \text{ARG} + \text{ASH})$$

AB1 and AB2 are boiler areas, APH1 and APH2 are preheater areas, ARG is the regenerator area, and ASH is the superheater area. All of these areas are computed in the program.

CDCOS = condenser and cooling tower cost

$$= 7.6 (\text{AC}) + 24.25 (\text{WCW})^{.65}$$

AC is the condenser area and WCW is the cooling water flow rate. Both are computed in the program.

ELCCOS = electrical conversion cost

$$= (18,835) (\text{PGROSS}) (1000)^{.42}$$

PGROSS is the gross power output in MW of the turbine as calculated in the program.

SECCOS = secondary fluid pump cost

$$= (2032.) (\text{PGROSS}) (1000)^{.48}$$

TRBCOS = turbine-generator cost

$$= (8268.5) (P_{GROSS}) (1000)^{.53}$$

$$SPYLCO = (.0383) (WB) (P_{NET})$$

$$SPYLCO = (28,400) (NOW) (P_{NET})$$

P_{NET} is the net power output in MW, and NOW is the number of brine wells required. The first equation determines supply cost by brine flow rate, the second by the number of brine wells required. Both were calculated for comparison.

The cost of power was determined thusly:

$$COSPOW = \frac{(.03436272) (EQCOS) + (.022968) (SPYLCO)}{(1000) (P_{NET})}$$

COSPOW was calculated for both versions of SPYLCO.

The derivation of these equations is described in detail in Appendix B.

The NDC, at 50 MW(e) net, is fixed with boilers at 240°F and 180°F, condensing at 105°F. Two factors which affect plant cost are boiler pinch point and flow split. The pinch point impacts cost because as the pinch point decreases from its minimum value, effectiveness increases, and heat exchanger area also increases. As pinch point increases from its minimum, effectiveness starts to decrease, but cost increases due to the increased flow requirements and heat transfer area. Flow split impacts cost because as more flow is channeled to the LP loop, the specific power produced from the LP turbine is lower, so more isobutane flow is required to produce power. At the same time, overall plant isobutane specific pumping power decreases, since a larger percentage of the flow is pumped to the low operating pressure of the LP loop. At some tradeoff point, the isobutane flow increase is greater than the pumping power decrease and the cost increase.

The NDC was run with varying flow splits and pinch points. Each case produced 50 MW(e) net, with both boilers and condenser operating at the

NDC pressures and temperatures. The pinch points were varied from 5°F to 15°F . Both pinch points were required to be minimized and equal, and the flow split was calculated to fit these criteria. The flow split was varied from 0.1 to 1.4. Since the flow split was fixed, only one pinch could be minimized (the controlling pinch point) and the other pinch point was allowed to float as necessary. In essence, therefore, a new plant was calculated for each case, with different heat exchanger areas and flow rates.

Figures 5.0-1 through 5.0-4 represent curves of effectiveness and cost vs. flow split or pinch point for a 50 MW(e) net plant. Figures 5.0-1 and 5.0-2 represent basically the same information. In Figure 5.0-1, the cost curve is smooth because brine supply cost was calculated on the basis of brine flow rate. This is not a very realistic approach, since a major part of brine cost is well drilling, and it is not possible to drill a part of a well. Therefore, the cost should reflect step changes as additional wells are required. Figure 5.0-2 shows these step changes as the number of brine supply (and reinjection) wells is increased from 20 to 23. It is interesting to note that Figure 5.0-1 indicates minimum cost (based upon flow rate) at a pinch point of approximately 8.5°F . However, looking at Figure 5.0-2, an 8.5°F pinch point is not minimum, but falls between the two minima of 7°F and 10°F . Figures 5.0-3 and 5.0-4 show the relationship between flow split and cost or effectiveness. Figure 5.0-3 represents the brine cost based upon brine flow, and Figure 5.0-4 shows the characteristic step changes in cost when brine supply cost is computed upon the number of wells required. Again, the cost minima are different for the two plots. The effectiveness curve changes as pinch point control shifts with the maximum effectiveness occurring at the flow split. However, the cost curve maximizes at a slightly different flow split. This is due to the fact

that as flow split changes, pinch points, flow rates, and pumping requirements and specific turbine output for each loop must change. The cost tradeoff point for these factors is close to the effectiveness tradeoff point, showing that effectiveness is a good basis for optimizing the system.

Figure 5.0-1 Pinch Point vs Effectiveness and Cost Based Upon
Brine Flow Rate for a 50 MW (net) Plant

NDC CYCLE

Brine Inlet Temperature = 290°F
HP Boiler Temperature = 240°F
LP Boiler Temperature = 180°F

Figure 5.0-2 Pinch Point vs Effectiveness and Cost Based Upon Number of Wells for a 50 MW (net) Plant

NDC CYCLE

Brine Inlet Temperature = 290°F
 HP Boiler Temperature = 240°F
 LP Boiler Temperature = 180°F

Figure 5.0-4 Flow Split vs Effectiveness
and Cost Based Upon Number of
Wells for a 50 MW (net) Plant

NDC CYCLE

Brine Inlet Temp. = 290°F
HP Boiler Temp. = 240°F
LP Boiler Temp. = 180°F

6.0 References

1. W. W. Madsen and I. J. Ingvarsson, "Analysis of the Binary Cycle for Geothermal Power Generation," ANCR-1245, December 1975.
2. Letter, G. R. Brown, Uba Heat Transfer Corporation, to R. H. Dart, ANC, April 14, 1975.
3. I. J. Ingvarsson and W. W. Madsen, "Flow Split Sensitivity Documentation Curves for (also RE-E-76-069 Nov. 29, 1976) TREE-1039, Determination of the 5MW Gross Nominal Design Case Binary Cycle for Power Generation at Raft River Idaho.
4. Letter, R. H. Dart, ANC, to W. W. Madsen, ANC, "Power Plant Cost Equations," Dart-4-76, March 11, 1976.
5. R. H. Dart, et. al., "Conceptual Design and Cost Evaluation of Organic Rankine Cycle Electric Generating Plant Powered by Medium Temperature Geothermal Water," ANCR-1226, December 1975.

APPENDIX A

GEØSYS

DOCUMENTATION

I. GEOSYS Program Changes - Original Documentation is Found in ANCR-1245

1. Isobutane properties, in the form of a tab deck were incorporated in GEOSYS. These include temperature, pressure, enthalpy, and entropy for the region inside the dome as well as for saturation conditions, superheat, and compressed liquid. These properties were obtained from ASHRAE data, and intermediate values were calculated by linear interpolation.

Properties are called by going in with pressure and enthalpy in this manner:

```
CALL PROPH (P,H,I)
```

PROPH is the properties subroutine which directs the lookup according to I. I is a flag from 1 to 9, which selects the property to be looked up. PROPH first calls POINT, a subroutine which locates the P and H in a two dimensional array, and defines the point by means of six coordinates. Four coordinates define the matrix points which bound that value. The other two coordinates are factors which indicate the interpolation distance between those matrix points. All of the property tables are set up so that they correspond to the P & H alignment described above. In this way, the point can be located without searching through the entire property table.

After defining the property in the POINT matrix, PROPH selects the property which is to be looked up by checking the flag, I. I flags the property functions as follows:

<u>I</u>	<u>Property to be obtained</u>
1	Temperature
2	Specific Volume and Density
3	Ratio of Specific Heats (dummy values)
4	Specific Heat at Constant Pressure
5	Saturation Properties*
6	Entropy

- 7 Thermal Conductivity (dummy values)
- 8 Viscosity (dummy values)
- 9 Specific Heat at Constant Volume (dummy values)

Each property function calls GRID, which is a linear interpolation function, to locate the property in the array. If pressure and enthalpy are not available an iterative technique is used to locate the property point in order to find enthalpy, then the usual call with pressure and enthalpy is performed.

These are the properties which were formerly input, and which are now called with PROPH:

- a) Turbine inlet entropy (HP and LP)
- b) Saturated vapor enthalpy at both boiler pressures and at the condensing pressure
- c) Latent heat of vaporization for both boilers and for the condenser.
- d) Boiler and condenser pressures
- e) A one dimensional table of enthalpy and entropy for each condensing pressure to do the turbine expansion

*When $I = 5$, PROPH is called going in with pressure and temperature in this manner: CALL PROPH (P,T,5) when P is a dummy variable since temperature defines a constant pressure and temperature line through the dome. The properties which are brought back are the saturated liquid and vapor enthalpies, latent heat, and pressure.

2. A subroutine called ITER is used to perform any iterations required.

ITER handles a number of types of iteration. The standard call is ITER(I,X,YI,YJ,FLAG) where I is fixed point number indicating the iteration loop number. The deck enclosed was used on a two iteration loop code. The deck as stands will handle 30 loops. X is the new guess value or initial guess on the first pass, and YI and YJ are the two values to close on. FLAG is a double precision number which indicates closure. If FLAG is not zero, the iteration is not closed.

In general, ITER uses an initial guess X, then YI and YJ are obtained and stored. The X value is initially bumped by a factor loaded in block data under PCNTI, then new ratios of YI and YJ are computed. A curve of X vs. error is estimated and the point of zero error is extrapolated. The X value is bumped along that curve by PCNTN, which is defined in block data. The program uses minimum and maximum values for X which are input in block data under MINX and MAXX respectively. However, it also sets its own values for each iteration as the iteration progresses. This value can be reset using entry ITERM (J,MIN,MAX) where J is the iteration number and MIN, MAX the minimum and maximum values of X allowable. The code is set to print if the loop takes more than ten passes to close, but all iterations can be dumped if ISWT(I) is set greater than zero for the particular I iteration loop wanted. If set at zero, it will not dump iterations. ISWT(I) is ordinarily input or specified in the main program. If ISWT(I)=0, MI specifies that the iterations will be printed starting at the MI iteration. NI specifies the maximum number of iterations. Therefore, if ISWT(I)=0 and MI NI, the last iteration of the loop will be printed. EPS in block data is the closure tolerance desired for each iteration. XNAM and YNAM name the iteration loops when they are dumped.

ICNT and ITF are parameters which may be set to modify the iteration routine if closure is difficult.

In summary, for each application of ITER in a program, ISWT(I) is required in main, and these data are required for the block data program; EPS, MINX, MAXX, PCNT1, PCNTN. Optionally, MI and NI may be changed. They are now set to print the 9th iteration for a maximum of 9 iterations if ISWT(I)=0.

A common example of the use of ITER involves doing an isentropic expansion across a turbine. If a properties lookup is used, going in with pressure and enthalpy, an iterative solution is required to close on entropy. The following series of statements in the main program solves the problem:

- a) CALL PROPH(PF2,HI2,6)
- b) SI2=ENTR
- c) H2G2=HI2
- d)43 CALL PROPH(PCOND,H2G2,6)
- e) CALL ITER(2,H2G2,ENTR,SI2,FLAG)
- f) IF (FLAG .NE. 0.0) TO TO 43

Statement a) calls the properties deck with turbine inlet enthalpy and pressure to get entropy. Statement b) specifies the entropy to be matched. Statement c) initializes outlet enthalpy with which to enter the properties deck. Statement d) calls the properties subroutine and brings back entropy for the given pressure and the guessed enthalpy (ENTR is brought across in COMMON). Statement e) calls ITER. The 2 indicates that this is a second iteration loop in the program, enthalpy (H2G2) is the independent variable, ENTR is the guessed entropy and SI2 is the value which must be closed on. Note: it is difficult to tell the correct order of YI and YJ. The working solution is to specify the two variables, and if the iteration diverges, to switch their order. Statement f) completes the iteration sequence, since if FLAG does not equal zero, the iteration has not closed.

ITER is also used to improve closure on brine exit temperature and isobutane LP preheater inlet temperature, and to balance the pinch points for the double boiler system. There are three iteration loops which accomplish these tasks. First, the brine temperatures at the entrance of the two boilers is checked with the boiler temperature against a required temperature difference. If the brine temperature is too low, the pinch points are raised, and the brine temperature heat balance is recalculated. The selection of the pinch point to be changed is dependent upon which pinch point is controlling. The program will alternately change both pinch points until the temperature difference requirement is satisfied. Then, the brine temperature at the exit of the LP preheater is compared to the isobutane temperature at the inlet to the LP preheater. Again there is a temperature difference requirement which must be satisfied. If it is not satisfied, the program changes the controlling pinch point and returns to the beginning to recalculate the brine temperature heat balance. Formerly, GEOSYS performed the pinch point change only by comparing brine exit temperature. This is not a problem with the medium temperature brine cases, since the controlling pinch point could be minimized at the required 10°F . For the high temperature brine cases, rigidly specifying the 10°F pinch point causes the brine flow to drop dramatically. The temperature difference between the brine entering the boiler and the isobutane at the exit of the boiler drops below the value of the pinch point and even becomes negative. This temperature overlap is not reflected in the brine exit temperature and must be checked and corrected in the portion of the program which calculates the brine temperature heat balances.

3. A new option, to vary flow split, is used for parametric studies. If the flow split is input as 100., the flow split input is varied from -0.1 to 1.6 in 0.1 increments. A new case is computed for each flow split.
4. A plot package was incorporated into GEQSYS. It will plot any variable in the A(n) array vs. any other variable in the program for up to 30 points per plot, and up to 10 plots.

There are three areas which control the plotting routine; two are input, one is program change. The first two input cards of each set of stacked cases must be:

(1) NSUBSC ,DEZT in I2,F8.2 format

(2) GRTITL in 10A4 format

NSUBSC is the number n, of the variable in the A(n) array which is chosen to be plotted on the x-axis. DEZT is the grid spacing for the x-axis.

For example, if temperature is to be plotted in 10⁰F increments, DEZT = 10.

GRTITL is the title of the variable on the x-axis. Forty spaces are allocated.

The last card of each case controls the option to plot. The input sequences is:
NSTOP, NPLTSW, NCASE, INDEX1, INDEX2, (B(I), I=1, INDEX2)

in 3I1,I2,1X,I2,2X,7E10.4 format

NPLTSW and NCASE are flags relating to the plotting routine. The other variables are used to input case data. They will be further explained in the input summary. NPLTSW>0 will dump the data points from the storage array, but the case will be printed as usual. NCASE = 0 indicates that there are more data points to come for a plot. The next sets of case cards should not have the two NSUBSC, DEZT and GRTITL cards in front until there is a card with NCASE>0. This says that all of the previous stored points from the last set of NSUBSC, DEZT and GRTITL cards up to and including the current point are to be plotted on one graph. It also indicates that the next case will be prefaced with NSUBSC, DEZT and GRTITL cards, indicating that a new set of points for another plot will be generated.

The A(n) array variable is specified and named in the input as above, but choosing the other program variable requires a program change in these cards:

RATPLT(NPOINT)= variable name to be plotted on the y-axis

.
.
.
.
.

CALL TITLE G(Z,40,GRTITL,NY,YNAME,NT,TNAME)

NY is the number of spaces for the Y-axis title (up to 40). YNAME is the Y-axis title. NT is the number of spaces for the plot title (up to 40), which will be centered beneath the x-axis title. TNAME is the plot title.

II. Input to the Program

A. First set of cards: Plotting information, describing the member of the A(n) array which is to be plotted on the X-axis, the grid spacing, and title for the X-axis. These cards are required at the beginning each time the program is run, and in order to initiate a new plot.

B. Second set of cards: Case Information

1. First Card: Title card containing any pertinent information.
2. Second Card: Heat exchanger data. This card flags the option for closing on heat exchanger areas and varying the net power output. The format is (1X,E10.4,I5). The heat transfer area is square feet is input in E10.4. IFLG is input in I5. This flags which area is to be kept constant

IFLG=0 - flag out this option

1 - flag out this option

2 - total heat transfer area

3 - preheaters, boilers and superheaters

4 - HP boiler

5 - LP boiler

6 - HP preheater

7 - LP preheater

8 - condenser

9 - regenerator

3. Third Card: starts data set for the case. For the first case, all 50 data must be input. The first column of a case data card is NSTOP, in I1 format, which calls several options:

NSTOP = 0 Go on to read the next card

= 1 Placed on last card of last case run to indicate the end of case data.

- = 2 Placed on last card of a base case. All information input for a base case will be saved until it is replaced by another base case.
- = 3 Placed on the last card of a stacking case. The information contained in the stacking case cards will replace base case information for one run only, then will be scratched, and the base case information is retrieved.
- = 4 Placed on the last card of a supercritical case. This flags the supercritical option in the program.
- = 6 Placed on the last card of the last supercritical case run to indicate the end of case data, as well as to flag the supercritical option.

The next two columns contain NPLTSW and NCASE to control the storage of data for plotting and to call for new NSUBSC, DEZT, and GRTITL cards and a new plot

These are followed by an index number (INDEX1) in the I2 format. The input parameters are placed in an array, numbered 1-50. The index number is the array number of the first data peice on the card. INDEX1 is followed by two spaces, then INDEX2, the number of pieces of input data following on that card is read in (I2 format). Starting in column 11, data is input in E10.4 format. Therefore 1 to 7 pieces of consecutively numbered data may be read on one card.

INPUT PARAMETERS
(A(n) Array Variable Names)

<u>Variable Name</u>	<u>Definition</u>	<u>NDC Value</u>
1. TF1	HP boiler temperature	240 ⁰ F
2. TF2	LP boiler temperature	180 ⁰ F
3. PF1	HP boiler pressure	381.57 psia
4. DUMM1	ISWT(1) for ITER print option loop 1	>0
5. DUMM2	ISWT(2) for ITER print option, loop 2	>0
6. DUMM3	ISWT(3) for ITER print option, Loop 3	>0
7. DUMM4	ISWT(4) for ITER print option, Loop 4	>0
8. DUMM5	ISWT(5) for ITER print option, loop 5	>0
9. TCOND	Condensing temperature	105 ⁰ F
10. VFCOND	Liquid specific volume @ TCOND	0.03 FT ³ /LB
11. PCOND	Dummy input	
12. HFCOND	Dummy input	
13. CPF1	Cp @ HP turbine inlet	0.63 BTU/LB- ⁰ F
14. XK	Ratio of specific heats	1.11
15. CONDH	Dummy input	
16. TB1	Brine inlet temperature	290 ⁰ F
17. DLTPP1	HP boiler pinch point	10 ⁰ F
18. DLTPP2	LP boiler pinch point	10 ⁰ F
19. DLTSC	Degrees of subcooling in condenser	4 ⁰ F
20. DTRG	Minimum terminal difference required for a regenerator	10 ⁰ F
21. CPB	Cp of the brine	1 BTU/LB- ⁰ F
22. NP	Pump efficiency,	0.9
23. TCWO	Coolant water temperature at condenser exit	95 ⁰ F

	<u>Variable Name</u>	<u>Description</u>	<u>NDC Value</u>
25.	TCWIN	Coolant water temperature at condenser inlet	75°F
26.	PNET	Net power output	10 MW
27.	WBW	Brine well flow rate	2.5×10^6 LB/HR
28.	DLTPF1	Pressure drop through HP leg of isobutane system	40 psid
29.	DLTPF2	Pressure drop through LP leg of isobutane system	40 psid
30.	UPH1	Overall heat transfer coefficient (U) for HP preheater	40 psid
31.	UBOIL1	U for HP boiler	157 BTU/HR-ft ² -°F
32.	UPH2	U for LP preheater	110 BTU/HR-FT ² -°F
33.	UBOIL2	U for LP boiler	145 BTU/HR-FT ² -°F
34.	UCOND	U for condenser	133 BTU/HR-FT ² -°F
35.	XRAT	Flow split	0.5
36.	NEL	Electircal efficiency,	0.95
37.	NGT1	HP turbine efficiency,	0.85
38.	NGT2	LP turbine efficiency,	0.85
39.	URG1	U for the HP regenerator	0.0
40.	URG2	U for the LP regenerator	0.0
41.	ST1	Dummy input	
42.	ST2	Dummy input	
43.	DLTSH1	Degrees of superheat for HP boiler	0.0
44.	DLTSH2	Degrees of superheat for LP boiler	0.0
45.	USH1	U for HP superheater	81 BTU/HR-ft ² -°F
46.	USH2	U for LP superheater	74.2 BTU/HR-FT ² -oF
47.	CPF2	Cp @ LP turbine inlet	0.51 BTU/LB-°F

PROGRAM LISTING

AND

SAMPLE RUN

LEVEL 21.8 (JUN 74)

05/360 FORTRAN H

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      COMPILER OPTIONS - NAME= MAIN,OPT=00,LINECNT=58,SIZE=0000K,
                        SOURCE,EBCDIC,NCLIST,NODECK,LCAD,MAP,NODEIT,NOID,XREF
      C**** PROGRAM FOR DUAL BOILING CYCLE POWER GENERATION SYSTEM
      ISN 0002      IMPLICIT REAL*8 (A-F,O-Z)
      ISN 0003      REAL*8 NGT1,NGT2,NEL,NP,ISWT
      ISN 0004      REAL*4 DEZT,GRITITL,MIN1,MINT,MAXT,MAX1,TEMPLT,Z,DEUZ,RATPLT
      ISN 0005      COMMON/ITERS/ISWT(30)
      ISN 0006      COMMON/FLUIDP/R,PRES,TEMP1,RHO,XK,CP,ENTR,COND,VIS,VOL,ENTH1,CV,UVO
      ISN 0007      L,DHCON,HSGAS,HSLIQ
      ISN 0008      DIMENSION Z(200),RATPLT(30)
      ISN 0009      DIMENSION TEMPLT(30),GRITITL(10)
      ISN 0010      DIMENSION A(51),B(7),TITLE(20),C(51)
      ISN 0011      DIMENSION ENTH(10),TEMP(10),TBRIN(10),SCPP(10),TBRINS(10)
      ISN 0012      EQUIVALENCE (A(1),TF1),(A(2),TF2),(A(3),PF1),(A(4),DUMM1),
      ISN 0013      6 (A(5),DUMM2),(A(6),DUMM3),(A(7),HG1),(A(8),HG2)
      ISN 0014      EQUIVALENCE (A(9),TCOND),(A(10),VFCOND),(A(11),PCOND),
      ISN 0015      1 (A(12),HFCOND),(A(13),CPF1),(A(14),XK1),(A(15),UTHERM),
      ISN 0016      2 (A(16),TB1),(A(17),DLTPP1),(A(18),DLTPP2),(A(19),DLTSC)
      ISN 0017      EQUIVALENCE (A(20),DTRG),(A(21),CPB),(A(22),NP),(A(23),CPCW),
      ISN 0018      1 (A(24),TCWO),(A(25),TCWIN),(A(26),PNET1),(A(27),WBW),
      ISN 0019      2 (A(28),DLPF1),(A(29),DLPF2)
      ISN 0020      EQUIVALENCE (A(30),UPH1),(A(31),UBGIL1),(A(32),UPH2),
      ISN 0021      1 (A(33),UBGIL2),(A(34),UCOND),(A(35),XRAT),(A(36),NEL),
      ISN 0022      2 (A(37),NGT1),(A(38),NGT2),(A(39),URG1),(A(40),URG2)
      ISN 0023      3,(A(41),THLW1),(A(42),THLW2),
      ISN 0024      6(A(43),DLTSH1),(A(44),DLTSH2),(A(45),USH1
      ISN 0025      4),(A(46),USH2),(A(47),CPF2),(A(48),CPF3),(A(49),CPF4),(A(50),CPF5)
      ISN 0026      EQUIVALENCE (A(51),RATIO8)
      ISN 0027      DATA IPLT/0/
      ISN 0028      DATA DRATIO,URATIO/.1,.01/
      ISN 0029      CALL ECHO
      ISN 0030      ISWT(1)=DUMM1
      ISN 0031      ISWT(2)=DUMM2
      ISN 0032      ISWT(3)=DUMM3
      ISN 0033      XK=XK1
      ISN 0034      C READ IN VARIOUS DATA FOR TABLES
      ISN 0035      4 READ (5,1602) NSUBSC,DEZT
      ISN 0036      1602 FORMAT(12,F8.2)
      ISN 0037      READ(5,1603) GRITITL
      ISN 0038      1603 FORMAT(10A4)
      ISN 0039      NPOINT=0
      ISN 0040      C**** READ TITLE AND PRIMARY INPUT DATA
      ISN 0041      C
      ISN 0042      C*****
      ISN 0043      C
      ISN 0044      C READ CASE TITLE CARD
      ISN 0045      C
      ISN 0046      C*****
      ISN 0047      5 READ(5,999)TITLE
      ISN 0048      ICT3=J
      ISN 0049      ICT4=0
      ISN 0050      ICT5=0
      ISN 0051      ICT6=0
      ISN 0052      LGPC=0
      ISN 0053      999 FORMAT(20A4)
      ISN 0054      C

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	C*****	DBV20630
	C	DBV20640
	C	DBV20650
	C	DBV20660
	C*****	DBV20670
	C	DBV20680
ISN 0035	READ(5,130)AHTX,IFLG	DBV20690
ISN 0036	130 FORMAT(1X,E10.4,I5)	DBV20700
ISN 0037	IF (IFLG .EQ. 0) IFLG=1	DBV20710
ISN 0039	IF(IFLG .NE. 10) GO TO 100	DBV20720
ISN 0041	READ(5,131) ABOL1,ABOL2,ATH11,ATH21	DBV20730
ISN 0042	131 FORMAT(1X,4F10.3)	DBV20740
	C	DBV20750
	C*****	DBV20760
	C	DBV20770
	C	DBV20780
	C	DBV20790
	C*****	DBV20800
ISN 0043	100 READ(5,589) NSTOP,NPLTSW,NCASE,INDEX1,INDEX2,(B(I),I=1,INDEX2)	DBV20810
ISN 0044	589 FORMAT (3I1,I2,1X,I2,2X,7E10.4)	DBV20820
ISN 0045	I1=1	DBV20830
ISN 0046	NALL=INDEX1+INDEX2-1	DBV20840
ISN 0047	DO 112 I=INDEX1,NALL	DBV20850
ISN 0048	A(I)=B(I1)	DBV20860
ISN 0049	112 I1=I1+1	DBV20870
ISN 0050	IF(NSTOP .GE. 1) GO TO 6	DBV20880
ISN 0052	GO TO 100	DBV20890
	C	DBV20900
	C*****	DBV20910
	C	DBV20920
	C	DBV20930
	C*****	DBV20940
	C	DBV20950
ISN 0053	6 IF(NSTOP .NE. 2) GO TO 8	DBV20960
ISN 0055	DO 7 I=1,50	DBV20970
ISN 0056	C(I)=A(I)	DBV20980
ISN 0057	7 CONTINUE	DBV20990
ISN 0058	8 ICK1=0	DBV21000
ISN 0059	ICK2 = 0	DBV21010
ISN 0060	RRAT = XRAT	DBV21020
ISN 0061	LNUM = 18	
ISN 0062	ZRAT = -.2	
ISN 0063	XPIN1 = DLTTP1	DBV21050
ISN 0064	XPIN2 = DLTTP2	DBV21060
ISN 0065	IF (NSTOP .NE. 4 .AND. NSTOP .NE. 6) GO TO 9	DBV21070
ISN 0067	CALL PROPH(PPP,TF1,5)	DBV21080
ISN 0068	ENTGG1 = HSGAS	DBV21090
ISN 0069	11 CALL PROPH(PF1,ENTGG1,1)	DBV21100
ISN 0070	CALL ITER(3,ENTGG1,TEMP1,TF1,FLAG)	DBV21110
ISN 0071	IF (FLAG .NE. 0.0) GO TO 11	DBV21120
ISN 0073	H11 = ENTGG1	DBV21130
ISN 0074	CALL PROPH(PCOND,TCCND,5)	DBV21140
ISN 0075	CONDH = HSGAS	DBV21150
ISN 0076	HFG1 = H11 - HSLIQ	DBV21160
ISN 0077	HFCOND = DHCCN	DBV21170
ISN 0078	TI1 = TF1	DBV21180

ISN 0079	LNUM = 1	DBV21190
ISN 0080	GO TO 12	DBV21200
ISN 0081	9 CONTINUE	DBV21210
ISN 0082	CALL PROPH(PF1,TF1,5)	DBV21220
ISN 0083	HG1=HSGAS	DBV21230
ISN 0084	HFG1=DHCON	DBV21240
ISN 0085	CALL PROPH(PF2,TF2,5)	DBV21250
ISN 0086	HG2=HSGAS	DBV21260
ISN 0087	HFG2=DHCON	DBV21270
ISN 0088	CALL PROPH(PCOND,TCCND,5)	DBV21280
ISN 0089	CONDH=HSGAS	DBV21290
ISN 0090	HFCOND=DHCON	DBV21300
ISN 0091	IF (RRAT .NE. 100.) LNUM = 1	DBV21310
ISN 0093	DO 4239 L = 1,LNUM	DBV21320
ISN 0094	IF (RRAT .NE. 100.) GO TO 12	DBV21330
ISN 0096	ZRAT = ZRAT + .1	DBV21340
ISN 0097	XRAT = ZRAT	DBV21350
ISN 0098	12 PGROSS=PNET1	
ISN 0099	DLTPP1 = XPIN1	DBV21360
ISN 0100	DLTPP2 = XPIN2	DBV21370
ISN 0101	WRITE(6,800)TITLE	DBV21390
ISN 0102	800 FORMAT(1H1,20A4)	DBV21400
ISN 0103	WRITE(6,802)	DBV21410
ISN 0104	802 FORMAT(1H0,80X,'INPUT EDIT THIS CASE')	DBV21420
ISN 0105	WRITE(6,700) (A(I),I=1,50)	DBV21430
ISN 0106	700 FORMAT(1H0,1P10E13.4)	DBV21440
ISN 0107	WRITE(6,130)AHTX,IFLG	DBV21450
ISN 0108	IF(IFLG .EQ. 10) WRITE(6,131)ABOL1,ABOL2,ATH1I,ATH2I	DBV21460
ISN 0110	DTRG2 = DTRG	DBV21470
ISN 0111	DTRG1 = DTRG	DBV21480
ISN 0112	IF((DLTSC .GT. DTRG) .OR. ((URG1 .LE. 0.0) .AND. (URG2 .LE. 0.0)))	DBV21490
	DLTSC=DLTSC	DBV21500
ISN 0114	CPF=(CPF1+CPF2)/2.	DBV21510
ISN 0115	ICTM=0	DBV21520
ISN 0116	ARG=0.0	DBV21530
ISN 0117	IF (NSTOP .EQ. 4 .OR. NSTOP .EQ. 6) GO TO 41	DBV21540
ISN 0119	TI1=TF1+DLTSH1	DBV21550
ISN 0120	HI1=HG1+CPF1*DLTSH1	DBV21560
ISN 0121	TI2=TF2+DLTSH2	DBV21570
ISN 0122	HI2=HG2+CPF2*DLTSH2	DBV21580
	C	RT DBV21590
	C	DBV21600
	C *** COMPUTE BRINE SUPERHEATER ONE OUTLET	DBV21610
ISN 0123	ZZ5=CPF1*DLTSH1/HFG1	DBV21620
ISN 0124	TB1P=(TB1+ZZ5*(TF1+DLTPP1))/(1.+ZZ5)	DBV21630
ISN 0125	10 IF(XRAT.LT. 0.0) GO TO 40	DBV21640
ISN 0127	ICK1=0	DBV21650
ISN 0128	ICK2=0	DBV21660
	C *** ASSUME PINCH POINT ONE CONTROLS	DBV21670
ISN 0129	TB1P=(TB1+ZZ5*(TF1+DLTPP1))/(1.+ZZ5)	DBV21680
ISN 0130	TB3=TF1+DLTPP1-CPF5/HFG1*(TF1-TF2)*(TB1P-TF1-DLTPP1)	DBV21690
	C	DBV21700
	C *** COMPUTE PINCH POINT TWO	DBV21710
ISN 0131	ZZ6=HFG2/HFG1*XRAT	DBV21720
ISN 0132	ZZ7=CPF2*DLTSH2/HFG1*XRAT	DBV21730
ISN 0133	DLTPP4=TB3-(ZZ6+ZZ7)*(TB1P-TF1-DLTPP1)-TF2	DBV21740

A-14

ISN 0134	C	CHECK FOR CONTROL	DBV21750
		IF(DLTPP4-DLTPP2) 20,22,22	DBV21760
ISN 0135	C	PINCH POINT TWO CONTROLS	DBV21770
ISN 0136	20	ZZ1=CPF*(TF1-TF2)	DBV21780
ISN 0137		ZZ2=XRAT*(CPF2*DLTSH2+HFG2)	DBV21790
ISN 0138		ZZ3=HFG1+CPF1*DLTSH1	DBV21800
ISN 0139		ZZ11=ZZ1+ZZ2+ZZ3	DBV21810
		ZZ22=ZZ1+ZZ2	DBV21820
	C		DBV21830
ISN 0140	C ***	COMPUTE PINCH POINT ONE	DBV21840
ISN 0141		DLTPP1=TB1+ZZ22/ZZ11+ZZ3/ZZ11*(TF2+DLTPP2)-TF1	DBV21850
ISN 0142		ICK2=ICK2+1	DBV21860
ISN 0143		TB1P=(TB1+ZZ5*(TF1+DLTPP1))/(1.+ZZ5)	DBV21870
		GO TO 40	DBV21880
ISN 0144	C	SET PINCH POINT TWO	DBV21890
ISN 0145	22	DLTPP2=DLTPP4	DBV21900
		ICK1=ICK1+1	DBV21910
	C		DBV21920
	C****	SOLVE EQ. 1 (RATIO1=WF1/WB)	DBV21930
	C	RATIO1 IS ISOBUTANE FLOW / BRINE FLOW FOR HP PATH	DBV21940
ISN 0146	40	RATIO1=(TB1P-TF1-DLTPP1)*CPB/HFG1	DBV21950
ISN 0147		ICT5=0	DBV21960
	C		DBV21970
	C****	SOLVE EQUATION 2	DBV21980
ISA 0148	C ***	SOLVE FOR BRINE OUTLET PREHEATER ONE	DBV21990
		TB3=(TF1+DLTPP1)-(CPF5*RATIO1*(TF1-TF2)/CPB)	DBV22000
	C		DBV22010
ISN 0149	C ***	SOLVE FOR BRINE INLET BOILER TWO	DBV22020
ISN 0150		ZZ9=CPF2*DLTSH2/HFG2	DBV22030
ISN 0151		TB3P=(TB3+ZZ9*(TF2+DLTPP2))/(1.+ZZ9)	DBV22040
ISN 0152		DTPP1M=TB1P-TF1	DBV22050
ISN 0153		DTPP2M=TB3P-TF2	DBV22060
		IF((DTPP1M.LT.0.0).OR.(DTPP2M.LT.0.0))GO TO 97	
	C		DBV22070
	C****	SOLVE EQUATION 3 (WF2/WF1=RATIO2)	DBV22080
ISN 0155		ZEROCK = TB1P - TF1 - DLTPP1	
ISN 0156		IF(ZEROCK .EQ. 0.0) ZEROCK = 0.0001	
ISN 0158		ZEROC2 = TB3P - TF2 - DLTPP2	
ISN 0159		IF(ZEROC2 .EQ. 0.0) ZEROC2 = 0.0001	
ISN 0161		RATIO2 = HFG1/HFG2*(ZEROC2/ZEROCK)	
ISN 0162		IF(XRAT.EQ.0.0) RATIO2 = 0.0	DBV22100
	C		DBV22110
ISN 0164	41	CONTINUE	DBV22120
ISN 0165		CALL PROPH(PF1,HI1,6)	DBV22130
ISN 0166		SI1=ENTR	DBV22140
ISN 0167		H1G1=HI1	DBV22150
ISN 0168	42	CALL PROPH(PCOND,F1G1,6)	DBV22160
ISN 0169		CALL ITER(1,H1G1,ENTR,SI1,FLAG)	DBV22170
ISN 0170		IF(FLAG .NE. 0.0) GO TO 42	DBV22180
ISN 0172		HG1G=HI1-NGT1*(HI1-H1G1)	DBV22190
ISN 0173		IF (NSTOP .EQ. 4 .OR. NSTOP .EQ. 6) GO TO 48	DBV22200
ISN 0175		CALL PROPH(PF2,HI2,6)	DBV22210
ISN 0176		SI2=ENTR	DBV22220
ISN 0177		H2G2=HI2	DBV22230
ISN 0178	43	CALL PROPH(PCOND,F2G2,6)	DBV22240
ISN 0179		CALL ITER(2,H2G2,ENTR,SI2,FLAG)	DBV22250

ISN 0180	IF(FLAG .NE. 0.0) GO TO 43	DBV22260
ISN 0182	HG2TO=HI2-NGT2*(HI2-H2G2)	DBV22270
	C**** SOLVE EQUATION 7 FOR QT1	DBV22280
ISN 0183	48 CONTINUE	DBV22290
ISN 0184	QT1=NEL*(HI1-HG1TO)	DBV22300
	C	DBV22310
	C**** SOLVE EQUATION 8 FOR QPW1	DBV22320
ISN 0185	QPW1=0.185*VFCOND*(PF1-PCOND +DLPF1)/NP	DBV22330
	C	DBV22340
	C**** SOLVE EQUATION 9 FOR QCW1	DBV22350
ISN 0186	DELHR1=HG1TO-CONDH-CPF3*(DTRG-DLTSC)	DBV22360
ISN 0187	IF(DELHR1 .LE. 0.0) GO TO 44	DBV22370
ISN 0189	IF(URG1 .LE. 0.0) GO TO 44	DBV22380
ISN 0191	QCW1 = 0.263*(HFCOND+CPF3*DTRG)/(CPCW*(TCWD-TCWIN))	DBV22390
ISN 0192	DELHR1=DELHR1	DBV22400
ISN 0193	GO TO 45	DBV22410
ISN 0194	44 QCW1 = 0.263*(DELHR1+HFCOND+CPF4*DLTSC)/(CPCW*(TCWD-TCWIN))	DBV22420
ISN 0195	DTRG1=DLTSC	DBV22430
ISN 0196	DELHR1=0.0	DBV22440
	C	DBV22450
	C**** SOLVE EQUATION 10 FOR QNET1	DBV22460
	C	DBV22470
ISN 0197	45 QNET1=QT1-QPW1-QCW1	DBV22480
ISN 0198	IF (NSTOP .EQ. 4 .OR. NSTOP .EQ. 6) GO TO 49	DBV22490
	C	DBV22500
	C**** SOLVE EQUATION 11 FOR QT2	DBV22510
ISN 0200	QT2=NEL*(HI2-HG2TO)	DBV22520
	C	DBV22530
	C**** SOLVE EQUATION 12 FOR QPW2	DBV22540
ISN 0201	QPW2=0.185*VFCOND*(PF2-PCOND+DLPF2)/NP	DBV22550
	C	DBV22560
	C**** SOLVE EQUATION 13 FOR QCW2	DBV22570
ISN 0202	DELHR2=HG2TO-CONDH-CPF3*(DTRG-DLTSC)	DBV22580
ISN 0203	IF(DELHR2 .LE. 0.0) GO TO 46	DBV22590
ISN 0205	IF(URG2 .LE. 0.0) GO TO 46	DBV22600
ISN 0207	QCW2 = 0.263*(HFCOND+CPF3*DTRG)/(CPCW*(TCWD-TCWIN))	DBV22610
ISN 0208	DELHR2=DELHR2	DBV22620
ISN 0209	GO TO 47	DBV22630
ISN 0210	46 QCW2 = 0.263*(DELHR2+HFCOND+CPF4*DLTSC)/(CPCW*(TCWD-TCWIN))	DBV22640
ISN 0211	DTRG2=DLTSC	DBV22650
ISN 0212	DELHR2=0.0	DBV22660
	C	DBV22670
	C**** SOLVE EQUATION 14 FOR QNET2	DBV22680
ISN 0213	47 QNET2=QT2-QPW2-QCW2	DBV22690
ISN 0214	49 CONTINUE	DBV22700
ISN 0215	IF (NSTOP .NE. 4 .AND. NSTOP .NE. 6) GO TO 76	DBV22710
ISN 0217	HG2TO = 0.	DBV22720
ISN 0218	QT2 = 0.	DBV22730
ISN 0219	QNET2 = 0.	DBV22740
ISN 0220	QPW2 = 0.	DBV22750
ISN 0221	QCW2 = 0.	DBV22760
	C	DBV22770
	C**** FIND TEMPERATURES OF THE FLUID IN THE HEATER	DBV22780
ISN 0222	DELN = (HFG1 - DELR1)/10.	DBV22790
ISN 0223	ENTH(1) = HI1	DBV22800
ISN 0224	DO 50 K=2,10	DBV22810

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ISN 0225	ENTH(K) = ENTH(K-1) - DELEN	DBV22820
ISN 0226	50 CONTINUE	DBV22830
ISN 0227	TEMP(1) = TF1	DBV22840
ISN 0228	DO 59 K=2,10	DBV22850
ISN 0229	CALL PROPH(PF1,ENTH(K),1)	DBV22860
ISN 0230	TEMP(K)=TEMP1	DBV22870
ISN 0231	59 CONTINUE	DBV22880
	C	DBV22890
	C**** COMPUTE BRINE TEMPERATURES WITH FIRST GUESS OF RATIO1 = 1.0	DBV22900
ISN 0232	MUD = 0	DBV22910
ISN 0233	RATIO1 = 1.0	DBV22920
ISN 0234	60 DBRIN = RATIO1*DELEN	DBV22930
ISN 0235	TBRIN(1) = TB1	DBV22940
ISN 0236	DO 62 I=2,10	DBV22950
ISN 0237	TBRIN(I) = TBRIN(I-1) - DBRIN	DBV22960
ISN 0238	62 CONTINUE	DBV22970
	C	DBV22980
	C**** CHECK FOR TEMPERATURE OVERLAP	DBV22990
ISN 0239	DO 70 I=1,10	DBV23000
ISN 0240	SCPP(I)=TBRIN(I)-TEMP(I)	DBV23010
ISN 0241	IF(SCPP(I)-DLTPP1)64,70,70	DBV23020
ISN 0242	64 IF(MUD .GT. 0)GO TO 75	DBV23030
ISN 0244	RATIO1 = RATIO1-DRATIO	DBV23040
ISN 0245	GO TO 60	DBV23050
ISN 0246	70 CONTINUE	DBV23060
ISN 0247	TB5 = TBRIN(10)	DBV23070
ISN 0248	DELRG = DELR1	DBV23080
ISN 0249	TRGC = TCOND - DLISC + DELRG/CPF4	DBV23090
ISN 0250	IF((TB5 - 10.) .GT. TRGC)GO TO 71	DBV23100
ISN 0252	RATIO1 = RATIO1 - DRATIO	DBV23110
ISN 0253	GO TO 60	DBV23120
ISN 0254	71 RATIO1 = RATIO1 + URATIO	DBV23130
ISN 0255	IF(MUD .GT. 10)GO TO 75	DBV23140
ISN 0257	MUD = MUD + 1	DBV23150
ISN 0258	DO 72 K=1,10	DBV23160
ISN 0259	TBRINS(K) = TBRIN(K)	DBV23170
ISN 0260	72 CONTINUE	DBV23180
ISN 0261	GO TO 60	DBV23190
ISN 0262	75 TB5 = TBRINS(10)	DBV23200
	C	DBV23210
	C**** SOLVE EQUATION 4A FOR QNET/WR=RATIO3	DBV23220
ISN 0263	76 RATIO3=RATIO1*(QNET1+RATIO2*QNET2)-1.922496	DBV23230
ISN 0264	RATIO9=RATIO1*(QT1+RATIO2*QT2)/3.413E06	
	C**** SOLVE EQUATION 4B FOR PNET/WR=RATIO4	DBV23240
ISN 0265	RATIO4=RATIO3/3.413	DBV23250
ISN 0266	WRITE(6,9000)RATIO1,HI1,CONDH,HFCOND,CPF,DTRG1,DELR1,RATIO2,HI2,	DBV23260
	10TRG2, DELR2,CPB	DBV23270
ISN 0267	9000 FORMAT(1X,12F10.5)	DBV23280
ISN 0268	IF (NSTOP .NE. 4 .AND. NSTOP .NE. 6) GO TO 78	DBV23290
ISN 0270	TB1TB5 = TB1 - TB5	DBV23300
ISN 0271	GO TO 79	DBV23310
	C	DBV23320
	C**** SOLVE EQUATION 5 FOR TB1-TB5=TB1TB5	DBV23330
ISN 0272	78 TB1TB5=RATIO1*((HI1-CONDH)+HFCOND+CPF4*DTRG1-DELR1+RATIO2*((HI2-CONDH)+HFCOND+CPF4*DTRG2-DELR2))/CPB	DBV23340
ISN 0273	WRITE(6,9000)RATIO2,RATIO3,RATIO4,TB3,TB5,TB1TB5,DTPL1M,DTPL2M,	DBV23350

	10TPP1M,DTPP2M	
	C	DBV23360
ISN 0274	C**** SOLVE EQUATION 6 FOR EFF	DBV23370
	79 EFF=(RATIO3/(CPB*TB1TB5))*100.0	DBV23380
	C	DBV23390
	C**** SOLVE EQUATION 15 THRU 23	DBV23400
ISN 0275	WB=PGROSS/RATIO9	
ISN 0276	WF1=RATIO1*WB	DBV23420
ISN 0277	WF2=RATIO2*WF1	DBV23430
ISN 0278	QBP= 1.922496*WB/3.413E06	DBV23440
ISN 0279	QCW=(WF1*QCW1+WF2*QCW2)/3.413E06	DBV23450
ISN 0280	QFP=(WF1*QFW1+WF2*QFW2)/3.413E06	DBV23460
ISN 0281	NOW=WB/7.51E05 + 0.99	DBV23470
ISN 0282	NCBWR=NOW/2	DBV23480
ISN 0283	PNET =RATIO3*WB/3.413E06	
ISN 0284	PNTPGR=PNET/PGROSS	DBV23500
ISN 0285	PNPWEL=PNET*WBW/WB	DBV23510
ISN 0286	IF (NSTOP .NE. 4 .AND. NSTOP .NE. 6) GO TO 87	DBV23520
ISN 0288	APH1 = 0.0	DBV23530
ISN 0289	AB2 = 0.0	DBV23540
ISN 0290	APH2 = 0.0	DBV23550
ISN 0291	ASH1 = 0.0	DBV23560
ISN 0292	ASH2 = 0.0	DBV23570
ISN 0293	ASH = 0.0	DBV23580
ISN 0294	A2 = 0.0	DBV23590
ISN 0295	QHEAT = WB*TB1TB5	DBV23600
ISN 0296	AB1 = QHEAT*DLOG((TB1-TF1)/(TB5-TRGO))/UBCIL1/(TB1TB5-TF1+TRGO)	DBV23610
ISN 0297	A1 = AB1	DBV23620
ISN 0298	ASUM = A1	DBV23630
ISN 0299	GO TO 95	DBV23640
ISN 0300	87 AB1=WB*CPB*DLOG((TB1P-TF1)/DLTPP1)/UBCIL1	DBV23650
ISN 0301	IF((TF1-TF2) .LE. 0.0) GO TO 88	DBV23660
ISN 0303	APH1=WB*CPB*DLOG((TB3-TF2)/DLTPP1)/(UPH1*((TF1-TF2)/(TF1+DLTPP1-111))	DBV23670
	GO TO 89	DBV23680
ISN 0304		DBV23690
ISN 0305	88 APH1=0.0	DBV23700
ISN 0306	89 A1=AB1+APH1	DBV23710
	C**** SOLVE EQUATIONS 24THRU 32	DBV23720
ISN 0307	AB2=WB*CPB*DLOG((TB3P-TF2)/DLTPP2)/UBCIL2	DBV23730
ISN 0308	IF(DLTSH1 .LE. 0.0) GO TO 90	DBV23740
ISN 0310	ASH1=WF1*CPF1*DLTSH1/USH1/(TB1P-TB1+DLTSH1)*DLOG((TB1P-TF1)/(TB1-TB3P-TF2+111))	DBV23750
	GO TO 91	DBV23760
ISN 0311		DBV23770
ISN 0312	90 ASH1=0.0	DBV23780
ISN 0313	91 IF(DLTSH2 .LE. 0.0) GO TO 92	DBV23790
ISN 0315	ASH2=WF2*CPF2*DLTSH2/USH2/(TB3P-TB3+DLTSH2)*DLOG((TB3P-TF2)/(TB3-TB5-TF2+112))	DBV23800
	GO TO 93	DBV23810
ISN 0316		DBV23820
ISN 0317	92 ASH2=0.0	DBV23830
ISN 0318	93 ASH=ASH1+ASH2	DBV23840
ISN 0319	DELRG=(DELR1+RATIO2*(DELR2))/(1.+RATIO2)	DBV23850
ISN 0320	TRGO=TCOHD-DLTSC+DELRG/CPF4	DBV23860
ISN 0321	TB5=-(TB1TB5-TB1)	DBV23870
ISN 0322	IF((TB5-10.) .GT. TRGO) GO TO 94	DBV23880
ISN 0324	97 CONTINUE	
ISN 0325	DTPP1M=DLTPP1+(EABS(DTPP1M-DLTPP1)/2.)	

ISN 0326	DTPP2N=DLTPP2+((DABS(DTPP2M-DLTPP2)/2.)	
ISN 0327	IF((ICK1.GE.1) .OR. (XRAT.LT.0.0))DLTPP1=DTPP1N	
ISN 0329	IF((ICK2.GE.1) .OR. (XRAT.LT.0.0))DLTPP2=DTPP2N	
ISN 0331	IF(ICTM .GT. 10) GO TO 94	DBV23930
ISN 0333	ICTM=ICTM+1	DBV23940
ISN 0334	GO TO 10	DBV23950
ISN 0335	94 APH2=WB *CPB*DLOG((TB5-TRGO)/DLTPP2)/(UPH2*((TF2-TRGO)/(TF2+DLTPP2	DBV23960
	1 -TB5)-1))	DBV23970
ISN 0336	IF((ICTM .GE. 10) .AND. (ICK1 .GE. 1)) WRITE(6,2130)	DBV23980
ISN 0338	2130 FORMAT(1X,' TEMP BCILER ONE IS TOO SMALL ')	DBV23990
ISN 0339	IF((ICTM .GE. 10) .AND. (ICK2 .GE. 1)) WRITE(6,2140)	DBV24000
ISN 0341	2140 FORMAT(1X,' TEMP BCILER TWC IS TOO SMALL ')	DBV24010
ISN 0342	A2=AB2+APH2	DBV24020
ISN 0343	ASUM=A1+A2	DBV24030
ISN 0344	95 CONTINUE	DBV24040
ISN 0345	WF11=WF1	DBV24050
ISN 0346	WF22=WF2	DBV24060
ISN 0347	ATHERM=0.0	
ISN 0348	QTHXM=0.0	
ISN 0349	IF ((URG1 .LE. 0.0) .AND. (URG2 .LE. 0.0)) GO TO 96	DBV24070
ISN 0351	WRG=WF1*DELRL1+WF2*DELRL2	DBV24080
ISN 0352	IF(URG1 .LE. 0.0) WF11=0.0	DBV24090
ISN 0354	IF(URG2 .LE. 0.0) WF22=0.0	DBV24100
ISN 0356	96 HMX=(WF11*EG1TO+WF22*EG2TO)/(WF11+WF22)	DBV24110
ISN 0357	TMIX=HMX/.7250+1007.	DBV24120
ISN 0358	QCOND=WF1*(DELRL1+CPF3*DTRG+HFCOND-DELRL1)+WF2*(DELRL2+CPF3*DTRG+HFC	DBV24130
	COND-DELRL2)	DBV24140
ISN 0359	TFCC=QCOND-DLTSC	DBV24150
ISN 0360	CONDTC=TFCC-TCWIN	DBV24160
ISN 0361	CONDTI=TMIX-TCWO	DBV24170
ISN 0362	AC=QCOND/(QCOND*(CONDTC-CONDTI))/(DLOG(CONDTC/CONDTI)))	DBV24180
ISN 0363	IF((URG1 .LE. 0.0) .AND. (URG2 .LE. 0.0)) GO TO 98	DBV24190
ISN 0365	IF((TMIX-TRGO) .LE. (.5*DTRG)) TMIX=TRGO+.5*DTRG	DBV24200
ISN 0367	ARG=QRG/((URG1+URG2)/2.*(DTRG+DLTSC-TMIX+TRGO)/DLOG((DTRG+DLTSC)/(	DBV24210
	TMIX-TRGO)))	DBV24220
ISN 0368	IF((URG1 .LE. 0.0) .OR. (URG2 .LE. 0.0)) ARG=ARG*2.	DBV24230
ISN 0370	98 HTA=A1+A2+AC+ARG+ASH	DBV24240
ISN 0371	WCW=QCOND/(CPCW*(TCWO-TCWIN))	DBV24250
ISN 0372	GPM=WCW/500.0	DBV24260
ISN 0373	NGCW=WCW/7.51E05+.99	DBV24270
ISN 0374	NOCWR=NOCW/2	DBV24280
		DBV24290
	C OVERALL EFF OF ENERGY SUPPLIED	DBV24300
	C QALN=RATIO3/CPB/(TB1-TCWIN)*100.	DBV24310
ISN 0375	GO TO (129,120,121,122,123,124,125,126,127,129) , IFLG	DBV24320
ISN 0376	120 ACK = HTA	DBV24330
ISN 0377	GO TO 128	DBV24340
ISN 0378	121 ACK = ASUM+ ASH	DBV24350
ISN 0379	GO TO 128	DBV24360
ISN 0380	122 ACK = AB1	DBV24370
ISN 0381	GO TO 128	DBV24380
ISN 0382	123 ACK = AB2	DBV24390
ISN 0383	GO TO 128	DBV24400
ISN 0384	124 ACK = APH1	DBV24410
ISN 0385	GO TO 128	DBV24420
ISN 0386	125 ACK = APH2	DBV24430
ISN 0387		

ISN 0388	GO TO 128	DBV24440
ISN 0389	126 ACK = AC	DBV24450
ISN 0390	GO TO 128	DBV24460
ISN 0391	127 ACK = ASUM-APH2	
ISN 0392	GO TO 128	DBV24480
ISN 0393	128 IF((DABS(ACK-AHTX)/AHTX) .LE. 0.001) GO TO 129	DBV24490
ISN 0395	PNETS = PNET	DBV24500
ISN 0396	PNET = PNET*(1.+(AHTX-ACK)/AHTX*(1.4-ICT3/10.))	DBV24510
ISN 0397	IF(PNET .LE. 0.0) PNET = .8*PNETS	DBV24520
ISN 0399	ICT3 = ICT3 + 1	DBV24530
ISN 0400	IF(ICT3 .GT. 11) GO TO 129	DBV24540
ISN 0402	GO TO 79	DBV24550
ISN 0403	129 CCNTINUE	DBV24560
ISN 0404	IF(IFLG .NE. 10) GO TO 500	DBV24570
ISN 0406	AIT=A1+A2	DBV24580
ISN 0407	AITI=ATH1I+ATH2I	DBV24590
ISN 0408	IF((DABS(AIT-AITI)/AITI) .LE. .01) GO TO 190	DBV24600
ISN 0410	ICT5=ICT5+1	DBV24610
ISN 0411	PNETS=PNET	DBV24620
ISN 0412	PNET=PNET*(1.+(AITI-AIT)/AITI*(1.4-ICT5/10.))	DBV24630
ISN 0413	IF(PNET .LE. 0.0) PNET=.8*PNETS	DBV24640
ISN 0415	WRITE(6,3000) AIT,AITI,PNET,PNETS,ICT5	DBV24650
ISN 0416	IF(ICT5 .GE. 10) GO TO 190	DBV24660
ISN 0418	GO TO 79	DBV24670
ISN 0419	190 IF(ICK2 .GE. 1) GO TO 200	DBV24680
ISN 0421	IF((DABS(ABCL1-AB1)/ABCL1) .LE. .01) GO TO 200	DBV24690
ISN 0423	ICT3=ICT3+1	DBV24700
ISN 0424	DLTPPN=((AB1-ABCL1)/ABCL1+1.)*DLTPP1	DBV24710
ISN 0425	WRITE(6,3000) AB1,ABCL1,DLTPPN,DLTPP1,ICT3	DBV24720
ISN 0426	IF(ICT3 .GE. 10) GO TO 200	DBV24730
ISN 0428	3000 FORMAT(1X,4(3X,F10.1),15)	DBV24740
ISN 0429	DLTPP1=DLTPPN	DBV24750
ISN 0430	IF(DLTPP1 .LE. .0) DLTPP1=.001	DBV24760
ISN 0432	IF(DLTPP1 .GE. 70.) DLTPP1=70.	DBV24770
ISN 0434	GO TO 203	DBV24780
ISN 0435	200 LCPC=1	DBV24790
ISN 0436	203 IF(ICK1 .GE. 1) GO TO 210	DBV24800
ISN 0438	IF((DABS(ABCL2-AB2)/ABCL2) .LE. .01) GO TO 210	DBV24810
ISN 0440	ICT4=ICT4+1	DBV24820
ISN 0441	DLTP2N=((AB2-ABCL2)/ABCL2+1.)*DLTPP2	DBV24830
ISN 0442	WRITE(6,3000) AB2,ABCL2,DLTP2N,DLTPP2,ICT4	DBV24840
ISN 0443	IF(ICT4 .GE. 10) GO TO 210	DBV24850
ISN 0445	IF(DLTPP2 .LE. .0) DLTPP2=.001	DBV24860
ISN 0447	IF(DLTPP2 .GE. 70.) DLTPP2=70.	DBV24870
ISN 0449	DLTPP2=DLTP2N	DBV24880
ISN 0450	GO TO 10	DBV24890
ISN 0451	210 IF(LQPC .LT. 1) GO TO 10	DBV24900
ISN 0453	230 AD=A1/A2	DBV24910
ISN 0454	ADI=ATH1I/ATH2I	DBV24920
ISN 0455	IF((DABS(AD-ADI)/ADI) .LE. .01) GO TO 240	DBV24930
ISN 0457	ICT6=ICT6+1	DBV24940
ISN 0458	XRAT=RATIO2	DBV24950
ISN 0459	XRATS=XRAT	DBV24960
ISN 0460	XRAT=((AD-ADI)/ADI+1.)*XRAT	DBV24970
ISN 0461	IF(XRAT .LE. 0.0) XRAT=.01	DBV24980
ISN 0463	WRITE(6,3000) AD,ADI,XRAT,XRATS,ICT6	DBV24990

ISN 0464	IF(X RAT .GE. 4.) X RAT=4.	DBV25000
ISN 0466	IF(ICT6 .GE. 10) GC TC 240	DBV25010
ISN 0468	ICT3=0	DBV25020
ISN 0469	ICT4=0	DBV25030
ISN 0470	GC TO 10	DBV25040
ISN 0471	240 CONTINUE	DBV25050
ISN 0472	500 WRITE(6,803)	DBV25060
ISN 0473	RATIO8=RATIO2	DBV25070
ISN 0474	803 FORMAT(1H0,10X,'CASE RESULTS')	DBV25080
ISN 0475	WRITE(6,850)RATIO3	DBV25090
ISN 0476	850 FORMAT(1H0,'QNET/WB (BTU/LB)',1PE10.4,5X,'EQUATION 4A')	DBV25100
ISN 0477	WRITE(6,851)RATIO4	DBV25110
ISN 0478	651 FORMAT(1H0,'PNET/WB (WATT-HR/LB)',1PE12.4,5X,'EQUATION 4B')	DBV25120
ISN 0479	WRITE(6,852)TB1TB5	DBV25130
ISN 0480	852 FORMAT(1H0,'DELTA T BRINE (DEGREES F)',1PE12.4,5X,'EQUATION 5')	DBV25140
ISN 0481	WRITE(6,853)EFF	DBV25150
ISN 0482	853 FORMAT(1H0,'THERMAL EFFICIENCY NET (%)',1PE12.4,5X,'EQUATION 6')	DBV25160
ISN 0483	WRITE(6,854)PNPWEL	DBV25170
ISN 0484	854 FORMAT(1H0,'PNET/WELL (LB/HR)',1PE12.4,5X,'EQUATION 20')	DBV25180
ISN 0485	WRITE(6,855)RATIO1	DBV25190
ISN 0486	855 FORMAT(1H0,'WF1/WB',1PE12.4,5X,'EQUATION 1')	DBV25200
ISN 0487	WRITE(6,856)RATIO2	DBV25210
ISN 0488	856 FORMAT(1H0,'WF2/WF1',1PE12.4,5X,'EQUATION 3')	DBV25220
ISN 0489	WRITE(6,857)TB3	DBV25230
ISN 0490	857 FORMAT(1H0,'TB3 (DEGREES F)',1PE12.4,5X,'EQUATION 2')	DBV25240
ISN 0491	WRITE(6,858)QT1	DBV25250
ISN 0492	858 FORMAT(1H0,'QT1 (BTU/HR)',1PE12.4,5X,'EQUATION 7')	DBV25260
ISN 0493	WRITE(6,859)QPW1	DBV25270
ISN 0494	859 FORMAT(1H0,'QPW1 (BTU/LB)',1PE12.4,5X,'EQUATION 8')	DBV25280
ISN 0495	WRITE(6,860)QCW1	DBV25290
ISN 0496	860 FORMAT(1H0,'QCW1 (BTU/LB)',1PE12.4,5X,'EQUATION 9')	DBV25300
ISN 0497	WRITE(6,861)QNET1	DBV25310
ISN 0498	861 FORMAT(1H0,'QNET1 (BTU/LB)',1PE12.4,5X,'EQUATION 10')	DBV25320
ISN 0499	WRITE(6,862)QT2	DBV25330
ISN 0500	862 FORMAT(1H0,'QT2',1PE12.4,5X,'EQUATION 11')	DBV25340
ISN 0501	WRITE(6,863)QPW2	DBV25350
ISN 0502	863 FORMAT(1H0,'QPW2',1PE12.4,5X,'EQUATION 12')	DBV25360
ISN 0503	WRITE(6,864)QCW2	DBV25370
ISN 0504	864 FORMAT(1H0,'QCW2',1PE12.4,5X,'EQUATION 13')	DBV25380
ISN 0505	WRITE(6,865)QNET2	DBV25390
ISN 0506	865 FORMAT(1H0,'QNET2 (BTU/LB)',1PE12.4,5X,'EQUATION 14')	DBV25400
ISN 0507	WRITE(6,866)PNET	DBV25410
ISN 0508	866 FORMAT(1H0,'PNET (MEGAWATTS)',1PE12.4,5X,'INPUT')	DBV25420
ISN 0509	WRITE(6,867)PGROSS	DBV25430
ISN 0510	867 FORMAT(1H0,'PGROSS (MEGAWATTS)',1PE12.4,5X,'EQUATION 18')	DBV25440
ISN 0511	WRITE(6,868)PNTPGR	DBV25450
ISN 0512	868 FORMAT(1H0,'PNET/PGROSS',1PE12.4,5X,'EQUATION 19')	DBV25460
ISN 0513	WRITE(6,869)WB	DBV25470
ISN 0514	869 FORMAT(1H0,'WB (LB/HR)',1PE12.4,5X,'EQUATION 16')	DBV25480
ISN 0515	WRITE(6,870)WF2	DBV25490
ISN 0516	870 FORMAT(1H0,'WF2 (LB/HR)',1PE12.4,5X,'EQUATION 17')	DBV25500
ISN 0517	WRITE(6,871)TF1	DBV25510
ISN 0518	871 FORMAT(1H0,'TF1 (DEGREES F)',1PE12.4,5X,'INPUT')	DBV25520
ISN 0519	WRITE(6,872)TF2	DBV25530
ISN 0520	872 FORMAT(1H0,'TF2 (DEGREES F)',1PE12.4,5X,'INPUT')	DBV25540
ISN 0521	WRITE(6,873)AB1	DBV25550

ISN 0522	873 FORMAT(1H0,'AB1 (FT**2)',1PE12.4,5X,'EQUATION 21')	DBV25560
ISN 0523	WRITE(6,874)APH1	DBV25570
ISN 0524	874 FORMAT(1H0,'APH1 (FT**2)',1PE12.4,5X,'EQUATION 22')	DBV25580
ISN 0525	WRITE(6,875)A1	DBV25590
ISN 0526	875 FORMAT(1H0,'A1 (FT**2)',1PE12.4,5X,'EQUATION 23')	DBV25600
ISN 0527	WRITE(6,876)AB2	DBV25610
ISN 0528	876 FORMAT(1H0,'AB2 (FT**2)',1PE12.4,5X,'EQUATION 24')	DBV25620
ISN 0529	WRITE(6,877)APH2	DBV25630
ISN 0530	877 FORMAT(1H0,'APH2 (FT**2)',1PE12.4,5X,'EQUATION 25')	DBV25640
ISN 0531	WRITE(6,878)A2	DBV25650
ISN 0532	878 FORMAT(1H0,'A2 (FT**2)',1PE12.4,5X,'EQUATION 26')	DBV25660
ISN 0533	WRITE(6,879)ASUM	DBV25670
ISN 0534	879 FORMAT(1H0,'ASUM (FT**2)',1PE12.4,5X,'EQUATION 27')	DBV25680
ISN 0535	WRITE(6,880)AC	DBV25690
ISN 0536	880 FORMAT(1H0,'ACOND (FT**2)',1PE12.4,5X,'EQUATION 29')	DBV25700
ISN 0537	WRITE(6,881)HTA	DBV25710
ISN 0538	881 FORMAT(1H0,'HTA (FT**2)',1PE12.4,5X,'EQUATION 30')	DBV25720
ISN 0539	WRITE(6,882)WCW	DBV25730
ISN 0540	882 FORMAT(1H0,'WCW (LB/HR)',1PE12.4,5X,'EQUATION 31')	DBV25740
ISN 0541	WRITE(6,883)GPM	DBV25750
ISN 0542	883 FORMAT(1H0,'GPM (GAL/MIN)',1PE12.4,5X,'EQUATION 32')	DBV25760
ISN 0543	WRITE(6,884)QCOND	DBV25770
ISN 0544	884 FORMAT(1H0,'QCOND (BTU/HR)',1PE12.4,5X,'EQUATION 28')	DBV25780
ISN 0545	WRITE(6,885)WF1	DBV25790
ISN 0546	885 FORMAT(1H0,'WF1 (LB/HR) ',1PE12.4,5X,'EQUATION 16')	DBV25800
ISN 0547	WRITE(6,886)TRGO	DBV25810
ISN 0548	886 FORMAT(1H0,'TEMP REG CUT ',1PE12.4,5X,' DEG F ')	DBV25820
ISN 0549	WRITE(6,887)TB5	DBV25830
ISN 0550	887 FORMAT(1H0,'TEMP BR DT T ',1PE12.4,5X,' DEG F ')	DBV25840
ISN 0551	WRITE(6,888)DELRG	DBV25850
ISN 0552	888 FORMAT(1H0,'DEL ENTH RGT ',1PE12.4,5X,' BTU/LB ')	DBV25860
ISN 0553	WRITE(6,889)ARG	DBV25870
ISN 0554	889 FORMAT(1H0,'REG AREA ',1PE12.4,5X,' FT SQ ')	DBV25880
ISN 0555	WRITE(6,890)DLTPP1	DBV25890
ISN 0556	890 FORMAT(1H0,'PIN PT 1 ',1PE12.4,5X,' DEG F ')	DBV25900
ISN 0557	WRITE(6,891)DLTPP2	DBV25910
ISN 0558	891 FORMAT(1H0,'PIN PT 2 ',1PE12.4,5X,' DEG F ')	DBV25920
ISN 0559	WRITE(6,892)TB1P	DBV25930
ISN 0560	892 FORMAT(1H0,'BRINE SUPERHEAT 1 EXIT',1PE12.4,5X,' DEG F ')	DBV25940
ISN 0561	WRITE(6,893)TB3P	DBV25950
ISN 0562	893 FORMAT(1H0,'BRINE SUPERHEAT 2 EXIT',1PE12.4,5X,' DEG F ')	DBV25960
ISN 0563	WRITE(6,894)H11	DBV25970
ISN 0564	894 FORMAT(1H0,'TUR ONE ENTH IN ',1PE12.4,5X,' BTU/LB ')	DBV25980
ISN 0565	WRITE(6,895)H12	DBV25990
ISN 0566	895 FORMAT(1H0,'TUR TWO ENTH IN',1PE12.4,5X,' BTU/LB ')	DBV26000
ISN 0567	WRITE(6,896)ASH1	DBV26010
ISN 0568	896 FORMAT(1H0,'AREA SUPHEAT ONE',1PE12.4,5X,' FTSQ ')	DBV26020
ISN 0569	WRITE(6,897)ASH2	DBV26030
ISN 0570	897 FORMAT(1H0,'AREA SUPHEAT TWO',1PE12.4,5X,' FTSQ ')	DBV26040
ISN 0571	WRITE(6,898)QALN	DBV26050
ISN 0572	898 FORMAT(1H0,'OVERALL EFFECTIVE USE OF ENERGY SUPPLIED % ',1PE12.4,5X,' ')	DBV26060
ISN 0573	WRITE(6,899)QBP	DBV26070
ISN 0574	899 FORMAT(1H0,'BRINE PUMPING POWER ',1PE12.4,5X,' MW ')	DBV26080
ISN 0575	WRITE(6,900)QCW	DBV26090
ISN 0576	900 FORMAT(1H0,'CONDENSING WATER PUMPING POWER ',1PE12.4,5X,' MW ')	DBV26100
ISN 0577	WRITE(6,901)QFP	DBV26110

ISN 0578	901	FORMAT(1H0,' WORKING FLUID PUMPING POWER ',1PE12.4,5X,' MW ')	DBV26120
ISN 0579		WRITE(6,903)TMIX	DBV26130
ISN 0580	903	FORMAT(1H0,' CONDENSER INLET TEMPERATURE ',1PE12.4,5X,' DEGREES F ')	DBV26140
		1)	DBV26150
ISN 0581		WRITE(6,902)NCW	DBV26160
ISN 0582	902	FORMAT(1H0,' NUMBER OF BRINE SUPPLY WELLS ',15)	DBV26170
ISN 0583		WRITE(6,904)NUBWR	DBV26180
ISN 0584	904	FORMAT(1H0,' NUMBER OF BRINE REINJECTION WELLS ',15)	DBV26190
ISN 0585		WRITE(6,905)NOCW	DBV26200
ISN 0586	905	FORMAT(1H0,' NUMBER OF COOLING WATER SUPPLY WELLS ',15)	DBV26210
ISN 0587		WRITE(6,906)NOCWR	DBV26220
ISN 0588	906	FORMAT(1H0,' NUMBER OF COOLING WATER REINJECTION WELLS ',15)	DBV26230
ISN 0589		WRITE(6,907)PF1	
ISN 0590	907	FORMAT(1H0,'PRESSURE HP BOILER',1PE12.4,5X,'PROP DECK')	
ISN 0591		WRITE(6,908)PF2	
ISN 0592	908	FORMAT(1H0,'PRESSURE LP BOILER',1PE12.4,5X,'PROP DECK')	
ISN 0593		WRITE(6,909)PCCND	
ISN 0594	909	FORMAT(1H0,'CONDENSING PRESSURE',1PE12.4,5X,'PRCP DECK')	
ISN 0595		WRITE(6,910)NP	
ISN 0596	910	FORMAT(1H0,'PUMP EFFICIENCY',1PE12.4,5X,'INPUT')	
ISN 0597		WRITE(6,911)NEL	
ISN 0598	911	FORMAT(1H0,'ELECTRICAL EFFICIENCY',1PE12.4,5X,'INPUT')	
ISN 0599		WRITE(6,912)NGT1	
ISN 0600	912	FORMAT(1H0,'HP TURBINE EFFICIENCY',1PE12.4,5X,'INPUT')	
ISN 0601		WRITE(6,913)NGT2	
ISN 0602	913	FORMAT(1H0,'LP TURBINE EFFICIENCY',1PE12.4,5X,'INPUT')	
ISN 0603		WRITE(6,914)WBW	
ISN 0604	914	FORMAT(1H0,'MAX FLCWRATE / BRINE SUPPLY WELL',1PE12.4,5X,'LBM/HR')	
ISN 0605		WRITE(6,915)CONDH	
ISN 0606	915	FORMAT(1H0,'SAT VAPOR ENTHALPY AT COND TEMP',1PE12.4,5X,'PROP DECK	
		1')	
ISN 0607		WRITE(6,998)	DBV26240
ISN 0608	998	FORMAT(6X,' TEMP BR INLET TP BR SPH 1 OT TP BR PRH 1 OT	DBV26250
		1 TP BR SPH 2 OT TP BR OUTLET BRINE FLOW RATE ')	DBV26260
ISN 0609		WRITE(6,1000) TB1,TB1P,TB3,TB3P,TB5,WB	DBV26270
ISN 0610	1000	FORMAT(1X,6(2X,E15.4,3X))	DBV26280
ISN 0611		WRITE(6,1200)	DBV26290
ISN 0612	1200	FORMAT(6X,' TP TUR1 INLET EN TUR1 INLET TP BOILER ONE	DBV26300
		1 FLOW RT TR ONE EN EST BOIL 1 EN ACT EX TUR1 ')	DBV26310
ISN 0613		WRITE(6,1000) TI1,HI1,TF1,WF1,HG1,HG1TO	DBV26320
ISN 0614		WRITE(6,1300)	DBV26330
ISN 0615	1300	FORMAT(6X,' TP TUR2 INLET EN TUR2 INLET TP BOILER TWO	DBV26340
		1 FLOW RT TR TWO EN EXT BOIL 2 EN ACT EX TUR2 ')	DBV26350
ISN 0616		WRITE(6,1000) TI2,HI2,TF2,WF2,HG2,HG2TO	DBV26360
ISN 0617		WRITE(6,1400)	DBV26370
ISN 0618	1400	FORMAT(6X,' AREA BOILER 1 AREA BOILER 2 AREA PREHET 1	DBV26380
		1 AREA PREHET 2 AREA CONDENSER AREA REGENATOR ')	DBV26390
ISN 0619		WRITE(6,1000) AB1,AB2,APH1,APH2,AC,ARG	DBV26400
ISN 0620		WRITE(6,1500)	DBV26410
ISN 0621	1500	FORMAT(6X,' AREA SUPHET 1 AREA SUPHET 2 DELT PIN PT 1	DBV26420
		1 DELT PIN PT 2 TEMP REG OUT FLOW RATE COOL ')	DBV26430
ISN 0622		WRITE(6,1300) ASH1,ASH2,DLTPP1,DLTPP2,TRGC,WCV	DBV26440
ISN 0623		NPCINT=NPOINT+1	DBV26450
ISN 0624		IF(NSUBSC .EQ. 0) GO TO 104	DBV26460
ISN 0625		TEMPLT(NPOINT)=A(NSUBSC)	DBV26470
ISN 0627		RATPLT(NPOINT)=RATIC3	DBV26480

ISN 0628	104 CONTINUE	DBV26490
ISN 0629	IF (RRAT .EQ. 100.) GC TO 106	DBV26500
ISN 0631	DO 105 I=1,50	DBV26510
ISN 0632	A(I)=C(I)	DBV26520
ISN 0633	105 CONTINUE	DBV26530
ISN 0634	106 CONTINUE	DBV26540

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PRINT COST INFORMATION

ISN 0635	HEXCOS=10.56*(AB2+AB1)+6.91*(APH1+APH2+ARG+ASH)
ISN 0636	TRBCOS=8268.5*(PGRCSS*1000.)**.53
ISN 0637	SECCOS=2032.0*(PGRCSS*1000.)**.48
ISN 0638	ELCCOS=18835.*(PGRCSS*1000.)**.42
ISN 0639	CDCOS=7.600*AC+24.25*WCW**.65
ISN 0640	EQCCS=HEXCOS+CDCOS+ELCCOS+SECCOS+TRBCOS
ISN 0641	SPLYCO=.0383*WB*PNET
ISN 0642	TOTSYS=1.68*EQCCS+SPLYCO
ISN 0643	COSPOW=(.03436272*EQCCS+.022968*SPLYCO)/(PNET*1000.)
ISN 0644	SPLYCI=NOW*28400.*PNET
ISN 0645	TOTSYI=1.68*EQCCS+SPLYCI
ISN 0646	COSPOI=(.03436272*EQCCS+.022968*SPLYCI)/(PNET*1000.)
ISN 0647	WRITE(6,1235)
ISN 0648	1235 FORMAT(3X,' HTXCOST TURGCST SECCST ELESCST 1 CDCTCST SPLYCST TOTSCST CSTPOW MILS PR KWHR' 2) WRITE(6,1234)HEXCOS,TRBCOS,SECCOS,ELCCOS,CDCOS,SPLYCO,TOTSYS,COSPO 1W WRITE(6,1234)HEXCOS,TRBCOS,SECCOS,ELCCOS,CDCOS,SPLYCI,TOTSYI,COSPO 1I
ISN 0651	1234 FORMAT(8D15.4)

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TEST PLOT SELECT SWITCH AND SUBSCR VALUES

ISN 0652	IF (NSUBSC .EQ. 0 .OR. NPLTSW .EQ. 0) GC TO 4238	DBV26550
ISN 0654	MINT=1.E+6	DBV26560
ISN 0655	MAXT=0.0	DBV26570
ISN 0656	MINI=0.	DBV26580
ISN 0657	MAXI=-100.	DBV26590
ISN 0658	DO 201 N=1,NPCINT	DBV26600
ISN 0659	MINT=AMIN1(TEMPLT(N),MINT)	DBV26610
ISN 0660	MAXI=AMAX1(RATPLT(N),MAXI)	DBV26620
ISN 0661	MAXT=AMAX1(TEMPLT(N),MAXT)	DBV26630
ISN 0662	201 CONTINUE	DBV26640
ISN 0663	MINT=DEZT*AMIN1(MINT/DEZT)-DEZT	DBV26650
ISN 0664	MAXT=DEZT*AMIN1(MAXT/DEZT)+DEZT	DBV26660
ISN 0665	MAXI=10.*AMIN1(MAXI/10.)+10.	DBV26670
ISN 0666	IF (IPLT .EQ. 0) CALL MODESG(Z,0)	DBV26680
ISN 0668	IPLT = 1	DBV26690
ISN 0669	CALL SUBJEG(Z,MINT,MINI,MAXT,MAXI)	DBV26700
ISN 0670	CALL OBJECTG(Z,.1..1..8..97)	DBV26710
ISN 0671	DEZU=DEZT/2.	DBV26720
ISN 0672	CALL GRIDG(Z,DEZU,1.,2,5)	DBV26730
ISN 0673	CALL LABELG(Z,0,DEZT,0,7.2)	DBV26740
ISN 0674	CALL LABELG(Z,1,5.0,0,5.2)	DBV26750
ISN 0675	CALL TITLEG(Z,40,GRITITL,33,33EFFECTIVENESS (BTU/ LB OF BRINE),33DBV26760 *,33HSENSITIVITY STUDY FOR 50 MW PLANT)	DBV26770 DBV26780 DBV26790 DBV26800

ISN 0676	CALL SETSMG(Z,53,1.5)	DBV26810
ISN 0677	CALL SETSMG(Z,55,2.0)	DBV26820
ISN 0678	CALL SETSMG(Z,84,1HR)	DBV26830
ISN 0679	CALL POINTG(Z,NPOINT,TEMPLT,RATPLT)	DBV26840
ISN 0680	CALL PAGEG(Z,0,0,1)	DBV26850
ISN 0681	4238 CONTINUE	DBV26860
ISN 0682	4239 CONTINUE	DBV26870
ISN 0683	IF (NSTOP .LT. 2 .OR. NSTOP .EQ. 6) GO TO 4250	DBV26880
ISN 0685	IF (NCASE .NE. 0) GO TO 4	DBV26890
ISN 0687	GO TO 5	DBV26900
ISN 0688	4250 IF (IPLT .NE. 0) CALL EXITG(Z)	DBV26910
ISN 0690	STOP	DBV26920
ISN 0691	END	DBV26930

LEVEL 21.8 (JUN 74)

OS/360 FORTRAN H

COMPILER OPTIONS - NAME= MAIN,OPT=00,LINECNT=58,SIZE=0000K.

SOURCE,EBCDIC,NOLIST,NODECK,LCAD,MAP,NOEDIT,NOID,XREF

ISN 0002	SUBROUTINE PRCPH(P,H,I)	DBS40100
ISN 0003	IMPLICIT REAL*8 (A-Z)	DBS40110
ISN 0004	INTEGER J,I,K,N	DBS40120
ISN 0005	COMMON/FLUIDP/R,PRES,TEMP1,RHO,XK,CP,ENTR,COND,VIS,VOL,ENTH1,CV,UVD	DBS40130
	1,DHCON,HSGAS,HSLIQ	DBS40140
	C SUBROUTINE TO FIND ISOBUTANE PROPERTIES	DBS40150
ISN 0006	DATA PUPPER,PLOWER,HUPPER,HLOWER/2000.,1.,-480.,-840./	DBS40160
ISN 0007	PRES=P	DBS40170
	C IF PRESSURE IS OUTSIDE TABLE LIMITS SET TO TABLE LIMITS	DBS40180
ISN 0008	IF(PRES .LE. PLOWER) PRES=PLOWER	DBS40190
ISN 0010	IF(PRES .GE. HUPPER) PRES=HUPPER	DBS40200
ISN 0012	ENTH=H	DBS40210
ISN 0013	ENTH1=ENTH	DBS40220
ISN 0014	ENTH2=H	DBS40230
	C IF ENTHALPY IS OUTSIDE TABLE LIMITS SET TO TABLE EXTREMS	DBS40240
ISN 0015	IF(ENTH .LE. HLOWER) ENTH=HLOWER	DBS40250
ISN 0017	IF(ENTH .GE. HUPPER) ENTH=HUPPER	DBS40260
	C FIND GRID IN TABLES AND EXTRAPOLATION FACTOR FOR PRES AND ENTH	DBS40270
ISN 0019	IF(I .EQ. 5) GO TO 40	DBS40280
ISN 0021	CALL POINT(PRES,ENTH)	DBS40290
ISN 0022	40 CONTINUE	DBS40300
ISN 0023	J=IABS(I)	DBS40310
ISN 0024	50 K=J	DBS40320
ISN 0025	J=K/10	DBS40330
ISN 0026	N=K-10*J	DBS40340
ISN 0027	GO TO (101,102,103,104,105,106,107,108,109).N	DBS40350
ISN 0028	101 TEMP1=PHTEMP(PRES,ENTH)	DBS40360
ISN 0029	GO TO 110	DBS40370
ISN 0030	102 VOL=PHVOL(PRES,ENTH)	DBS40380
ISN 0031	RHO=1.0/VOL	DBS40390
ISN 0032	GO TO 110	DBS40400
ISN 0033	103 XK=DMINI(2.00,PHGAMN(PRES,ENTH))	DBS40410
ISN 0034	GO TO 110	DBS40420
ISN 0035	104 CP=DMINI(1.001,PHCP(PRES,ENTH))	DBS40430
ISN 0036	GO TO 110	DBS40440
ISN 0037	105 CALL PHSC(P,ENTH2,CP,CCN,HSGAS,HSLIQ)	DBS40450
ISN 0038	GO TO 110	DBS40460
ISN 0039	106 ENTR=UHENTR(PRES,ENTH)	DBS40470
ISN 0040	GO TO 110	DBS40480
ISN 0041	107 COND=PHCOND(PRES,ENTH)	DBS40490
ISN 0042	GO TO 110	DBS40500
ISN 0043	108 VIS=PHVIS(PRES,ENTH)	DBS40510
ISN 0044	GO TO 110	DBS40520
ISN 0045	109 CV=PHCV(PRES,ENTH)	DBS40530
ISN 0046	110 CONTINUE	DBS40540
ISN 0047	IF(J .GT. 0) GO TO 50	DBS40550
ISN 0049	RETURN	DBS40560
ISN 0050	END	DBS40570

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OS/360 FORTRAN H

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CCMPILER OPTIONS - NAME= MAIN,OPT=00,LINECNT=58,SIZE=000JK,
                   SCURCE,EBDCIC,NOLIST,NODECK,LCAD,MAP,NOEDIT,NQID,XREF
ISN 0002      SUBROUTINE POINT(P,H)                                DBS40580
ISN 0003      IMPLICIT REAL*8(A-Z)                                DBS40590
C             SUBROUTINE TO OBTAIN DESIRED GRID SQUARE FOR PROPERTIES CALCULATION DBS40600
ISN 0004      INTEGER I,J,IC,JC,NPR,NEN                                DBS40610
ISN 0005      COMMON/POIN/NPR,NEN,FI,FJ,IC,JC,I,J                    DBS40620
ISN 0006      DIMENSION PR(25),EN(25)                                DBS40630
ISN 0007      DATA PR/1.,10.,14.7,20.,25.,30.,40.,50.,60.,70.,80.,90.,100.,150., DBS40640
1200.,250.,300.,400.,500.,600.,800.,1000.,2000./                      DBS40650
ISN 0008      NPR=23                                                DBS40660
ISN 0009      DATA EN/-840.,-820.,-800.,-780.,-760.,-740.,-720.,-700.,-680.,-660 DBS40670
1.,-640.,-620.,-600.,-580.,-560.,-540.,-520.,-500.,-480./          DBS40680
ISN 0010      NEN=19                                                DBS40690
ISN 0011      FI=1                                                  DBS40700
ISN 0012      FJ=1                                                  DBS40710
C             FIND SUBSCRIPT POINT THAT BOUNDS PRESSURE            DBS40720
ISN 0013      DO 30 I=1,NPR                                          DBS40730
ISN 0014      IC=I                                                  DBS40740
ISN 0015      IF (PR(I)-P) 30,40,50                                  DBS40750
ISN 0016      30 CONTINUE                                           DBS40760
C             IF PRESSURE IS EXACTLY ON GRID SET ENTHALPY FACTOR TO ZERO DBS40770
ISN 0017      40 IC=IC+1                                             DBS40780
ISN 0018      FI=0.0                                                DBS40790
C             FIND SUBSCRIPT POINT THAT BOUNDS ENTHALPY            DBS40800
ISN 0019      50 DO 50 J=1,NEN                                       DBS40810
ISN 0020      JC=J                                                  DBS40820
ISN 0021      IF (EN(J)-H) 80,90,100                                  DBS40830
ISN 0022      80 CONTINUE                                           DBS40840
ISN 0023      90 JC=JC+1                                             DBS40850
C             IF ENTHALPY IS EXACTLY ON GRID SET ENTHALPY FACTOR TO ZERO DBS40860
ISN 0024      FJ=0.0                                                DBS40870
C             COMPUTE PRESSURE AND ENTHALPY FACTORS                DBS40880
ISN 0025      100 I=IC-1                                             DBS40890
ISN 0026      J=JC-1                                                DBS40900
ISN 0027      IF (FI .EQ. 0.0) GO TO 120                             DBS40910
ISN 0029      FI=(P-PR(I))/(PR(IC)-PR(I))                          DBS40920
ISN 0030      120 IF (FJ .EQ. 0.0) GO TO 140                         DBS40930
ISN 0032      FJ=(H-EN(J))/(EN(JC)-EN(J))                          DBS40940
ISN 0033      140 RETURN                                           DBS40950
ISN 0034      END                                                  DBS40960

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LEVEL 21.8 (JUN 74)

OS/360 FORTRAN H

COMPILER OPTIONS - NAME= MAIN,OPT=00,LINECNT=58,SIZE=0000K,
SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,NOID,XREF

ISN 0002	FUNCTION GRID(F1,F2,X1,X2,X3,X4)	DBS40970
ISN 0003	IMPLICIT REAL*8 (A-Z)	DBS40980
	C COMPUTATION OF LINEAR INTERPOLATION FOR TWO DIMENSION TABLES	DBS40990
ISN 0004	GRID=X1*(1-F1-F2+F1*F2)+X2*F1*(1.0-F2)+X3*F2*(1.0-F1)+X4*F1*F2	DBS41000
ISN 0005	RETURN	DBS41010
ISN 0006	END	DBS41020

LEVEL 21.8 (JUN 74)

OS/360 FORTRAN H

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CCMPILER OPTIONS - NAME= MAIN,OPT=00,LINECNT=58,SIZE=0000K,
SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,NOID,XREF
ISN 0002      FUNCTION PHTEMP(PRES,ENTH)                                DBS41030
ISN 0003      IMPLICIT REAL*8 (A-Z)                                    DBS41040
ISN 0004      INTEGER IO,JO,I,J,NPR,NEN                                DBS41050
ISN 0005      COMMON/POIN/NPR,NEN,FI,FJ,IO,JO,I,J                      DBS41060
ISN 0006      DIMENSION TEMP(23,15),TEM1(161),TEM2(161),TEM3(115)     DBS41070
ISN 0007      EQUIVALENCE (TEMP(1,1),TEM1(1)),(TEMP(1,8),TEM2(1)),(TEMP(1,15),TEDB
IM3(1))                                                    DBS41090
ISN 0008      C      FUNCTION TO FIND TEMPERATURE FROM PRESSURE AND ENTHALPY DBS41100
DATA TEM1/-50.,-7.,15*0.0,-2.,-3.,-4.,-5.,-6.,-7.,-49.,-7.,10.89,2DBS41110
16.5,37.5,37.5,38.,36.3,2*36.3,35.5,9*35.,30.,20.,10.,-48.,-7.,10 DBS41120
2.89,26.5,37.5,47.5,63.,71.3,71.4,71.5,6*71.,70.5,6*70.,-47.,-7.,10DBS41130
3.89,26.5,37.5,47.5,63.,77.,89.,98.5,7*105.,3*104.,3*103.,-46.,-7.,DBS41140
410.89,26.5,37.5,47.5,63.,77.,89.,98.5,107.,115.5,123.,137.,3*136.5DBS41150
5,136.,135.,135.,3*136.,-45.,-7.,10.89,26.5,37.5,47.5,63.,77.,89., DBS41160
698.5,107.,115.5,123.,154.,3*166.,4*167.,166.5,166.,-44.,-7.,10.89,DBS41170
726.5,37.5,47.5,63.,77.,89.,98.5,107.,115.5,123.,155.,178.5,193.,1DBS41180
893.5,194.,195.,195.5,196.,197.,199./ DBS41190
ISN 0009      DATA TEM2/-42.2,-6.67,10.89,25.6,36.93,46.67,62.88,76.35,87.89,98.DB
103,107.2,115.5,123.1,154.4,178.5,198.7,216.1,220.0,221.0,222.,224.DB
2,224.5,226.,2.5,5.0,10.89,25.6,36.93,46.67,62.88,76.35,87.89,98.03DB
3,107.2,115.5,123.1,154.4,178.5,198.7,216.1,243.,246.,249.,252.,255DB
4.,259.9,55.3,60.,58.23,59.9,60.,63.,68.,76.35,87.89,98.03,107.2,11DB
55.5,123.1,154.4,178.5,198.7,216.1,244.9,265.,272.,280.,283.7,291.1DB
6,104.4,106.,107.1,108.,110.,111.,114.,115.9,118.,120.5,124.,126., DBS41260
7128.5,154.4,178.5,198.7,216.1,244.9,268.7,283.3,298.3,305.6,318.1,DB
8150.3,152.,152.8,154.,155.,156.,158.,159.8,162.,164.,166.,168.,169DB
9.5,179.6,190.,201.,216.1,244.9,268.7,290.7,313.7,325.3,344.7,194.,DB
1195.9,196.2,197.,197.5,198.,200.,201.6,204.,205.,207.,208.,209.5,DB
217.5,225.8,234.3,243.3,262.3,282.7,301.2,328.9,344.,370.6,235.6,23DB
37.3,237.3,237.1,237.4,238.,240.,241.8,243.5,244.1,246.,247.5,248.5DB
4,255.2,262.,269.,276.1,290.7,304.8,319.2,345.6,362.9,395.9/ DBS41330
ISN 0010      DATA TEM3/274.9,275.8,276.3,276.9,277.4,278.0,279.1,280.2,281.3,28DB
12.4,283.6,284.7,285.8,291.4,296.8,302.3,307.8,319.1,330.9,342.5,360DB
25.3,383.2,421.0,312.5,313.2,313.6,314.1,314.6,315.0,316.0,316.9,31DB
37.6,318.7,319.6,320.5,321.4,326.0,330.6,335.2,339.8,349.3,359.0,36DB
48.7,388.4,405.3,445.0,348.5,349.2,349.6,350.0,350.4,350.8,351.5,35DB
52.3,353.1,353.8,354.6,355.3,356.1,360.0,364.0,367.9,371.8,380.2,38DB
68.5,397.0,414.2,423.3,468.9,383.5,384.0,384.2,384.6,384.9,385.2,38DB
75.9,386.6,387.3,387.9,388.6,389.2,389.9,393.4,394.4,400.3,403.9,41DB
81.4,418.9,423.9,433.9,443.9,493.8,417.0,417.5,417.8,418.1,418.4,41DB
98.8,419.4,420.0,420.7,421.4,422.1,422.8,423.5,426.5,429.5,432.5,43DB
15.8,442.5,449.1,453.3,461.8,470.3,512.8/ DBS41440
ISN 0011      IF (IO .EQ. (NPR+1)) IC=NPR DBS41450
ISN 0013      IF (JO .EQ. (NEN+1)) JO=NEN DBS41460
ISN 0015      X1=TEMP(I,J) DBS41470
ISN 0016      X2=TEMP(IC,J) DBS41480
ISN 0017      X3=TEMP(I,JC) DBS41490
ISN 0018      X4=TEMP(IC,JO) DBS41500
ISN 0019      PHTEMP=CRIC(FI,FJ,X1,X2,X3,X4) DBS41510
ISN 0020      RETURN DBS41520
ISN 0021      END DBS41530

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LEVEL 21.8 (JUN 74)

OS/360 FORTRAN H

COMPILER OPTIONS - NAME= MAIN,OPT=00,LINECNT=58,SIZE=0000K,
SOURCE,EBCDIC,NOLIST,NODECK,LCAD,MAP,NOEDIT,NOID,XREF

ISN 0002	FUNCTION PHVOL(PRES,ENTH)	DBS41540
ISN 0003	IMPLICIT REAL*8 (A-Z)	DBS41550
ISN 0004	INTEGER IO,JO,I,J,NPR,NEN	DBS41560
ISN 0005	COMMON/PGIN/NPR,NEN,FI,FJ,IO,JO,I,J	DBS41570
ISN 0006	DIMENSION VOL(23,15),VC1(161),VC2(161)	DBS41580
ISN 0007	DIMENSION VC3(115)	DBS41590
ISN 0008	EQUIVALENCE (VOL(1,1),VC1(1)),(VOL(1,8),VC2(1))	DBS41600
ISN 0009	EQUIVALENCE (VOL(1,15),VC3(1))	DBS41610
	C FUNCTION TO FIND SPECIFIC VOLUME FROM PRESSURE AND ENTHALPY	DBS41620
ISN 0010	DATA VOL/	DBS41630
	& 39.00,.2000,.0267,.0267,.0267,.0267,.0267,.0267,.0267,.0266,	DBS41640
	& .0266,.0266,.0265,.0265,.0264,.0263,.0261,.0257,.0251,.0242,	DBS41650
	& .0232,.0220,.0208,42.0,1.200,.6000,.2300,.0278,.0278,.0278,	DBS41660
	& .0278,.0278,.0278,.0278,.0278,.0277,.0277,.0276,.0276,.0275,	DBS41670
	& .0274,.0273,.0272,.0270,.0266,.0260,46.00,2.230,1.360,.8000,	DBS41680
	& .5050,.3150,.1000,.0289,.0289,.0289,.0289,.0289,.0289,.0288,	DBS41690
	& .0288,.0287,.0287,.0286,.0285,.0284,.0283,.0281,.0277,50.00,	DBS41700
	& 3.350,2.000,1.330,.9500,.7110,.3820,.2380,.1330,.0660,.0302,	DBS41710
	& .0302,.0302,.0302,.0301,.0300,.0299,.0298,.0297,.0296,	DBS41720
	& .0295,.0293,.0284,55.00,4.470,2.710,1.870,1.380,1.080,.7080,	DBS41730
	& .4900,.3400,.2580,.1870,.1310,.0959,.0316,.0316,.0315,.0314,	DBS41740
	& .0312,.0311,.0309,.0307,.0305,.0295,62.00,5.410,3.470,	DBS41750
	& 2.380,1.840,1.470,1.000,.7490,.5610,.4390,.3550,.2900,.2320,	DBS41760
	& .0715,.0335,.0334,.0332,.0330,.0327,.0325,.0321,.0318,.0306,	DBS41770
	& 70.00,6.330,4.130,2.930,2.280,1.850,1.310,1.000,.7850,.6320,	DBS41780
	& .5120,.4310,.3690,.1700,.0770,.0358,.0355,.0350,.0347,.0344,	DBS41790
	& .0339,.0335,.0312/	DBS41800
ISN 0011	DATA VOL2/	DBS41810
	& 77.40,7.200,4.880,3.490,2.740,2.240,1.610,1.250,1.000,.8310,	DBS41820
	& .6890,.5920,.5000,.2710,.1550,.8900,.0448,.0380,.0375,.0371,	DBS41830
	& .0362,.0354,.0335,84.60,8.060,5.640,4.040,3.210,2.650,1.930,	DBS41840
	& 1.500,1.220,1.020,.8600,.7420,.6510,.3780,.2350,.1540,.1000,	DBS41850
	& .0429,.0417,.0404,.0391,.0382,.0350,95.50,8.790,6.310,4.490,	DBS41860
	& 3.650,3.060,2.220,1.720,1.430,1.180,1.020,.8910,.7840,.4680,	DBS41870
	& .3090,.2190,.1590,.0810,.0480,.0474,.0440,.0417,.0369,103.0,	DBS41880
	& 9.500,6.930,4.940,4.060,3.350,2.500,1.950,1.610,1.340,1.150,	DBS41890
	& 1.030,.9070,.5640,.3850,.2810,.2110,.1400,.0770,.0591,.0497,	DBS41900
	& .0465,.0388,112.0,10.20,7.540,5.400,4.370,3.640,2.700,2.140,	DBS41910
	& 1.770,1.510,1.280,1.140,1.020,.6450,.4560,.3350,.2640,.1680,	DBS41920
	& .1120,.0864,.0595,.0521,.0411,120.0,10.90,8.120,5.870,4.680,	DBS41930
	& 3.930,2.900,2.320,1.930,1.630,1.410,1.250,1.120,.7110,.5120,	DBS41940
	& .3890,.3110,.2070,.1480,.1089,.0735,.0600,.0439,128.0,11.50,	DBS41950
	& 8.620,6.260,4.990,4.170,3.100,2.500,2.130,1.760,1.530,1.350,	DBS41960
	& 1.210,.7740,.5600,.4300,.3460,.2360,.1760,.1348,.0891,.0710,	DBS41970
	& .0467/	DBS41980
ISN 0012	DATA VOL3/	DBS41990
	& 136.0,12.00,9.130,6.630,5.300,4.390,3.300,2.650,2.210,1.880,	DBS42000
	& 1.630,1.460,1.300,.8310,.6070,.4670,.3810,.2650,.2020,.1575,	DBS42010
	& .1058,.0819,.0496,142.0,12.40,9.640,7.030,5.610,4.620,3.500,	DBS42020
	& 2.800,2.350,2.000,1.730,1.550,1.350,.8840,.6480,.5040,.4130,	DBS42030
	& .2940,.2210,.1768,.1206,.0841,.0531,149.0,12.80,10.00,7.420,	DBS42040
	& 5.920,4.840,3.690,2.940,2.490,2.100,1.830,1.630,1.480,.9360,	DBS42050
	& .6880,.5380,.4390,.3160,.2410,.1958,.1354,.1043,.0568,154.0,	DBS42060
	& 13.20,10.50,7.830,6.190,5.070,3.890,3.050,2.590,2.220,1.930,	DBS42070

ISN 0013
ISN 0015
ISN 0017
ISN 0018
ISN 0019
ISN 0020
ISN 0021
ISN 0022
ISN 0023

& 1.710,1.500,.9860,.7300,.5720,.4670,.3380,.2610,.2100,.1500,
& .1150,.0610,162.0,13.60,11.00,8.150,6.430,5.300,4.060,3.190,
& 2.200,2.320,2.020,1.750,1.590,1.030,.7710,.6080,
& .4940,.3560,.2800,.2230,.1610,.1290,.0650/
IF(I0.EQ.(NPR+1)) IC=NPR
IF(J0.EQ.(NEN+1)) J0=NEN
X1=VOL(I,J)
X2=VOL(IG,J)
X3=VOL(I,J0)
X4=VOL(I0,J0)
PHVOL=GRID(FI,FJ,X1,X2,X3,X4)
RETURN
END

DBS42080
DBS42090
DBS42100
DBS42110
DBS42120
DBS42130
DBS42140
DBS42150
DBS42160
DBS42170
DBS42180
DBS42190
DBS42200

LEVEL 21.8 (JUN 74)

DS/360 FORTRAN H

CCMPILER OPTIONS - NAME= MAIN,OPT=00,LINECNT=58,SIZE=0000K,
SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NODEDIT,NOID,XREF

ISN 0002	FUNCTION PHGAMN(PRES,ENTH)	DBS42210
ISN 0003	IMPLICIT REAL*8 (A-Z)	DBS42220
ISN 0004	INTEGER IO,JO,I,J,NPR,NEN	DBS42230
ISN 0005	COMMON/POIN/NPR,NEN,FI,FJ,IO,JO,I,J	DBS42240
ISN 0006	DIMENSION GAMN(25,25)	DBS42250
	C FUNCTION TO FIND RATIO OF SPECIFIC HEATS	DBS42260
ISN 0007	DATA GAMN/625*10./	DBS42270
ISN 0008	IF(IO .EQ. (NPR+1)) IC=NPR	DBS42280
ISN 0010	IF(JO .EQ. (NEN+1)) JO=NEN	DBS42290
ISN 0012	X1=GAMN(I,J)	DBS42300
ISN 0013	X2=GAMN(IG,J)	DBS42310
ISN 0014	X3=GAMN(I,JG)	DBS42320
ISN 0015	X4=GAMN(IC,JO)	DBS42330
ISN 0016	PHGAMN=GRID(FI,FJ,X1,X2,X3,X4)	DBS42340
ISN 0017	RETURN	DBS42350
ISN 0018	END	DBS42360

LEVEL 21.8 (JUN 74)

OS/360 FORTRAN H

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CCMPILER OPTIONS - NAME= MAIN,CPT=00,LINECNT=58,SIZE=0000K,
SOURCE,EBCDIC,NOLIST,NODECK,LCAO,MAP,NOEDIT,NOID,XREF
ISN 0002      FUNCTION PHCP(PRES,ENTH)                                DBS42370
ISN 0003      IMPLICIT REAL*8 (A-Z)                                  DBS42380
ISN 0004      INTEGER IO,JO,I,J,NPR,NEN                              DBS42390
ISN 0005      COMMON/POIN/NPR,NEN,F1,FJ,IC,JO,I,J                    DBS42400
ISN 0006      DIMENSION CPFN(23,19),CPF1(161),CPF2(161),CPF3(115)   DBS42410
ISN 0007      EQUIVALENCE (CPFN(1,1),CPF1(1)),(CPFN(1,8),CPF2(1))   DBS42420
ISN 0008      EQUIVALENCE (CPFN(1,15),CPF3(1))                       DBS42430
ISN 0009      C FUNCTION TO FIND CP FROM PRESSURE AND ENTHALPY       DBS42440
DATA CPF1/3.,.56,4*.555,8*.55,2*.545,.54,.535,.53,.525,.52,.51,   DBS42450
& .505,3.,.57,.56,2*.57,.565,11*.56,.555,.55,.54,.53,.525,.52,4*3.,DBS42460
& 2*.58,.61,.63,.59,.58,.575,9*.57,.56,.55,.54,6*3.,2*.62,.63,.67, DBS42470
& .66,.65,.64,9*.61,.55, 10*3.,.68,.69,.71,.67,3*.66,3*.635,2*.625,DBS42480
& .61,12*3.,.76,.75,.72,.71,.7,.69,.67,.665,.66,.655,.635,13*3.,.79DBS42490
& .78,.77,.76,.755,.74,.73,.70,.69,.665/                             DBS42500
ISN 0010      DATA CPF2/.385,.45,.46,11*3.,.8,.79,.83,.815,.785,.75,.715,.69,.66DBS42510
& .365,.395,.42,.43,.44,.485,.55,.5,8*3.,.94,.92,.91,.80,.715,.69,DBS42520
& .655,.39,.395,.40,.41,.42,.425,.45,.465,.485,.5,.505,.59,.56,.59,DBS42530
& 3*3.,.96,1.,1.165,.865,.79,.685, 2*.42,3*.425,.43,.445,.45,.46, DBS42540
& .47,.48,.49,.51,.58,.65,.8,.9,3.,1.5,2.14,1.19,.96,.745, 2*.445, DBS42550
& 2*.45,.455,.46,2*.465,.47,.475,.48,.485,.49,.53,.56,.6,.675,.92, DBS42560
& 1.18,2.24,1.31,1.04,.76, 2*.47,.475,.48,.485,4*.49,3*.50,.505, DBS42570
& .53,.555,.59,.665,.875,1.11,1.4,1.25,1.06,.78, .495,5*.5, DBS42580
& .505,.51,2*.515,2*.52,.525,.54,.565,.59,.64,.705,.83,.97,1.1, DBS42590
& 1.02,.82/                                                            DBS42600
ISN 0011      DATA CPF3/6*.52,.525,.53,2*.535,.545,2*.55,.565,.585,.6,.63,.68, DBS42610
& .74,.81,.935,.945,.84, 4*.545,3*.55,2*.555,.56,2*.565,.57,.585, DBS42620
& .595,.61,.625,.655,.695,.735,.82,.85,.86, 4*.565,3*.57,2*.575, DBS42630
& 3*.58,.585,.595,.605,.615,.625,.645,.67,.725,.795,.84,.87, DBS42640
& 4*.585,6*.59,3*.595,.6,.61,.62,.63,.64,.66,.71,.78,.84,.87, DBS42650
& 5*.595,4*.6,4*.605,.615,.625,.635,.65,.66,.7,.77,.83,.86,.87/ DBS42660
ISN 0012      IF(IO.EQ.(NPR+1)) IC=NPR                                DBS42670
ISN 0014      IF(JO.EQ.(NEN+1)) JO=NEN                                DBS42680
ISN 0016      X1=CPFN(I,J)                                             DBS42690
ISN 0017      X2=CPFN(IC,J)                                            DBS42700
ISN 0018      X3=CPFN(I,JO)                                            DBS42710
ISN 0019      X4=CPFN(IC,JO)                                           DBS42720
ISN 0020      PHCP=GRID(F1,FJ,X1,X2,X3,X4)                             DBS42730
ISN 0021      RETURN                                                    DBS42740
ISN 0022      END                                                       DBS42750

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LEVEL 21.8 (JUN 74)

OS/360 FORTRAN H

COMPILER OPTIONS - NAME= MAIN,OPT=00,LINECNT=58,SIZE=0000K,
SOURCE,EBCDIC,NOLIST,NODECK,LCAD,MAP,NOEDIT,NOID,XREF

ISN 0002	SUBROUTINE PHSC(PHSAT,T,DHCON,HSGAS,HSLIQ)	DBS42760
ISN 0003	IMPLICIT REAL*8(A-Z)	DBS42770
ISN 0004	INTEGER I	DBS42780
ISN 0005	DIMENSION PSAT(31),TSAT(31),HCON(31),HGAS(31)	DBS42790
ISN 0006	DATA PSAT/7.5,9.28,11.53,14.41,17.82,21.83,26.48,31.86,38.04,45.06,52.98,61.95,72.04,83.22,95.73,109.72,125.18,141.98,160.55,180.89,203.04,227.20,255.41,281.85,312.60,345.82,381.57,420.11,461.54,505.06/	DBS42800
		DBS42810
		DBS42820
		DBS42830
ISN 0007	DATA TSAT/-20.,-10.,0.,10.,20.,30.,40.,50.,60.,70.,80.,90.,100.,110.,120.,130.,140.,150.,160.,170.,180.,190.,200.,210.,220.,230.,240./	DBS42840
		DBS42850
		DBS42860
ISN 0008	DATA HCON/162.8,160.9,158.9,156.8,154.6,152.2,149.7,147.2,144.5,140.9,139.1,136.1,133.1,130.1,127.,123.7,120.2,116.4,112.3,108.2,103.0,99.,93.5,88.4,82.4,75.6,68.1,59.3,48.7,33.9,0./	DBS42870
		DBS42880
		DBS42890
ISN 0009	DATA HGAS/-668.4,-685.1,-681.8,-678.5,-675.2,-671.5,-668.7,-665.5,-662.2,-659.1,-656.0,-652.9,-649.8,-646.7,-643.7,-640.6,-637.5,-634.6,-631.8,-629.0,-626.3,-623.8,-621.4,-619.0,-617.0,-615.6,-614.7,-614.2,-614.5,-616.7,-631.2/	DBS42900
		DBS42910
		DBS42920
		DBS42930
	C IF TEMPERATURE IS OUTSIDE TABLE LIMITS SET TO TABLE LIMITS	DBS42940
ISN 0010	IF(T .LE. TSAT(1)) T=TSAT(1)	DBS42950
ISN 0012	IF(T .GE. TSAT(31)) T=TSAT(31)	DBS42960
ISN 0014	DO 30 I=1,31	DBS42970
ISN 0015	IF(TSAT(I)-T) 30,10,20	DBS42980
ISN 0016	10 PHSAT=PSAT(I)	DBS42990
ISN 0017	DHCON=HCON(I)	DBS43000
ISN 0018	HSGAS=HGAS(I)	DBS43010
ISN 0019	GO TO 40	DBS43020
ISN 0020	20 X1=(T-TSAT(I-1))/(TSAT(I)-TSAT(I-1))	DBS43030
ISN 0021	PHSAT=PSAT(I-1)*(1.-X1)+X1*PSAT(I)	DBS43040
ISN 0022	DHCON=HCON(I-1)*(1.-X1)+X1*HCON(I)	DBS43050
ISN 0023	HSGAS=HGAS(I-1)*(1.-X1)+X1*HGAS(I)	DBS43060
ISN 0024	GO TO 40	DBS43070
ISN 0025	30 CONTINUE	DBS43080
ISN 0026	40 HSLIQ=HSGAS-DHCON	DBS43090
ISN 0027	RETURN	DBS43100
ISN 0028	END	DBS43110

LEVEL 21.8 (JUN 74)

OS/360 FORTRAN H

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CCMPILER OPTIONS - NAME= MAIN,OPT=00,LINECNT=58,SIZE=0000K,
SOURCE,EBCCIC,NCLIST,NODECK,LOAD,MAP,NOEDIT,NOID,XREF
ISN 0002      FUNCTION UHENTR(PRES,ENTH)                                DBS43120
ISN 0003      IMPLICIT REAL*8 (A-Z)                                    DBS43130
ISN 0004      INTEGER IC,JO,I,J,NPR,NEN                                DBS43140
ISN 0005      COMMON/POIN/NPR,NEN,FI,FJ,IC,JO,I,J                      DBS43150
ISN 0006      DIMENSION ENTR(23,19),ENT1(161),ENT2(161),ENT3(115)    DBS43160
ISN 0007      EQUIVALENCE (ENTR(1,1),ENT1(1)),(ENTR(1,8),ENT2(1)),(ENTR(1,15),ENDS43170
IT3(1))
C      FUNCTION TO FIND ENTROPY FROM PRESSURE AND ENTHALPY            DBS43180
ISN 0008      DATA ENT1/23*.816,.862,.860,.858,.856,.855,.855,.856,.856,.857,.8DBS43200
156,.856,.856,.857,.856,.8565,.856,.854,.853,.852,.8515,.850,.848,.DBS43210
2346,.908,.905,.9002,.8985,.897,.896,.8961,.894,.893,.893.6*.892,.8DBS43220
3915,.891,.890,.889,.887,.8855,.863,.952,.949,.943,.939,.9565,.9355DBS43230
4,.933,.932,.931,.931,3*.930,2*.929,2*.928,.927,.9265,.926,.924,.92DBS43240
51,.915,1.01,.993,.985,.980,.9765,.9745,.971,.969,.967,.967,.966,.9DBS43250
66,.965,.967,.964,2*.963,.962,.961,.960,.958,.956,.951,1.05,1.037,1DBS43260
7.028,1.022,1.0175,1.015,1.010,1.006,1.004,1.003,1.002,1.000,.999,.DBS43270
8997,3*.996,.9955,.995,.994,.992,.990,.981,1.09,1.081,1.070,1.063,1DBS43280
9.058,1.054,1.049,1.044,1.041,1.036,1.037,1.035,1.035,1.054,1.050,1.029,1DBS43290
1.028,1.027,1.027,1.026,1.025,1.023,1.020,1.016/
ISN 0009      DATA ENT2/1.214,1.126,1.114,1.105,1.098,1.093,1.087,1.081,1.077,1.0DBS43310
1.074,1.072,1.070,1.069,1.063,1.060,1.055,1.057,1.056,1.055,1.04,1.0DBS43320
2.052,1.049,1.040,1.246,1.168,1.155,1.145,1.139,1.134,1.126,1.120,1.0DBS43330
3.116,1.112,1.109,1.107,1.104,1.097,1.092,1.089,1.087,1.084,1.083,1.0DBS43340
4.082,1.080,1.078,1.073,1.286,1.209,1.195,1.185,1.177,1.172,1.163,1.0DBS43350
5.157,1.152,1.147,1.145,1.140,1.138,1.130,1.124,1.119,1.117,1.113,1.0DBS43360
6.110,1.109,1.107,1.105,1.095,1.324,1.245,1.230,1.221,1.214,1.207,1.0DBS43370
7.159,1.152,1.187,1.182,1.178,1.176,1.171,1.160,1.155,1.149,1.146,1.0DBS43380
8.141,1.138,1.136,1.133,1.131,1.122,1.358,1.279,1.266,1.256,1.249,1.0DBS43390
9.243,1.233,1.226,1.220,1.216,1.212,1.206,1.204,1.193,1.185,1.179,1.0DBS43400
1.175,1.169,1.166,1.163,1.160,1.157,1.147,1.391,1.308,1.298,1.296,1.0DBS43410
2.267,1.260,1.263,1.257,1.252,1.246,1.242,1.238,1.235,1.223,1.215,1.0DBS43420
3.3208,1.204,1.197,1.193,1.190,1.186,1.182,1.171,1.418,1.342,1.327,1.0DBS43430
4.4317,1.309,1.304,1.294,1.286,1.281,1.276,1.271,1.268,1.264,1.252,1.0DBS43440
5.5243,1.236,1.232,1.225,1.219,1.216,1.211,1.206,1.193/
ISN 0010      DATA ENT3/1.446,1.372,1.355,1.349,1.341,1.335,1.325,1.314,1.311,1.0DBS43460
1.306,1.301,1.297,1.291,1.279,1.269,1.264,1.258,1.250,1.245,1.241,1.0DBS43470
2.2235,1.229,1.216,1.472,1.397,1.382,1.373,1.365,1.359,1.349,1.341,1.0DBS43480
3.3335,1.330,1.326,1.322,1.318,1.304,1.296,1.289,1.284,1.275,1.269,1.0DBS43490
4.4264,1.258,1.252,1.239,1.498,1.420,1.407,1.396,1.389,1.383,1.373,1.0DBS43500
5.5366,1.359,1.354,1.349,1.345,1.342,1.329,1.321,1.313,1.307,1.299,1.0DBS43510
6.6292,1.288,1.281,1.276,1.262,1.521,1.443,1.430,1.419,1.411,1.405,1.0DBS43520
7.7395,1.388,1.381,1.376,1.371,1.367,1.365,1.352,1.341,1.335,1.330,1.0DBS43530
8.8322,1.315,1.303,1.293,1.285,1.283,1.544,1.464,1.452,1.440,1.433,1.0DBS43540
9.9427,1.417,1.411,1.403,1.398,1.393,1.389,1.385,1.372,1.362,1.354,1.0DBS43550
1.1348,1.338,1.330,1.324,1.314,1.307,1.304/
ISN 0011      IF (IC .EQ. (NPR+1)) IC=NPR                                DBS43560
ISN 0013      IF (JO .EQ. (NEN+1)) JO=NEN                                DBS43570
ISN 0015      X1=ENTR(I,J)                                                DBS43580
ISN 0016      X2=ENTR(1,J)                                                DBS43590
ISN 0017      X3=ENTR(1,JO)                                              DBS43600
ISN 0018      X4=ENTR(1,JO)                                              DBS43610
ISN 0019      UHENTR=GRIC(FI,FJ,X1,X2,X3,X4)                            DBS43620
ISN 0020      RETURN                                                    DBS43630
ISN 0021      END                                                        DBS43650

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LEVEL 21.6 (JUN 74)

DS/360 FORTRAN H

CCMPILER OPTIONS - NAME= MAIN,OPT=00,LINECNT=58,SIZE=0000K,
SOURCE,EBCDIC,NOLIST,NODECK,LCAD,MAP,NOEDIT,NOID,XREF

ISN 0002	FUNCTION PHCOND(PRES,ENTH)	DBS43660
ISN 0003	IMPLICIT REAL*8(A-Z)	DBS43670
ISN 0004	INTEGER IO,JO,I,J,NPR,NEN	DBS43680
ISN 0005	COMMON/POIN/NPR,NEN,FI,FJ,IG,JO,I,J	DBS43690
ISN 0006	DIMENSION COND(25,25)	DBS43700
	C FUNCTION TO FIND CONDUCTIVITY	DBS43710
ISN 0007	DATA COND/625*10./	DBS43720
ISN 0008	IF(IO .EQ. (NPR+1)) IC=NPR	DBS43730
ISN 0010	IF(JO .EQ. (NEN+1)) JO=NEN	DBS43740
ISN 0012	X1=COND(I,J)	DBS43750
ISN 0013	X2=COND(IG,J)	DBS43760
ISN 0014	X3=COND(I,JO)	DBS43770
ISN 0015	X4=COND(IG,JO)	DBS43780
ISN 0016	PHCOND=GRID(FI,FJ,X1,X2,X3,X4)	DBS43790
ISN 0017	RETURN	DBS43800
ISN 0018	END	DBS43810

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LEVEL 21.8 (JUN 74)

OS/360 FORTRAN H

COMPILER OPTIONS - NAME= MAIN,OPT=00,LINECNT=58,SIZE=0000K,		
SOURCE,EBCDIC,NOLIST,NODECK,LCAD,MAP,NOEDIT,NOID,XREF		
ISN 0002	FUNCTION PHVIS(PRES,ENTH)	DBS43820
ISN 0003	IMPLICIT REAL*8(A-Z)	DBS43830
ISN 0004	INTEGER IO,JO,I,J,NPR,NEN	DBS43840
ISN 0005	COMMON/POIN/NPR,NEN,FI,FJ,IO,JO,I,J	DBS43850
ISN 0006	DIMENSION VISF(25,25)	DBS43860
	C FUNCTION TO FIND VISCOSITY	DBS43870
ISN 0007	DATA VISF/625*10./	DBS43880
ISN 0008	IF(IO .EQ. (NPR+1)) IC=NPR	DBS43890
ISN 0010	IF(JO .EQ. (NEN+1)) JO=NEN	DBS43900
ISN 0012	X1=VISF(I,J)	DBS43910
ISN 0013	X2=VISF(IO,J)	DBS43920
ISN 0014	X3=VISF(I,JO)	DBS43930
ISN 0015	X4=VISF(IO,JO)	DBS43940
ISN 0016	PHVIS=GRID(FI,FJ,X1,X2,X3,X4)	DBS43950
ISN 0017	RETURN	DBS43960
ISN 0018	END	DBS43970

LEVEL 21.8 (JUN 74)

OS/360 FORTRAN H

COMPILER OPTIONS - NAME= MAIN,CPT=00,LINECNT=58,SIZE=0000K,
SOURCE,EBCDIC,NOLIST,NODECK,LCAD,MAP,NODEIT,NOID,XREF

ISN 0002	FUNCTION PHCV(PRES,ENTH)	DBS43980
ISN 0003	IMPLICIT REAL*8(A-Z)	DBS43990
ISN 0004	INTEGER IO,JO,I,J,NPR,NEN	DBS44000
ISN 0005	COMMON/POIN/NPR,NEN,FI,FJ,IC,JO,I,J	DBS44010
ISN 0006	DIMENSION CVFN(25,25)	DBS44020
	C FUNCTION TO FIND SPECIFIC HEAT AT CONSTIANT VOLUME	DBS44030
ISN 0007	DATA CVFN/625*10./	DBS44040
ISN 0008	IF(JO .EQ. (NEN+1)) JO=NEN	DBS44050
ISN 0010	IF(IO .EQ. (NPR+1)) IC=NPR	DBS44060
ISN 0012	X1=CVFN(I,J)	DBS44070
ISN 0013	X2=CVFN(IO,J)	DBS44080
ISN 0014	X3=CVFN(I,JO)	DBS44090
ISN 0015	X4=CVFN(IO,JO)	DBS44100
ISN 0016	PHCV=GRID(FI,FJ,X1,X2,X3,X4)	DBS44110
ISN 0017	RETURN	DBS44120
ISN 0018	END	DBS44130

LEVEL 21.8 (JUN 74)

OS/360 FORTRAN H

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      CCMPILER OPTIONS - NAME= MAIN,OPT=00,LINECNT=58,SIZE=0000K,
                        SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,NOID,XREF
ISN 0002      SUBROUTINE ITER(I,X,YI,YJ,FLAG)                                DBS44140
ISN 0003      IMPLICIT REAL*8 (A-Z)                                          DBS44150
ISN 0004      INTEGER I,J,ICLK                                                DBS44160
ISN 0005      COMMON/ITERS/ISWT(30)                                           DBS44170
ISN 0006      COMMON/ITERS1/EPS(30),MINX(30),MAXX(30),PCNT1(30),PCNTN(30),    DBS44180
                        ICNT(30),ITF(30),XNAM(30),YNAM(30),MI,NI                DBS44190
ISN 0007      COMMON/ITERS2/ XOLD(30),YOLD(30),XMIN(30),XMAX(30)              DBS44200
      C GENERAL NEWTON TYPE ITERATION SCHEME                                  DBS44210
      C CALL ITER(I,X,YI,YJ,*)                                                DBS44220
      C I - ITERATION NUMBER                                                  DBS44230
      C X - INDEP VARIABLE                                                    DBS44240
      C YI - DEP VARIABLE F(X)                                                DBS44250
      C YJ - DEP VARIABLE G(X)                                                DBS44260
      C ISWT - PRINT FLAG                                                      DBS44270
      C DEL - DEP VARIABLE TOLERANCE                                          DBS44280
      C MINX - MINIMUM X                                                       DBS44290
      C MAXX - MAXIMUM X                                                       DBS44300
      C PCNT1 - FRACTIONAL AMOUNT TO INCREMENT 1ST X                         DBS44310
      C PCNTN - FRACTIONAL AMOUNT TO INCREMENT NTH X                         DBS44320
      C ICNT - COUNTER(1-15,NOT CLOSED) (0,CLOSED)                           DBS44330
      C ITF - FLAG, POS=NEWTONS, NEG=COUNTER TYPE ITERATION                  DBS44340
      C XNAM - INDEP VARIABLE NAME(8 CHAR MAX)                               DBS44350
      C MIJQ = NON-CLOSURE FLAG --- NON-CLOSURE = NON-ZERO                  DBS44360
      C YNAM - DEP VARIABLE NAME(8 CHAR MAX)                                  DBS44370
      C                                                                        DBS44380
      C ITERATION LOCATED IN STATEMENT                                         DBS44390
      C NUMBER SUBROUTINE NUMBER                                              DBS44400
      C 1 MAIN 42                                                              DBS44410
      C 2 MAIN 43                                                              DBS44420
ISN 0008      NI=9.00                                                         DBS44430
ISN 0009      IF(ICNT(I).NE.0. ) GO TO 10                                     DBS44440
      C SAVE ORIGINAL MIN,MAX X ON 1ST PASS                                  DBS44450
ISN 0011      XMIN(I) = MINX(I)                                                DBS44460
ISN 0012      XMAX(I) = MAXX(I)                                                DBS44470
ISN 0013      10 DIFY = YI-YJ                                                  DBS44480
ISN 0014      EPSY =DABS(DIFY/YJ)                                              DBS44490
      C CLOSURE TOLERANCE TEST                                                DBS44500
ISN 0015      IF(EPSY.GT.EPS(1))GO TO 20                                     DBS44510
ISN 0017      ICNT(I) = 0.                                                     DBS44520
ISN 0018      GO TO 80                                                         DBS44530
      C CHECK FOR COUNTER ONLY PATH                                          DBS44540
ISN 0019      20 IF(ICNT(I).GE.NI) GO TO 160                                   DBS44550
ISN 0021      IF(ITF(I).LT.0.0) GO TO 70                                       DBS44560
ISN 0023      IF(ICNT(I).NE. 0.)GO TO 30                                       DBS44570
      C 1ST PASS X INCREMENT CALCULATION                                     DBS44580
ISN 0025      DELX = DSIGN(PCNT1(I),-DIFY) * DABS(X)                          DBS44590
ISN 0026      GO TO 40                                                         DBS44600
ISN 0027      30 DIFX = X -XOLD(I)                                             DBS44610
ISN 0028      DELY = YOLD(I) - DIFY                                           DBS44620
      C NTH PASS X INCREMENT CALCULATION                                     DBS44630
ISN 0029      IF(DELY.EQ.0.0) GO TO 36                                         DBS44640
ISN 0031      DELX= PCNTN(I)*DIFX*DIFY/DELY                                   DBS44650
ISN 0032      Z= X+DELX                                                       DBS44660
ISN 0033      IF(X.GT.Z.AND.YI.GT.YJ) GO TO 40                               DBS44670

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ISN 0035	IF(X.LT.Z.AND.YI.LT.YJ) GO TO 40	DBS44680
ISN 0037	IF(X.GT.Z.AND.YI.LT.YJ) GO TO 36	DBS44690
ISN 0039	IF(X.GE.Z. CR.YI.LE.YJ) GO TO 40	DBS44700
ISN 0041	36 DELX=DABS(X)*DSIGN(5.0-2,-DIFY)	DBS44710
ISN 0042	40 XOLD(I) = X	DBS44720
ISN 0043	IF(DE LX) 42,45,41	DBS44730
ISN 0044	41 MINX(I)= XOLD(I)	DBS44740
ISN 0045	GO TO 43	DBS44750
ISN 0046	42 MAXX(I)= XOLD(I)	DBS44760
ISN 0047	43 X RANGE= (MAXX(I)-MINX(I))*0.5	DBS44770
ISN 0048	IF(DABS(DE LX).LT.X RANGE) GO TO 45	DBS44780
ISN 0050	IF(MAXX(I).EQ.X MAX(I)) GO TO 44	DBS44790
ISN 0052	IF(MINX(I).NE.X MIN(I)) GO TO 45	DBS44800
ISN 0054	44 DELX=DSIGN(X RANGE,DELX)	DBS44810
ISN 0055	45 IF(DE LX.EQ.0.0) DELX=DSIGN(1.0-2,-DIFY)	DBS44820
	C INCREMENT X	DBS44830
ISN 0057	X = X + DELX	DBS44840
ISN 0058	IF(MINX(I).LT.X) GO TO 50	DBS44850
	C X EXCEEDS MIN, X = MIN	DBS44860
ISN 0060	X = MINX(I)	DBS44870
ISN 0061	GO TO 60	DBS44880
	C X EXCEEDS MAX, X = MAX	DBS44890
ISN 0062	50 IF(X.GT.MAXX(I))X = MAXX(I)	DBS44900
ISN 0064	60 IF(X.NE.XOLD(I))GO TO 70	DBS44910
ISN 0066	IF(ICNT(I).NE. 0.)GO TO 160	DBS44920
ISN 0068	70 ICNT(I) = ICNT(I) + 1.	DBS44930
	C PRINT AFTER THE 10TH ITERATION	DBS44940
ISN 0069	IF(ICNT(I).LE.MI)GO TO 80	DBS44950
	C FORCE CLOSURE AFTER 15 PASSES	DBS44960
ISN 0071	IF(ICNT(I).GT.NI)GO TO 160	DBS44970
ISN 0073	GO TO 90	DBS44980
	C PRINT EVERY PASS IF FLAGGED	DBS44990
ISN 0074	80 IF(ISWT(I).EQ. 0.)GO TO 100	DBS45000
ISN 0076	90 CONTINUE	DBS45010
ISN 0077	95 WRITE(6,180)I,ICNT(I),XNAM(I),XOLD(I),X,YNAM(I),YI,YJ,EPSY	DBS45020
ISN 0078	180 FORMAT(' L'.I3.' N'.F3.0,1X,A8,G12.5,1X,G12.5,1X,A8,G12.5,1X,	DBS45030
	*G12.5,1X,'E ',1PE9.3)	DBS45040
ISN 0079	100 IF(ICNT(I).EQ. 0.)GO TO 170	DBS45050
ISN 0081	IF(ITF(I).LT.0.)GO TO 140	DBS45060
ISN 0083	YOLD(I) = DIFY	DBS45070
	C NON-CLOSURE RETURN	DBS45080
ISN 0084	140 GO TO 175	DBS45090
ISN 0085	ENTRY ITERZ(I)	DBS45100
ISN 0086	160 IF(ICNT(I).EQ.0.)GO TO 175	DBS45110
ISN 0088	ICNT(I) = 0.	DBS45120
ISN 0089	GO TO 90	DBS45130
	C RESTORE ORIGINAL MIN,MAX X ON NTH PASS	DBS45140
ISN 0090	170 MINX(I) = XMIN(I)	DBS45150
ISN 0091	MAXX(I) = XMAX(I)	DBS45160
	C NORMAL RETURN(CLOSURE)	DBS45170
ISN 0092	175 FLAG= ICNT(I)	DBS45180
ISN 0093	RETURN	DBS45190
	C SECONDARY ENTRY TO REINITIALIZE TOLERANCE,MINIMUM, AND MAXIMUM	DBS45200
ISN 0094	ENTRY ITERM(J,MIN,MAX)	DBS45210
ISN 0095	MINX(J)=MIN	DBS45220
ISN 0096	MAXX(J)=MAX	DBS45230

ISN 0097
ISN 0098

RETURN
END

DBS45240
DBS45250

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LEVEL 21.6 (JUN 74)

OS/360 FORTRAN H

CCMPILER OPTIONS - NAME= MAIN.OPT=00.LINECNT=58.SIZE=0000K.

SGURCE,EBCDIC,NOLIST,NGOECK,LCAD,MAP,NOEDIT,NOID,XREF

ISN 0002	BLOCK DATA	DBS45260
ISN 0003	IMPLICIT REAL *8(A-Z)	DBS45270
ISN 0004	COMMON/ITERS/ISWT(30)	DBS45280
ISN 0005	DATA ISWT/30*0.00/	DBS45290
ISN 0006	COMMON/ITERS1/EPS(30),MINX(30),MAXX(30),PCNT1(30),PCNTN(30), IICNT(30),ITF(30),XNAM(30),YNAM(30),MI,NI	DBS45300
ISN 0007	DATA EPS/5.0-5.5.0-5.5.0-5/	DBS45320
ISN 0008	DATA MINX/-1.03,-1.03,-1.03/	DBS45330
ISN 0009	DATA PCNT1/5.0-2.5.0-2.5.0-2/	DBS45340
ISN 0010	DATA MAXX/5.00.5.00.5.00/	DBS45350
ISN 0011	DATA PCNTN/1.00.1.00.1.00/	DBS45360
ISN 0012	DATA IICNT/30*0.00/	DBS45370
ISN 0013	DATA ITF/30*1.00/	DBS45380
ISN 0014	DATA XNAM/' ENH1 ',' ENH2 ',' ENTH ',' NONE ',' NONE ',' NONE ' 1,' NONE ',' NCNE ',' NCNE ',' NONE ',' NONE ',' NONE ',' NONE ' 1,' NONE ',' NCNE ',' NCNE ',' NONE ',' NONE ',' NONE ',' NONE ' 1,' NONE ',' NCNE ',' NCNE ',' NONE ',' NONE ',' NONE ',' NONE ' 1,' NONE ',' NCNE ',' NCNE '/'	DBS45390 DBS45400 DBS45410 DBS45420 DBS45430
ISN 0015	DATA YNAM/' ENT1 ',' ENT2 ',' TF1 ',' NONE ',' NONE ',' NONE ' 1,' NONE ',' NCNE ',' NONE ',' NONE ',' NONE ',' NONE ',' NONE ' 1,' NONE ',' NCNE ',' NCNE ',' NONE ',' NONE ',' NONE ',' NONE ' 1,' NONE ',' NCNE ',' NCNE ',' NONE ',' NONE ',' NONE ',' NONE ' 1,' NONE ',' NCNE ',' NCNE '/'	DBS45440 DBS45450 DBS45460 DBS45470 DBS45480
ISN 0016	DATA MI/9.00/	DBS45490
ISN 0017	DATA NI/9.00/	DBS45500
ISN 0018	END	DBS45510

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DCUELE BCILER, 240F & 180F TB1=290F 5 MW GROSS

INPUT EDIT THIS CASE

2.4000D 02	1.8000D 02	3.8157D 02	1.6055D 02	7.5600D 01	1.1230D 02	-6.1470D 02	-6.2630D 02	1.0500D 02	3.0200D-02
7.7630D 01	1.3160D 02	6.3000D-01	1.1130D 00	0.0	2.9000D 02	1.0000D 01	1.0000D 01	4.0000D 00	1.0000D 01
1.0000D 00	8.0000D-01	1.0000D 00	9.5000D 01	7.5000D 01	5.0000D 00	2.5000D 06	4.0000D 01	4.0000D 01	1.2000D 02
1.5700D 02	1.1000D 02	1.4500D 02	1.3300D 02	-1.0000D 00	9.5000D-01	8.5000D-01	8.5000D-01	0.0	0.0
0.0	0.0	0.0	0.0	8.1000D 01	7.4200D 01	5.1000D-01	4.6000D-01	5.9000D-01	7.9600D-01
0.0	1								
L 1 N 1.	ENH1	-614.70	-645.43	ENT1	1.2209	1.1776	E 3.679D-02		
L 1 N 2.	ENH1	-645.43	-640.78	ENT1	1.1699	1.1776	E 6.559D-03		
L 1 N 3.	ENH1	-640.78	-640.82	ENT1	1.1776	1.1776	E 5.065D-05		
L 1 N 0.	ENH1	-640.78	-640.82	ENT1	1.1776	1.1776	E 0.0		
L 2 N 1.	ENH2	-626.30	-657.61	ENT2	1.2022	1.1752	E 2.302D-02		
L 2 N 2.	ENH2	-657.61	-642.35	ENT2	1.1495	1.1752	E 2.189D-02		
L 2 N 3.	ENH2	-642.35	-642.25	ENT2	1.1750	1.1752	E 1.496D-04		
L 2 N 0.	ENH2	-642.35	-642.25	ENT2	1.1752	1.1752	E 0.0		
0.58737-614.69995-648.24988	131.59999	0.57000	4.00000	0.0	0.52399-626.29980	4.00000	0.0	1.00000	
0.52399	10.96520	3.21277	221.94713	130.49327	146.37592	50.00000	41.94713*****	41.94713	

CASE RESULTS

GNET/WB (BTU/LB) 1.0965D 01 EQUATION 4A

PNET/WB (WATT-HR/LB) 3.2128D 00 EQUATION 4B

DELTA T BRINE (DEGREES F) 1.4638D 02 EQUATION 5

THERMAL EFFICIENCY NET (%) 7.4911D 00 EQUATION 6

PNET/WEEL (LB/HR) 8.0319D 00 EQUATION 20

WF1/WB 5.8737D-01 EQUATION 1

WF2/WF1 5.2399D-01 EQUATION 3

TB3 (DEGREES F) 2.2195D 02 EQUATION 2

QT1 (BTU/HR) 2.1092D 01 EQUATION 7

QPW1 (BTU/LB) 2.4020D 00 EQUATION 8

QCW1 (BTU/LB) 1.9108D 00 EQUATION 9

GNET1 (BTU/LB) 1.6779D 01 EQUATION 10

QT2 1.2878D 01 EQUATION 11

QPW2 1.1552D 00 EQUATION 12

QCW2 1.8720D 00 EQUATION 13

GNET2 (BTU/LB) 9.8510D 00 EQUATION 14

PNET (MEGAWATTS) 3.3527D 00 INPUT

PGROSS (MEGAWATTS) 5.0000D 00 EQUATION 18

PNET/PGROSS 6.7350D 01 EQUATION 15

A-43

PNEI/PERLSS 6.7000D-01 EQUATION 19
 WB (LB/HR) 1.0436D 06 EQUATION 16
 WF2 (LB/HR) 3.2118D 05 EQUATION 17
 TF1 (DEGREES F) 2.4000D 02 INPLT
 TF2 (DEGREES F) 1.8000D 02 INPUT
 AB1 (FT**2) 1.0698D 04 EQUATION 21
 APH1 (FT**2) 1.0949D 04 EQUATION 22
 A1 (FT**2) 2.1647D 04 EQUATION 23
 AB2 (FT**2) 1.0319D 04 EQUATION 24
 APH2 (FT**2) 1.9552D 04 EQUATION 25
 A2 (FT**2) 2.9872D 04 EQUATION 26
 ASUM (FT**2) 5.1519D 04 EQUATION 27
 ACOND (FT**2) 3.4882D 04 EQUATION 29
 HTA (FT**2) 8.6401D 04 EQUATION 30
 WCV (LB/HR) 6.7152D 06 EQUATION 31
 GPM (GAL/MIN) 1.3430D 04 EQUATION 32
 QCCND (BTU/HR) 1.3430D 08 EQUATION 28
 WF1 (LB/HR) 6.1296D 05 EQUATION 16
 TEMP REG CUT 1.0100D 02 DEG F
 TEMP BR CT T 1.4362D 02 DEG F
 DEL ENTH RGT 0.0 BTU/LB
 REG AREA 0.0 FT SQ
 PIN PT 1 1.0000D 01 DEG F
 PIN PT 2 1.0000D 01 DEG F
 BRINE SUPERHEAT 1 EXIT 2.9000D 02 DEG F
 BRINE SUPERHEAT 2 EXIT 2.2195D 02 DEG F
 TUR ONE ENTH IN -6.1470D 02 BTU/LB
 TUR TWO ENTH IN -6.2630D 02 BTU/LB
 AREA SUPHEAT ONE 0.0 FTSQ
 AREA SUPHEAT TWO 0.0 FTSQ
 OVERALL EFFECTIVE USE OF ENERGY SUPPLIED % 5.1001D 00
 BRINE PUMPING POWER 5.8783D-01 MW
 CONDENSING WATER PUMPING POWER 5.1933D-01 MW
 LOCKING FLUID PUMPING POWER 5.1933D-01 MW

WORKING FLUID PUMPING POWER 0.40100-01 MW

CONDENSER INLET TEMPERATURE 1.2711D 02 DEGREES F

NUMBER OF BRINE SUPPLY WELLS 2

NUMBER OF BRINE REINJECTION WELLS 1

NUMBER OF COOLING WATER SUPPLY WELLS 9

NUMBER OF COOLING WATER REINJECTION WELLS 4

PRESSURE HP BOILER 3.8157D 02 PROP DECK

PRESSURE LP BOILER 2.0304D 02 PROP DECK

CONDENSING PRESSURE 7.7630D 01 PROP DECK

PUMP EFFICIENCY 8.0000D-01 INPUT

ELECTRICAL EFFICIENCY 9.5000D-01 INPUT

HP TURBINE EFFICIENCY 8.5000D-01 INPUT

LP TURBINE EFFICIENCY 8.5000D-01 INPUT

MAX FLOWRATE / BRINE SUPPLY WELL 2.5000D 06 LBM/HR

SAT VAPOR ENTHALPY AT COND TEMP -6.4825D 02 PROP DECK

TEMP BR INLET	TP BR SPH 1 OT	TP BR PRH 1 OT	TP BR SPH 2 OT	TP BR OUTLET	BRINE FLOW RATE
0.2900D 03	0.2900D 03	0.2219D 03	0.2219D 03	0.1436D 03	0.1044D 07
TP TUR1 INLET	EN TUR1 INLET	TP BOILER ONE	FLOW RT TR ONE	EN EST BOIL 1	EN ACT EX TUR1
0.2400D 03	-0.6147D 03	0.2400D 03	0.6130D 06	-0.6147D 03	-0.6369D 03
TP TUR2 INLET	EN TUR2 INLET	TP BOILER TWO	FLOW RT TR TWO	EN EXT BOIL 2	EN ACT EX TUR2
0.1800D 03	-0.6263D 03	0.1800D 03	0.3212D 06	-0.6263D 03	-0.6399D 03
AREA BOILER 1	AREA BOILER 2	AREA PREHET 1	AREA PREHET 2	AREA CONDENSER	AREA REGENATOR
0.1070D 05	0.1032D 05	0.1095D 05	0.1955D 05	0.3488D 05	0.0
AREA SUPHET 1	AREA SUPHET 2	DELT PIN PT 1	DELT PIN PT 2	TEMP REG OUT	FLOW RATE COOL
0.0	0.0	0.1000D 02	0.1000D 02	0.1010D 03	0.6715D 07

HTXCST	TURGCST	SEPCST	ELESCST	COCTCST	SPLYCST	TOTSCST	CSTPOW MILS PR KWHR
0.4327D 06	0.7549D 06	0.1212D 06	0.6738D 06	0.9293D 06	0.1340D 06	0.5026D 07	0.3076D 02
0.4327D 06	0.7549D 06	0.1212D 06	0.6738D 06	0.9293D 06	0.1904D 06	0.5082D 07	0.3115D 02

(Brine Flow Rate)
(no. of wells)

APPENDIX B

COST EQUATION

DERIVATIONS

COST EQUATION DERIVATIONS

I. Total System Cost

A. Derivation

$$\Phi_T = \{\Phi_E + \sum_i f_i \Phi_E\} F_I + \{\Phi_W + \sum_W f_W \Phi_W\} F_{II}$$

- where:
- Φ_T = total system cost
 - Φ_E = total equipment cost
 - Φ_W = supply system cost
 - F_I = factor for Engineering, Design, and Inspection, overhead and contingency
 - F_{II} = factor for exploration, land use, and exploratory drilling
 - f_i = factors for piping, buildings, instrumentation, etc., and the remaining energy conversion cost
 - f_W = factors for supply and disposal piping, pumps, insulation, etc., and energy supply cost

1. The total equipment cost, Φ_E , is the sum of the major equipment costs of the energy conversion system:

$$\Phi_E = \Phi_{HE} + \Phi_C + \Phi_{T-G} + \Phi_P + \Phi_{ES}$$

- where:
- a) Φ_{HE} = heat exchanger cost
 - b) Φ_C = condenser and cooling tower cost
 - c) Φ_{T-G} = turbine-generator cost
 - d) Φ_P = secondary fluid pump cost
 - e) Φ_{ES} = electrical system cost

2. The supply system cost, Φ_W , is the sum of the costs of drilling, casing, cementing, etc.

B. Calculation (all areas in ft^2 , all flow rates in lbm/hr , all power in KW)

1. ϕ_E , Total Equipment Cost

a) ϕ_{HE} , heat exchangers cost

$$= \phi \text{ BOILERS} + \phi \text{ PREHEATERS}$$

$$= (10.56) (\text{area of boilers}) + (6.91) (\text{area of preheaters, regenerator, and superheaters})$$

b) ϕ_C , condenser and cooling tower cost

$$= (7.6) (\text{area of condenser}) + (24.25) (\text{cooling water flow rate})^{0.65}$$

c) ϕ_{T-G} , turbine-generator cost

$$= (8268.5) (\text{gross power})^{0.53}$$

d) ϕ_P , secondary fluid pump cost

$$= (2032.) (\text{gross power})^{0.48}$$

e) ϕ_{ES} , electrical system cost

$$= (18,835) (\text{gross power})^{0.42}$$

2. $\{\phi_W + \sum_W f_W \phi_W\} F_{II}$, Total Supply System Cost

a) Based upon brine flow rate,

$$= (540.) (\text{net power})$$

b) Based upon the number of wells,

$$= (28,400.) (\text{new power}) (\text{no. of wells})$$

3. $\sum_i f_i = 0.25$ and $F_I = 1.34$, exclusive of contingency

4. Therefore, the Total System Cost is:

$$\phi_T = 1.68 \phi_E + 540 \{\text{net power (KW)}\} \text{ based upon brine flow rate}$$

and

$$\phi_T = 1.68 \phi_E + (28,400) (\text{no. of wells}) \{\text{net power (KW)}\} \text{ based upon}$$

the number of wells

II. Cost of Power

Cost of Power =

$$\left[\frac{1}{\text{Net Power (KW)}} \right] \left[\frac{1000 \text{ mils}}{\text{KW-hr}} \right] \left\{ \left[\frac{1 \text{ yr}}{(8760 \text{ hr/yr})} \right] \right. \\ \left. \left[\frac{i (1+i)^n}{(1+i)^n - 1} \right] \left[(\phi_E + \sum_i f_i \phi_E) F_I \right] + \left[\frac{i (1+i)^n}{(1+i)^n - 1} \right] \left[(\phi_W + \sum_W f_W \phi_W) F_{II} \right] \right\}$$

Gathering Terms:

Cost of Power =

$$\frac{(2.0454 \times 10^{-2}) (\phi_E + \sum_W f_i \phi_E) F_I + (2.2968 \times 10^{-2}) (\phi_W + \sum_W f_W \phi_W) F_{II}}{\text{Net Power Output (KW)}}$$

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