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RESEARCH AND DEVELOPMENT OF A 3 MW POWER
PLANT FROM THE DESIGN, DEVELOPMENT, AND
DEMONSTRATION OF A 100 KW POWER SYSTEM
UTILIZING THE DIRECT CONTACT HEAT EXCHANGER
CONCEPT FOR GEOTHERMAL BRINE ENERGY
RECOVERY PROGRAM

Final Report

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September 1980

Work Performed Under Contract No. FG05-78ET28456

Arkansas Power and Light Company
Little Rock, Arkansas

U. S. DEPARTMENT OF ENERGY
Geothermal Energy

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Price: Printed Copy A07
Microfiche A01

Research and Development of a 3 MW Power Plant from the Design, Development, and Demonstration of a 100 KW Power System Utilizing the Direct Contact Heat Exchanger Concept for Geothermal Brine Energy Recovery Program.

FINAL REPORT

Submitted to:

United States Department of Energy
Division of Geothermal Energy

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This report was prepared with the support of the U.S. Department of Energy, Grant Number ET-78-G-05-5917. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the authors and do not necessarily reflect the views of the Department of Energy.

September, 1980

ABSTRACT

Arkansas Power and Light Company (AP&L) was authorized a Grant Award from the United States Department of Energy (DOE) on May 19, 1978 to proceed with the design, development, demonstration, and evaluation of a 100 KW power plant that would use the energy recovered from waste geothermal brine at Great Lakes Chemical Corporation's (GLC) bromine extraction plant at Marysville, Arkansas. Daedalean Associates, Incorporated (DAI) was subcontracted by AP&L to perform that work by utilizing the direct contact heat exchanger concept for geothermal brine energy recovery. Additionally, DAI was to perform the necessary research and development of a 3 MW power plant based on the overall results of the 100 KW system.

DAI's design phase for the 100 KW unit consumed the months of May through November, 1978, with the final design selected as having a direct contact boiler and condenser, a single-stage radial inflow induction turbine-generator using isopentane as the working fluid, and a single cell ejector-type cooling tower. The unit was constructed on two, forty-foot flatbed trailers between the months of October, 1978 and June, 1979. Systems start-up testing, in-field modifications, unit operation, and performance testing by DAI were performed between July and December, 1979. AP&L personnel assumed responsibility of the unit at that time and conducted further maintenance, operations, and testing through August, 1980.

Production of electricity by the direct contact heat exchange scheme of energy recovery from geothermal brines can be achieved. Based on the experience gathered with the 100 KW pilot plant, however, it is the opinion of Arkansas Power and Light Company that larger, commercial facilities of this type would incur higher production costs than conventional power generation equipment. It also appears that certain design modifications coupled with further testing will be necessary before final recommendations can be made concerning the design and construction of a similar commercial facility.

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OBJECTIVE

The overall objective of the project was to investigate the technical, economical, and commercial feasibility of electrical generation from the recovery of heat contained in low temperature brines abundant in southern Arkansas. Specifically, this was to be accomplished by designing, constructing, and operating a small binary power cycle using a direct contact boiling and condensing concept in conjunction with a 100 KW induction turbine-generator so that heat could be transferred from the brine to a hydrocarbon working fluid to produce electricity. Overall system information on such items as operations and thermal performance, maintenance, economics, reliability, and safety was to be used to evaluate the feasibility of a commercial 3 MW power plant.

Other objectives were to investigate all aspects of the individual components of the 100 KW system, since some recently developed technology was being applied. Thermal performance, operating characteristics, materials selection and compatibility to the working fluids and environment, design and function of the control systems, cost, maintenance, and safety were all to be considered on a component basis for the direct contact boiler, direct contact condenser, turbine-generator, cooling tower, and auxiliary equipment.

Thus, the state-of-the-art technology of direct contact heat transfer from low temperature geothermal brines, coupled with proven electrical generation systems, would provide the basis for commercial feasibility of such facilities.

INTRODUCTION

Depletion of all forms of natural resources, among other things, has brought into focus the worldwide problem of continuing the present standard of living and comforts that are often taken for granted. Virtually every product that is used or produced today, whether by commercial or individual consumers, is the end product of some process that ultimately relies on a natural resource in one form or another. This is particularly true of those that deal with fossil fuels. Manufacturers rely on electricity or fossil fuels to produce their goods, electric utilities rely heavily on fossil, and to some extent nuclear fuels to generate electricity, and the individual consumer relies on fuels and/or electricity for home heating, personal transportation, recreation, et.al. This situation is very prevalent in the United States due to its advanced technology and manufacturing/ consumer oriented society.

The electric utilities in the United States are among those hit hardest by the depletion of fossil fuel resources, since abundant sources of fossil fuels were readily available through the early 1970's. Many utilities, up to that time, relied mainly on oil and natural gas as their primary boiler fuels, with only a relative few opting to develop and expand the use of nuclear and coal fuels. Even though it was apparent that fossil fuel reserves were being steadily depleted, the impetus to conserve or diversify came only during the last ten years, when the combined effects of inflation, loss or reduction of foreign fuel supplies, and other events began to take effect.

The depletion of fossil fuel sources, then, has put emphasis on the need for conservation and diversification of fuel and energy sources. Conservation, certainly an important consideration, is only important for fossil fuels so long as there are still adequate supplies to be conserved, because so long as fossil fuels are being used, there will at some point be a time in which the only way to conserve any will be to quit using any at all. Diversification is also important, especially if it includes the development and use of such energy sources as solar, geothermal, wind, ocean-thermal, bio-mass, and other alternatives to fossil fuels. Such diversification would lengthen the amount of time that each could be used (such as fossil), plus it would bring into play several renewable or inexhaustable energy sources.

As the move towards diversification of energy sources, particularly those renewable ones, began, increased emphasis was rightfully placed on the development of geothermal energy. Several areas of the United States are known to have sizeable geothermal reserves, principally in the form of convective hydrothermal, geopressured hydrothermal, and hot dry rock types. A significant portion of those are liquid dominated, some of which are used by industry as sources for valuable chemicals. Of the total supply of geothermal resources available, however, only a small percentage is used primarily for its heat energy content. The aforementioned needs for conservation and diversification of energy sources, accompanied by the relative abundance of geothermal sources, makes it very desirable to expand the use of geothermal sources for their heat content.

The successful expansion and utilization of geothermal energy sources in the United States depends largely on the development of pertinent technology and hardware, since that is the one principal holdback at this time. Those localities presently using geothermal resources for the production of electricity in the United States or Europe are fortunate in that their sources are either relatively pure high temperature (400-600^o F) brine or else directly available dry steam. Thus, they are able to depend largely on existing heat transfer and turbine technology. Unfortunately, a large portion of available geothermal resources in the United States are low temperature (200-210^o F) liquid brines "contaminated" with various chemicals and are unfeasible for utilization by presently available tube and shell heat exchangers and turbines, because of the inherent problems of corrosion, scaling, large surface needed for low level heat transfer, etc.

To effectively make use of such low temperature brines, particularly for electrical generation, several energy recovery schemes have been devised. The most feasible appears to be the binary cycle using direct contact heat exchangers, in which a relatively low vapor point hydrocarbon is brought into intimate contact with the brine, vaporized, expanded through a turbine to produce electricity, and finally condensed by fresh water in either a shell and tube heat exchanger or another direct contact heat exchanger. With proper sizing and materials selection, the problems of corrosion, scaling, and heat transfer rate should be avoidable. Realizing that, the Division of Geothermal Energy of the Department of Energy has been actively supporting the techno-

logical development of the direct contact heat exchanger concept. Such development would make the use of low temperature geothermal energy feasible, thus contributing in a positive manner to the world's energy needs.

PROJECT HISTORY (PRIOR TO NOVEMBER, 1979)

The Geothermal Brine Energy Recovery (GEOBER) Project was initiated in April, 1978 by Arkansas Power and Light Company (AP&L) as one effort to determine the feasibility of using the waste geothermal brine available in southern Arkansas for the production of electricity, particularly at Great Lakes Chemical Corporation's (GLC) bromine extraction plant at Marysville, Arkansas. In May, 1978 a grant was awarded to AP&L by the Department of Energy (DOE) for the purpose of demonstrating the technical and economic feasibility of electrical generation from southern Arkansas geothermal brines.

The grant essentially provided that DOE would contribute a sum of money on a cost reimbursement basis to AP&L, with the stipulation that the money would be used by AP&L to subcontract Daedalean Associates, Incorporated (DAI) to fabricate, test, and evaluate the 100 KW pilot plant.

While all involved parties had an overall goal of investigating and furthering the use of the direct contact heat exchange cycle for low level geothermal brine energy recovery, each had specific interests and mutually agreed upon project tasks. For example, AP&L agreed to provide engineering time to determine operating efficiencies, preventative maintenance schedules, power grid input for the 100 KW pilot plant, to evaluate the individual component needs of a 3 MW plant electrical

system, and provide relay and power technicians for electrical instrumentation connections. GLC agreed to furnish the hot brine from their bromine extraction plant's tail brine line, provide technical assistance and extraordinary maintenance, and to provide information on the brine temperature and chemistry. DAI agreed to design, construct, operate, and test the 100 KW pilot plant, with such work to include vendor, material, and fluid selection, performance testing to verify component design parameters, and operation to determine, in general, O&M and production costs. The information gathered from the 100 KW system would then be used by DAI to finalize a report on the design and cost estimate of the 3 MW facility. It was agreed that DAI would make use of DSS Engineers, Incorporated in designing the preheater, boiler, and condenser (all direct contact), Rotoflow Corporation for the design, optimization, and cost estimates for the turbine-generator unit for both the 100 KW and 3 MW plants, and the University of Utah as a consultant on the design and final selection of various components.

The plant was constructed on two, 40 foot flatbed trailers and delivered to the test site at the GLC plant near Marysville, Arkansas in July, 1979. The GEOBER plant utilized the brine tailings from the GLC bromine extraction plant as a heat source to the boiler.

The boiler design was of the direct contact type which provided for intimate mixing of the brine tailings from GLC and the working fluid. Commercial isopentane was chosen for the working fluid due to its thermodynamic properties and relatively low price.

Vapor from the boiler flows through fiberglass pipe to the turbine, which was designed and built by Rotoflow Corporation in Los Angeles, California. The turbine is of the radial inflow type with a titanium rotor for corrosion resistance. It drives an induction generator through a 10:1 gear reducer.

Turbine exhaust flows to the condenser vessel, which is also of the direct contact type. In the condenser, the exhaust vapor bubbles up through approximately two feet of water and condenses in a six inch layer on top of the water. Condensate from this layer is pumped back to the boiler for vaporization. Circulating water for the condenser is provided from an ejector type cooling tower mounted adjacent to the condenser. Storage tanks mounted under the trailer hold isopentane for make-up to the system, as required.

A flare was positioned about 100 feet from the plant as a plant safety feature. It was used for burning isopentane vapor that was released from the condenser during venting as well as any vapor released when the safety valves mounted on the boiler, condenser or storage tanks lifted.

Brine to the boiler was provided from a centrifugal pump that takes suction from the GLC brine tailings line.

After the unit was set up at the test site, the debugging operations by DAI began. Numerous difficulties were encountered, and operations were generally intermittent. The original brine pump required replacement

after a short period of time due to impeller erosion. Precipitates from the brine caused the brine pump suction line to become plugged during shutdown periods. Difficulties were also encountered with the turbine lube oil system and filters. Condenser overpressure caused the condenser safety valve to lift frequently which, in turn, caused considerable loss of isopentane to the flare. It also became apparent that the installed electrical meters were not properly measuring the plant's electrical output.

In late October, 1979 two AP&L personnel were assigned to learn the plant operation from the DAI operators on-site. The AP&L personnel were also directed to provide technical assistance to help overcome the operational difficulties previously mentioned. Since AP&L desired more information regarding system performance and electrical production capabilities, it was decided that AP&L personnel would operate the plant after the departure of the DAI personnel on December 20, 1979. Also, it was desired to obtain more samples of the various plant fluid systems in order to better evaluate the amount of isopentane losses expected during operation.

PROJECT HISTORY (NOVEMBER, 1979 TO PRESENT)

The AP&L personnel assigned to learn the operation of the GEOBER plant first visited the plant site on October 29, 1979. Diagrams of several of the plant systems were studied prior to beginning the hands-on operational training. Due to problems with the brine pump suction line, operation of the plant was not possible during several visits, and most of the operational training consisted of review of plant systems and familiarization with the location and operation of various plant equipment and components. The DAI personnel made changes to the brine pump piping system, but then problems with the turbine lube oil system were encountered. The lube oil filters collapsed during operation and caused low lube oil pressure to the bearings. This problem occurred several times, requiring replacement of the filter cartridges each time.

It had been determined that for adequate testing, a more precise measurement of plant net electrical production or consumption was necessary than had been installed in the control room metering. AP&L personnel installed watt-hour meters for measuring those quantities, as opposed to the originally designed method. A strip chart recorder and watt-hour meters were also installed to measure gross generator output. There were also problems with the electrical meters installed in the plant control room, and AP&L electricians were utilized for troubleshooting and correcting the wiring to these meters.

By November 30, 1979, the plant was fully operational and was operated for brief intervals. This provided operational training for the AP&L

personnel, and allowed the DAI operators to collect data. Problems with the turbine lube oil filters occurred again after a short period of time and caused another plant shutdown. The filter cartridges were replaced and operations continued.

Condenser overpressure became a serious problem. Continuous operating times were short, of about 15 to 20 minutes duration, at which time the condenser pressure reached 15 psig. This was much higher than the normal operating pressure expected, and upon reaching 15 psig, the condenser safety valve lifted, causing unsteady system operation and venting of isopentane to the flare. The cause of the overpressure was suspected to be a leaking ball check valve in the pressure equalization line between the turbine exhaust line and the condenser vapor space. The high condenser pressure caused the turbine backpressure to be much higher than design and severely limited turbine output.

On December 16, 1979, the plant antifreeze system failed, and numerous lines and valves were cracked during an overnight freeze. The DAI personnel were unable to operate the plant subsequent to their departure on December 20, 1979, because repairs were in progress by maintenance personnel provided by AP&L. The broken lines and valves were replaced, and two pump casings that had cracked were removed, repaired, and replaced. By this time, the weather had become quite cold, and nightly freezes were common. It was decided that the best course of action would be to drain all plant systems to avoid further freeze damage. It was decided to use this shutdown time to make various repairs and mod-

ifications that would, hopefully, improve plant operation. The plant would remain shut down until more favorable weather during the spring.

After the freeze damage was repaired, the brine pump was removed for disassembly and repair. The brine pump had suffered from problems with a leaking mechanical seal. Upon disassembly, it was found that the stuffing box for the mechanical seal was filled with precipitate from the brine, and particles lodged between the faces of the seal were causing the seal to leak. The pump was reassembled and a fresh water flush was installed on the seal stuffing box to prevent recurrence of this problem. It was suspected that the condenser safety valve was leaking and causing loss of isopentane from the condenser. This valve was removed and disassembled. It was found that irregularities in the surface of the disc and a bent stem were causing the leakage. The valve was repaired and reinstalled.

After the brine pump was reinstalled, it was discovered that the pump motor was inoperable. An attempt to operate the pump for testing revealed that the motor had been flooded with water during a recent rain. The decision was made to construct a platform upon which to mount the pump and motor since future heavy rains in the spring were anticipated. A platform was constructed to mount the pump and motor about four feet above the ground level.

At this time, it was considered prudent to check out the electrical system and correct the electrical prints, as previous maintenance ex-

periences revealed that the electrical prints provided did not agree with the systems as installed. This task proved somewhat difficult since all of the electrical wiring was sealed with epoxy in metal conduit in order to comply with applicable electrical safety codes. In several cases, wiring color codes were changed in the conduit run, and it was difficult to trace out circuits. Corrosion of copper conductors was also a problem because of the presense of the hydrogen sulfide environment at the bromine plant. The check of the electrical system proved to be quite time consuming and revealed many discrepancies between the design as shown on the prints and the equipment that was actually installed and operating. The boiler high level alarm, brine pump failure alarm and flare pilot light failure alarms were found to be disconnected because of previous problems encountered with these circuits. The brine pump low pressure cut-off switch was a serious shock hazard and was removed as an unnecessary item. The 480 volt feeder to the brine pump was lying on the ground and posed a safety hazard. The "Gas Tech" combustibles detector that was supposed to detect the presence of isopentane in various areas around the plant was found to be unreliable and required calibration.

Further damage to the plant piping systems was discovered in March, 1980, when a check of various plant liquid systems was made. Impulse lines to the circulating water flow meter were found to be cracked and needed repair as well as several other lines which had not been filled since the freeze damage which occurred in December, 1979.

It was determined that some of the instrumentation required for proper heat balance testing of the plant was either non-existent or improperly located. Also, the accuracy of the pressure gauges and thermocouples, as installed, was uncertain since they had never been checked for proper calibration. All pressure gauges were calibrated, and the thermocouples were checked for accuracy. Additional pressure gauges and thermocouples were installed at the turbine inlet and outlet. The brine flow and circulating water flow measurements utilized a magnetic flow sensor and annubar flow sensor, respectively. Those transmitters could not be easily checked against a known standard and were assumed to be correct within the manufacturer's specification.

By mid-March, 1980, operation of several of the plant systems had begun in an effort to ascertain proper operation, since the plant had not been operated in several months. The condenser and circulating water system were filled with water, and the various alarms and trips for those systems were checked for proper operation. All operated correctly. The control system for the condenser also seemed to function normally without isopentane in the system.

Prior to operation of the plant, it was decided to disassemble and inspect the turbine and gear case assembly. It had been noted in the past that some particulate matter had accumulated in the vapor lines from the turbine, and it was feared that some damage may have occurred to the turbine wheel as a result of carry-over of this material. Additionally, it was discovered that moisture had accumulated in the

turbine lube oil. It was suspected that the moisture carried over in the isopentane vapor from the boiler was somehow leaking past the turbine seal into the bearings. Thus, the turbine and reducing gear were disassembled. The turbine wheel showed some erosion of metal between the turbine blades, along with some slight pitting and deposits on a few blades. Since the limits of erosion that could be tolerated were not known, the turbine wheel was returned to the manufacturer for inspection and testing.

Visual inspection of the gear case revealed two small cracks in the casting. That casting, as well as the turbine high speed shaft, and the nozzle block assembly, were delivered to Independent Testing Laboratories in Searcy, Arkansas for non-destructive examination (NDE). Magnaflux inspection of the gear case revealed several more cracks, the largest of which was about 1/2 inch long. After discussion with the manufacturer, it was determined that these cracks were not in a high stress area and no repair work was required. The nozzle block assembly was checked with dye penetrant, and no defects were found. The high speed shaft showed two crack indications, but it was later discovered that the crack indications were actually fusion lines from welding that was performed on the shaft during manufacture.

A large amount of particulate material was found in the bottom of the turbine case when it was disassembled. A sample of the material was delivered to the GLC laboratory for analysis. The material was mostly calcium carbonate and sand which was carried over from the brine with the isopentane vapor.

The turbine gear case was reassembled and installed on April 22, 1980. At this time, the lube oil, which was contaminated with water, was drained. The lube oil reservoir was cleaned, and new oil and filter cartridges were installed.

It was thought that some savings of nitrogen could be realized if the plant was operated with a cold flare. This would eliminate the need for a continuous flow of nitrogen to purge the flare line. It was necessary to install a water trap at the base of the flare stack to prevent the possibility of an accidental fire in the flare line. These modifications were approved by the Arkansas State Boiler Inspection Division of the Department of Labor.

The leaking ball check valve between the turbine exhaust line and the condenser was remounted in a vertical position. Since the valve could not be reworked to make it seal gas tight, it was hoped that this repositioning would at least minimize leakage of the hot turbine exhaust into the condenser vapor space. The line to the condenser vent valve was also modified in order to provide for better scavenging of the non-condensable gases and hopefully, to reduce the amount of isopentane vapor that was vented from the condenser.

The brine pump, which had been previously mounted on an elevated platform, was connected to the brine piping system and an overhead feeder circuit was installed to provide electrical power. The first test of the brine pump was unsuccessful because the pump motor windings shorted

and required rewinding. After repair of the motor the brine system was operated and ran normally.

On April 30, 1980, start-up was attempted. While filling the isopentane storage tanks, it was discovered that the safety valves on those tanks were leaking. The valves were removed and disassembled, and a large amount of rust was discovered inside the valves. Some of the rust had lodged between the disc and seat, thus preventing proper sealing. The valves were reworked, installed, and operated properly.

While the safety valves were being repaired, it was decided to open the boiler to make a brief inspection of the inside of the vessel. The Teflon^R coating on the sides and bottom of the boiler was mostly intact and in good shape. The coating on the top dome of the boiler was almost entirely peeled off, and the vessel was corroded over most of that area. There is presently no positive explanation for peeling of the Teflon^R coating in that area. However, since this area is in the vapor space of the boiler, it is possible that locally high vapor flow velocities with entrained particulate material adversely affected the Teflon^R coating. There was a 1/4 inch layer of salt in the bottom of the boiler. The salt was washed out, and the boiler was closed.

The system was charged with isopentane, and another start-up attempt was made. The isopentane level control system on the condenser did not operate properly, and the condenser became flooded with isopentane. Several attempts were made to calibrate the isopentane level control

transmitter at the plant site, but all were unsuccessful. The transmitter was removed, disassembled, and cleaned. When the transmitter was reinstalled and calibrated to factory specifications, it was still unsuitable for use because the unit responded too slowly to changing levels in the condenser, and flooding continued to occur. After several trial and error adjustments, the transmitter operated in an acceptable manner.

The plant was finally brought on line on May 13, 1980 for a brief period of time. It was also operated for brief periods on May 14 and May 19. A delivery of isopentane was delayed, so operations after May 19 were delayed pending delivery.

During the operations that were conducted, some pump problems were experienced. The circulating water pump to the condenser frequently tripped due to cavitation and low discharge pressure. The pump trip would initiate a plant shutdown and would usually occur without warning. The brine pump flow was quite low at 120 to 170 gallons per minute, whereas it normally operated at 210 gpm. The low flow rate was eventually discovered to be due to low flow from the GLC bromine plant. This allowed the brine pump suction line to entrain some air, causing pump cavitation and loss of flow.

After the isopentane delivery was received, the plant was operated for about 12 total hours on four occasions. It appeared that the plant could operate indefinitely if the condenser was vented about every

thirty minutes. The condenser pressure was much higher than design during these operations and losses of isopentane from the condenser vent to the flare were considerable. One hundred gallons per hour of isopentane loss were normal. The condenser overpressure also caused a considerably higher than design back pressure, so turbine output was severely limited.

After several hours of operation on June 10, 1980, the brine line ruptured at a "T" fitting in the line. It was several days before the needed repair parts were received and installed. During this time, the boiler pressure and temperature transmitters were calibrated. The pressure transmitter calibration was satisfactory. The temperature transmitter was reading about 10 °F high and required adjustment.

After the brine line was repaired, a check valve was installed at the brine inlet to the boiler to prevent a blow out of brine and isopentane if another brine line rupture occurred. After the "T" fitting was replaced, the brine line was tested to 50 psig, and several small leaks were discovered at other fittings in the brine line. These leaks were also repaired.

During the latter part of June, 1980, the daytime temperatures averaged in the range of 95-105 °F and caused the condenser performance to worsen. It also became very hazardous to transfer isopentane from the shipping drums to the storage tanks mounted on the unit. Under atmospheric pressure, isopentane boils at approximately 80 °F and when the bungs were removed from the drums, the isopentane would boil furiously.

Cooling the drums with service water prior to opening them was tried, but this was too time consuming. Due to the problems caused by the extremely hot weather, the plant was not operated between June 26 and July 21, 1980. The extremely hot weather set new records for Arkansas with 20 consecutive days over 100°F.

On July 21, 1980, the plant was operated during nighttime hours. The ambient temperature was low enough to permit safe handling of the isopentane, and the plant could be operated steadily for several hours. Higher than design wet bulb temperatures caused poor cooling tower performance, and subsequently, poor condenser performance. Unit operation was continued, and heat balance data was collected, even though the condenser overpressure severely limited plant output. On July 22, 1980, the unit was again operated at night, under similar weather conditions. Heat balance data was also collected as well as samples of the brine from the boiler, circulating water from the condenser, vapor to the turbine, and vapor in the condenser shell. These samples were delivered to the GLC laboratory for analysis.

The plant remained shut down for several weeks to permit some preliminary analysis of the heat balance data collected to that point. It was determined that more system samples needed to be collected for analysis for a better overall idea of the unit's performance. The plant was operated again on August 12, 1980 during the early morning and late evening hours. Six sets of samples were collected during about 4 hours of operation. Plant performance and output were still restricted due to high wet bulb temperatures.

RESULTS OF OPERATIONS AND TEST PROGRAM

Boiler

The direct contact boiler presented few problems in operation. Its design was such that there were essentially no moving parts subject to wear or failure. The boiler vessel itself was operationally adequate, as it did allow for vaporization of isopentane by directly mixing it with the hot brine.

One shortfall of the vessel surfaced in the form of material selection. The boiler was sheet steel with the internal surfaces coated by Teflon^R for resistance to fluid induced corrosion. An inspection of the boiler was performed in May, 1980, and the Teflon^R coating on the sides and bottom of the vessel was mostly intact with only minor separation and peeling visible. The coating on the upper dome of the vessel was entirely gone, however, and the upper dome was completely corroded and rusted. No definite explanation exists for that occurrence, but it is thought to be due to abrasion by particulate matter carried over in the isopentane vapor. Regardless of the reason, it is obvious that for the Teflon^R coating to be effective, means of maintaining its permanent integrity must be sought or the vessel itself will need to be constructed of material capable of withstanding the fluid corrosion problem. Similarly, any outside areas of the boiler where paint failed, rapidly corroded due to the hydrogen sulfide environment. Thus, painting techniques or material selection must also take into consideration the surrounding atmosphere. Experience with the 100KW pilot plant clearly

indicates that material selection or painting/coating techniques need to be carefully studied in order to achieve a cost effective, lasting boiler for commercial application.

The boiler control system presented some problems in operation that were never suitably overcome. The original control system included a differential vapor pressure cell installed in the boiler to act as a superheat transmitter. Constant superheat of the outlet vapor would be automatically maintained regardless of varying boiler pressure. Due to problems with cell leakage, it was returned to the manufacturer, and a simple temperature transmitter was installed and used for the entire AP&L test period. Use of this system required the desired outlet vapor temperature to be set manually, so that if superheated vapor was desired, then the temperature setpoint had to be maintained higher than the saturation temperature. Any change in boiler pressure required that the temperature setpoint be manually readjusted. Such a system is effective but is hardly desirable on a commercial facility, as it requires too much attention by the operator.

The temperature and pressure controls as a whole, presented other difficulties, since a combined signal from those transmitters was used to control brine and isopentane flows when set on "automatic." Brine flow was usually adequate when operated automatically, but isopentane flow tended to be low until calibration of the temperature transmitter was changed. This area of the control system needs to be evaluated further.

The brine liquid level control in the boiler was very stable. It generally maintained a steady brine level at all times, although no provisions existed for measuring the exact level. Such information is desirable in evaluating heat transfer characteristics of the boiler.

Technical evaluation of the test data showed that the boiler heat duty was adequate for the system needs. The heat duty during testing varied from 3.2249 MMBTU/Hr. to 5.2358 MMBTU/Hr. as was necessary, and similarly, the overall boiler volumetric heat transfer coefficient varied from 1416 BTU/Hr.-Ft.³-°F to 2299.8 BTU/Hr.-Ft.³-°F. The latter was evaluated from an overall boiler approach rather than from a separate preheating and boiling section approach by assuming a constant brine volume. For the boiler as it exists, there are no provisions for accurately determining the actual brine volume, nor are there provisions for determining how that volume is subdivided into measurable, separate volumes for preheating, and then boiling, of the isopentane. Such is the reasoning for an overall heat transfer approach, and it is obvious that more instrumentation is required for in-depth evaluation of direct contact heat transfer coefficient characteristics.

As a general comparison, the brine flows, isopentane flows, temperatures and temperature changes approximately matched the values predicted by DAI for a 63.8KWe gross generation at 60°F wetbulb temperature. Some differences existed between the test boiler heat duties when calculated using isopentane flow or brine flow. This is possible evidence of inaccurate flow metering. The isopentane flowmeter (sharp edge orifice) was inspected and checked, and its accuracy appeared to be satisfactory.

No information or facilities were available for calibrating the brine (magnetic) flowmeter, but it appears that it was slightly out of calibration.

Samples of the brine fluid leaving the boiler and the vapor entering the turbine were taken during several test periods. Analyses of those samples indicated isopentane carryunder with the brine on the order of 5 to 140ppm, water carryover with the vapor on the order of 3.39 to 8.25% by mass, and noncondensibles carryover with the vapor of .39 to 3.41% by mass. Losses and carryover of these types have been experienced with other binary cycle direct contact heat exchanger tests, and it is not known what effort was made in the design of the 100KW pilot plant to minimize their occurrence.

Water and noncondensibles carryover from the brine have effects on turbine efficiency and condenser pressure, and can cause corrosion of piping, turbine, or condenser. Solid particle entrainment with the water could cause erosion of boiler protective coatings or turbine components. Demisters, though not used in this project, have been used successfully on other direct contact boilers as a means of minimizing water carryover. Since the main source of noncondensibles was probably air and the other gasses entrained in the brine entering the boiler, an attempt at minimizing them could have been made by including an ejector system or vent vessel in the brine inlet piping system. Finally, it is felt that in the future, attempts at controlling isopentane loss should be made, possibly by including a separator system in the brine outlet piping system. Cost due to isopentane loss with the brine was on the

order of \$1.55 to \$6.99 per hour of operation, based on a June, 1980 isopentane cost of \$2.55/gallon.

Turbine-Generator

The turbine-generator and associated equipment performed adequately during the AP&L operations. Aside from problems with some of the sub-systems, no major failures attributable to the turbine-generator occurred. Turbine controls, operating characteristics and vibration levels were all acceptable, and it appears that the radial inflow design is adequate.

Perhaps the most persistent problem was that of water contamination of the turbine lube oil and failure (collapse) of the lube oil filter cartridges. The nitrogen seal system for the turbine shaft was designed to prevent leakage of working fluid into the shaft bearings behind the impeller and should have prevented nitrogen leakage into the working fluid. Though the seal system was operated in accordance with the manufacturer's recommendations, leakage of working fluid into the shaft bearings was apparent. Since steam was being carried over with the isopentane from the boiler, any leakage of isopentane vapor into the bearings allowed steam to contaminate the bearing lube oil. This contamination greatly increased the pressure drop through the filter cartridges, resulting in their failure. Discussion with the lube oil vendor revealed that the lube oil contained an anti-wear additive that caused the water to be entrained rather than allowing it to separate in the reservoir. Changing to a lube oil with no anti-wear additive would be

recommended for future operations. It was found that preheating the lube oil to 90°F and then slowly applying pressure to the filters circumvented the problem.

The nitrogen seal system also needs further analysis. In addition to allowing oil contamination, this is also another means of introducing noncondensibles into the isopentane vapor, which contributes to poor system performance.

The turbine disassembly in March-April, 1980 proved valuable in that it generated some information for evaluation of the design and materials. The impeller, made of titanium, showed some signs of blade erosion and pitting. Rotoflow Corporation inspected, cleaned, and balanced the impeller and then performed an overspeed test. It was their judgement that the impeller erosion was within acceptable limits. It appears that titanium is an adequate choice for the turbine impeller material so far as corrosion/ erosion resistance is concerned. The need for control of solid particle entrainment in the vapor leaving the boiler is again indicated.

The high speed shaft, nozzle block assembly, and gear reduction case casting were all visually inspected and delivered to Independent Testing Laboratories in Searcy, Arkansas for non-destructive examination (NDE). Visual inspection and dye-penetrant testing of the nozzle block assembly revealed no cracking or erosion. Magnetic particle testing of the high speed shaft showed two circumferential crack indications, but discussions with Rotoflow Corporation personnel revealed that the shaft had

been constructed of two dissimilar metals and that the crack indications were actually fusion lines. The gear case casting examination revealed one crack in the area of the high speed shaft bearing hole and three cracks radiating from the bearing hole for the low speed shaft. Roto-flow Corporation was notified of these results, and they determined that the cracks were not in areas of high stress and that the unit could be operated safely without repair. The cause of the cracking was never ascertained, and it is not certain whether it occurred during manufacture or operations.

Further inspection of other components of the turbine showed no unusual wear. Some amount of whitish particulate matter was found on the bearing heat barrier, oil retainer, and lube oil reservoir, and a chemical analysis indicated it to be primarily carbonates, calcium, chlorides, and sand. This, combined with the presence of water in the lube oil, strongly indicated that water vapor and solid particles were being carried over from the boiler brine with the isopentane vapor and leaking through the seal system. This again points out the need to control carryover from the boiler. Such control would decrease materials requirements of some components and possibly increase component life. It also indicates the need for an adequate shaft seal system.

The test data indicated several items of consideration for the turbine. The turbine efficiency varied from 58.2% to 90% with the average being 70.7%. This average is lower than the manufacturer's claimed efficiency, and it is probably due to the large amount of water carryover combined with extremely high condenser pressures. Also, turbine gross

electrical generation never exceeded the auxiliary requirements of the system, indicating a possible turbine/system mismatch.

A review of project documents indicated that the turbine-generator was designed and manufactured for an extremely low wetbulb temperature climate (and thus low exhaust pressure). Unfortunately, it was matched with equipment designed for higher wetbulbs. Test data indicates that the turbine inlet and exhaust temperature and pressures were much higher than the machine was designed to accommodate. Since expansion of the vapor down to the design exhaust pressure was not possible, the gross generation never approached 100 KW. The maximum gross output obtained was 36.7KW.

Condenser

From an operations viewpoint, the condenser and associated control system performed poorly. For a variety of reasons, the condenser's operation was generally unstable, and large losses of isopentane occurred during operation.

The condenser control system was designed to maintain a constant water level and also a constant isopentane condensate layer on top of the water. The isopentane level control was erratic at times, and level indications were inaccurate due to condensation of isopentane in the vapor leg of the impulse lines to the isopentane level control transmitter. As such, it was necessary to periodically blow the liquid from the impulse line. The isopentane transmitter was also slow to respond

to isopentane level changes, and condenser flooding occurred occasionally during unit startup.

The level controls were also unstable during startup because of turbulent conditions in the condenser. When isopentane vapor from the turbine first entered the condenser, the water and isopentane levels increased by a few inches, sometimes causing a condenser high level control failure, followed by a unit trip. The rise in liquid levels also caused condenser pressure to increase, often causing the safety valve to lift and vent isopentane to the flare. To prevent those problems on startup, it was necessary to manually bypass the condenser high level trip and leave the condenser vent valve open until transient conditions subsided. All of these problems should be carefully evaluated.

The materials for the condenser appear to have been adequate for the pilot plant, but consideration of other materials should be studied for long-term operation. In a materials study performed by Radian Corporation, it was indicated that coal tar epoxy coatings, as used in this project, often failed within a few years. An occurrence of this nature would be unacceptable for a commercial facility. Paint on the outer surface of the vessel was adequate only so long as it was not scratched or inadvertently damaged. Carbon steel exposed to the hydrogen sulfide rich environment corroded rapidly. Outside coatings should be seriously considered for effective corrosion control in future applications.

Undoubtedly, the major problem with the condenser was that of overpressure. The condenser had been designed for operation below 14.9 psig and at a wetbulb temperature of 60°F. Safety valves were set to lift at 14.9 psig for conformance to pressure vessel code requirements. During operation, the condenser pressure continually reached the setpoint, which either automatically lifted safety valves and vented isopentane to the flare or caused the operator to manually vent the condenser. Automatic lifting of the safety valves caused the condenser liquid levels to increase, which in turn initiated the high level alarm and usually a unit trip. High pressure also prevented the isopentane makeup system from operating since the isopentane storage tanks were only pressurized to 13 psig.

The condenser was designed for a 60°F wetbulb and pressures less than 14.9 psig. The cooling tower was designed and manufactured for 78°F wetbulbs with a 7°F approach. The situation created was one in which the cooling tower, although performing near design in the summer, was providing water to the condenser at a higher temperature than it was expected to handle. The higher temperatures naturally caused an increase in the operating shell pressure, often exceeding the design pressure and causing associated problems. As mentioned earlier, the high condenser pressures presented a severe limitation to the turbine and limited its electrical output. It is conceivable that wintertime operation at low wetbulb temperatures would have shown better unit performance.

It is recommended that all future projects be designed for the worst expected wetbulb conditions at the test site rather than designing for a yearly average expected wetbulb. This would allow the unit to meet design performance in the worst summertime conditions. For this project, such design philosophy would have entailed a different turbine-generator design and would have resulted in a higher pressure, coded vessel condenser. Although cost would have been higher, it would have been offset by better unit performance. The need to match all equipment designs is again indicated.

Technical analysis of test data shows that the condenser heat duty was 3.6518 MMBTU/Hr., and the average condenser heat transfer coefficient was 3123.4 BTU/Hr.-Ft.³-°F. The heat duty was adequate compared to the system's needs, and problems resulted since heat transfer occurred at a higher plane of temperatures and pressures than expected. This is probably the reason for the lower-than-design heat transfer coefficient.

Fluid samples of the circulating water leaving the condenser and the vapor in the condenser shell were taken during operation. The vapor space samples showed large concentrations of nitrogen, oxygen, and isopentane with lesser amounts of carbon dioxide and water. Noncondensibles were clearly a factor contributing to condenser overpressure, and as mentioned earlier, the probable sources were air in the brine entering the boiler and nitrogen from the turbine seal gas system. Stable operation with the noncondensibles ejector system in service was not possible because of large isopentane losses to the flare. Losses due to valve leakage and venting to the flare averaged 100 gallons (\$255.00) per hour of operation, which offers further evidence of the

need for positive control or ejection of noncondensibles from the system.

The circulating water samples showed isopentane levels of 208 to 726ppm (avg. 354ppm) and chloride levels of 39.6 to 222ppm (avg. 139.44ppm). Isopentane losses of this nature are the result of the direct contact design and on the average result in losses of 21.3 gallons per hour of operation (\$54.32/Hr.). Thought should be given towards the installation of an isopentane recovery system or possibly to improved direct contact condenser design. A tube and shell condenser application would certainly be within reason, but materials selection must include consideration of the chloride levels present.

Cooling Tower

The cooling tower operational characteristics were satisfactory, and it appears that the ejector type cooling tower was well-suited to the project needs. Very little maintenance was required. Corrosion of the tower or its components was not in evidence, and it appears that the material selection was adequate.

The cooling tower was designed for a 78°F wetbulb temperature, a 7°F approach, and a 10°F range. During testing it provided temperature ranges of 10 to 15°F and approaches of 7.4 to 17°F. As such, its performance was somewhat marginal compared to design. As mentioned earlier, however, the major problem was that of mismatching the turbine, condenser, and cooling tower. Even if the cooling tower had operated at

design conditions, it would have still provided hotter water to the condenser than the condenser was designed to accommodate.

Auxiliary Equipment

After operating the plant for some period of time, it became apparent that the auxiliary load requirements were large, on the order of 55 to 58 KW. In fact, the gross electrical output was never sufficient to supply the auxiliary needs, meaning that the plant always drew power from the AP&L grid when operating. The reason for this was the design and operational problems previously mentioned and improperly sized electrical equipment.

The circulating water pumps were both oversized. During operation, both pumps were throttled and discharge valves were only open 25 to 30%. The condenser pump was a constant source of trouble due to cavitation. It was mounted above the cooling tower basin and often became air bound until the cooling tower basin level was raised. Use of a priming pump was required during startup to prevent the condenser pump from becoming airbound. Erratic operation also resulted from operation of the isopentane separator column, because it drained into the condenser pump suction. The ejector pump, which pumped water from the condenser to the cooling tower, operated without problems except that it was oversized.

The isopentane pump was also a source of trouble since it also cavitated frequently. The cause for this is not certain. The cavitation caused pressure surges that upset the isopentane flow metering, and accurate

flow measurements were only possible when cavitation was not occurring. This also made isopentane flow control difficult.

The brine pump generally operated well and with little maintenance, although it was necessary to install a fresh water flush to the mechanical seal stuffing box to prevent solids buildup and seal leakage. Upon inspection of the pump, corrosion of the pump casing and erosion of the impeller were apparent. This was probably a result of the salt content and acidity of the brine, indicating that better pH control or materials selection should be studied.

Copper electrical components were particularly affected by hydrogen sulfide corrosion, as were various pipes, valves, etc. at the plant site. Any unprotected, exposed surface, such as bolt threads, were rapidly corroded, which created difficulty in maintenance. Little or no corrosion of pressure gauges was noticed, but experience at GLC has shown that it will indeed occur with time. The fiberglass reinforced polyester resin piping for the brine and turbine vapor systems was well suited to those applications, and no materials compatibility problems were noted. Several failures of the brine supply line occurred at bonded joints, but those failures were probably due to improper installation. Repairs were quick and relatively inexpensive.

Unit Economics

Gross cycle thermal efficiencies ranged only from 1.13% to 3.02%, as opposed to the originally expected 5% to 7%. Since the basic concept of

the binary cycle using direct contact heat exchangers was demonstrated, it is believed that refined design and construction could result in improved performance.

The following cost comparisons illustrate DAI's projected costs for the 800 KWH net commercial geothermal facility versus several other widely used forms of producing electricity. It is apparent that the installed costs and O&M costs are very high, even compared to the relatively expensive combustion turbine peaking units. Production costs are also high and do not appear to include the cost of brine. Cost figures were calculated for the 100 KW pilot plant, but the results were exceedingly high and meaningless since a net electrical output had to be assumed. Experience with the pilot plant and consideration of all the cost data supports the idea that further research and refinement of this type of technology is necessary before a commercial venture is attempted.

INSTALLED NET CAPACITY COST COMPARISON¹

<u>Unit Type</u>	<u>Capacity</u>	<u>Unit Capital Cost</u>	<u>Unit Capital Cost Range</u>
	(Net)	(1980 \$/KWe)	(1980 \$/KWe)
Coal Fired w/ regenerative FGD	2-500 MWe	1035	918-1200
Nuclear Light Water Reactor	2-1000 MWe	985	891-1197
Oil Fired	2-500 MWe	631	490-728
Combustion Turbine	2-75 MWe	233	-
Geothermal Binary Cycle ²	800 KWe	4581	-

Note: 1) All figures except Geothermal Binary Cycle were obtained from EPRI's Technical Assessment Guide PS-1201-SR Special Report, July, 1979. Those figures were inflated to 1980 dollars using information on Cost Trends of Electric Utility Construction contained in the Data Resources Utility Cost Forecasting Service Forecast Review, Second Half, 1979.

2) Figures for the Geothermal Binary Cycle are DAI estimates.

O&M AND PRODUCTION COST COMPARISON¹

	<u>O&M Cost</u>	<u>Production Cost</u>
	(Mills/net KWH)	(Mills/Net KWH)
AP&L Nuclear Plant Summary	3.33	8.31
AP&L Fossil Plant Summary	1.61	28.22
AP&L Combustion Turbine Summary	13.68	101.51
Geothermal Binary Cycle-800 KWe ²	71.8	199.20

Note: 1) AP&L Summary figures are running averages as of August, 1980.

2) Geothermal 800 KWe plant figures are DAI estimates.

CONCLUSIONS AND RECOMMENDATIONS

The success of this project is in the large amount of hands-on experience gained on a low temperature geothermal energy recovery system. These types of units will, of necessity, require this type of pilot plant experience as they progress toward commercialization. As such, an attempt has been made to closely document the operating experience in this report.

Based on experience gathered during this project and in operating the pilot plant, a number of specific conclusions and recommendations were identified. These are applicable to both preliminary studies and commercial facilities using direct contact heat exchangers for geothermal brine energy recovery and electrical production and are summarized herein.

Overall Plant

It was demonstrated that electricity can be produced by the direct contact heat exchanger concept of geothermal brine energy recovery. Performance of the 100 KW system was inadequate as a means of effectively and efficiently utilizing that energy, however, and it is felt that further research and development is needed before commercial application of this binary cycle to southern Arkansas brines would be feasible. Further research work is encouraged.

It is believed that many of the problems encountered in the 100 KW plant were due to component designs being mismatched. It is recommended for all future projects that design be based on the worst expected ambient conditions at the test site. Any improvement (or optimization) of ambient conditions would then result in improvement of plant performance.

Electrical demands by auxiliary equipment were very high in relation to the gross electrical output expected. It is recommended that all auxiliary equipment be selected for future plants so that more reasonable auxiliary loads result.

Some of the operational problems with the 100 KW system were believed to be due to the restrictions placed on equipment location and arrangement. It is believed that fewer operational problems would result if equipment and component physical arrangements were optimized.

Isopentane losses in the form of valve leakage, losses to the flare, and losses with the brine and circulating water were excessive in the 100 KW system. Some of those losses could be reduced by adequate component matching and designing for the worst expected ambient conditions.

Improved design of the boiler's brine and isopentane distribution nozzles might also reduce losses. It is recommended that future plants of this type experiment with recovery systems for extracting isopentane from the outlet brine, the water to the cooling tower, and the vented gases.

Buildup of noncondensable gases in the condenser contributed to condenser overpressure and poor 100 KW unit performance. The existing noncondensibles ejection system was inadequate, in that it also caused large isopentane losses and unsteady operation. Experimentation with systems to eject air and other noncondensibles from the boiler's incoming brine and more effective condenser noncondensibles ejectors is recommended.

Maintenance of the incoming brine at a steadier, higher pH value would reduce demands on individual component materials. A pH stabilization system would increase component life and prove cost effective for commercial operation.

In order to prevent or control corrosion of surfaces exposed to hydrogen sulfide rich environments, it is recommended that effective paints, coatings, and application techniques be used on future projects. Also to be considered are complete plant enclosures using activated charcoal filtering and constant air purge to maintain a sulfide free environment.

Boiler

As a means of transferring heat from a highly corrosive, high solids content fluid to another fluid, the direct contact boiler was adequate. It did provide for sufficient heat transfer.

Failure of the Teflon^R inner boiler coating on the upper head indicates the need for an improved application technique or a better materials selection for the boiler. Fiberglass reinforced polyester resin piping

appears to be adequate for handling acidic, high solids content brine. Other materials have been identified as possibly suitable for boiler vessel or brine system use and should be considered for future application.

Demisters, which have proven effective in controlling and reducing water carryover to the turbine in other geothermal projects, were not incorporated in the 100 KW pilot plant. It is recommended that they be considered for future applications.

Brine and isopentane distribution nozzles appear inadequate. Improved design of those elements could result in more efficient heat transfer with reduced isopentane losses and less water, solids, and noncondensibles carryover.

The original control system, based on the differential vapor pressure cell, should receive further attention. It's features are more desirable than the simple temperature transmitter system that was ultimately used.

In order to gain knowledge of direct contact heat exchanger heat transfer coefficients, means of accurately measuring and displaying the brine height in the boiler vessel should be provided.

Turbine-Generator

The radial inflow single stage turbine with induction generator operated

in a satisfactory manner. The turbine-generator should be designed for operation at exhaust pressures corresponding to the worst expected condenser pressures at the highest expected wetbulb temperatures. This would prevent the condenser from limiting electrical output of the turbine-generator.

A more effective means of shaft sealing should be investigated. The present system allows for water contamination of the lube oil and also permits noncondensibles (nitrogen) to enter the condenser.

Material selection appears adequate. Any selection must be made with consideration given to chloride contamination in the brine carryover.

Condenser

Performance of the direct contact condenser was poor, and it is believed that a well designed tube and shell condenser would better serve the purpose. Control system problems and isopentane losses could virtually be eliminated. Otherwise, a considerable amount of development work is needed to optimize the direct contact condenser's operation.

Future condensers should be designed to operate at pressures corresponding to the highest circulating water temperatures and wetbulb temperatures expected.

On the basis of other geothermal project findings, it is feared that the coal tar epoxy coating in the condenser will not be lasting. The availability of other condenser materials should be investigated.

Cooling Tower

The ejector cooling tower selection appeared adequate for the project's needs. It was designed for a relatively high wetbulb temperature, and its operation was satisfactory. Its materials adequately withstood the operating environment and little maintenance was required. It would probably be a good choice for future projects.

ACKNOWLEDGEMENTS

The authors would like to thank employees of the United States Department of Energy, without whose assistance this project could not have been completed. In particular, the contributions of Messrs. Clifton McFarland and Raymond LaSala are appreciated.

Co-sponsorship by Great Lakes Chemical Corporation was necessary for the project to be undertaken, and the assistance of that company was appreciated. The efforts of Messrs. Ken Karmel, Bill McGuire, Thomas Mathis, Chuck Groustra, and Dr. David McAlister were particularly helpful.

The contributions of Mr. Roy Robertson of Oak Ridge National Laboratory were appreciated, particularly his work in the area of Thermodynamic performance analysis.

The contributions of Mr. Marino di Marzo of Daedalean Associates, Incorporated were particularly valuable with respect to system operation of the 100 KW pilot plant.

The contributions of Messrs. Michael Urbanek and Geoffrey Hart of DSS Engineers, Inc., and Messrs. Peter F. Ellis, III and Dennis Anliker of Radian Corporation are appreciated, as their work and comments aided in the evaluation of the 100 KW pilot plant design.

Assistance by the following personnel of Arkansas Power & Light Company was also appreciated: Mr. Tom Kilgore, Mr. Roy Hogan, Mr. Wieble Alley, Mr. E. L. Sanders, Mr. Dewitt T. Tarlton, Ms. Janet Dierkes, Mr. George Rowe, and employees of Couch Steam Electric Station.

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APPENDICES

1. Simplified Piping and Flow Diagrams
2. Equipment Specifications and Design Parameters
3. Computer Heat Balance Program Listing With Sample
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4. Computer Heat Balance Program Results Using AP&L Data
5. Fluid Sample Analyses
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APPENDIX 1 - SIMPLIFIED PIPING & FLOW DIAGRAMS

AIR OPERATED VALVES - NORMALLY OPEN - K1 K3 K6
CLOSED - K2 K5

PRESSURE RELIEF VALVES - H2 H6 H14

PRESSURE, TEMPERATURE, FLOW MEASUREMENTS - P, T, F

SS

BOILER P#10

BRINE FEED SYSTEM PIPING

CONDENSER P&ID

APPENDIX 2 - EQUIPMENT SPECIFICATIONS & DESIGN PARAMETERS

TURBINE

Vendor: Rotoflow Corporation
2235 Carmelina Avenue
Los Angeles, California 90064
Telephone: (213) 477-3083

Unit I.D.: Turboexpander

Model Number: 30-8E1P

Serial Number: 19313

Working Fluid: Isopentane @ 42.5 psia & 150^o F
design inlet condition

@ 14.0 psia & 111^o F
design exit condition

Design Flow: 18,745 LBM/HR

Design Speed: 18,000 RPM

Design Efficiency: 86%

Design Power: 114 hp.

General Description: The unit was designed exclusively for Daedalean Associates, Incorporated as a power-recovery system for the GEOBER Project at Marysville, Arkansas. It is a single stage radial inflow turboexpander driven by the expansion of isopentane. It drives an induction generator at 1,800 rpm through a 10:1 reduction gearbox. The turbine casing, nozzle block, and exhaust areas are Hastelloy C-276, and the turbine rotor is unalloyed titanium.

GENERATOR

Vendor: LOUIS-ALLIS Division of Litton Industries
Milwaukee, Wisconsin 53201

Brand Name: PACEMAKER Motor

Model: 9127352001

Type: CJ4B

Frame: 444T

Nominal Specifications: 125 HP, 460 Volts, 147 Amperes,
3 phase, 60 cycle.

General Description: This equipment was a general purpose
squirrel cage motor with enclosed fan
cooling. It was used as an induction
generator driven at 1,800 RPM for the
GEOBER project.

BOILER

Vendor: J. C. Pardo & Sons

Reames Road

Baltimore, Maryland 21220

Dimensions: 48 inch O.D. x 96 inch tank height overall, including top and bottom 2:1 ratio elliptical heads.

Materials: Nominal .25 inch sheet steel vessel with internals coated with Teflon^R for corrosion resistance.

Maximum Design Working Pressure: 100 psia

Design Heat load: 3.655 MMBTU/HR

Design Heat Transfer Coefficient (Boiling):

5000 BTU/HR-FT³-°F

(Preheating):

1000 BTU/HR-FT³-°F

Design Fluid Conditions: Brine inlet=

85,700 LBM/HR @ 205°F

Brine outlet=

85,300 LBM/HR @ 153°F

Isopentane inlet=

22,600 LBM/HR @ 90°F Liquid

Isopentane outlet=

23,000 LBM/HR @ 154°F Vapor

(Design = 10°F superheat)

These design figures are for 63.8 KWe and 60°F wetbulb.

General Description: The boiler was of all welded steel construction, with two removable manways and two replaceable site glasses. It made use of direct contact heat transfer between the isopentane and brine, with the isopentane vapor being supplied to the turbine.

Teflon^R is a registered trademark of E.I. DuPont de Nemours and Company.

CONDENSER

Vendor: Buffalo Tank Division of Bethlehem Steel Corporation

Dimensions: 48 inch O.D. x 15 feet overall length

Materials: Nominal .25 inch sheet steel vessel, internals
coated with coal tar epoxy for corrosion resistance.

Maximum Design Working Pressure: 14.9 psig

Design Heat Load: 3.438 MMBTU/HR

Design Heat Transfer Coefficient: 5000 BTU/HR-FT³-°F

Design Fluid Conditions: Water inlet: 343,750 LBM/HR @ 70°F
Water outlet: 344,150 LBM/HR @ 80°F
Isopentane inlet: 23,000 LBM/HR @
102.3°F Sat. Vapor
Isopentane outlet: 22,600 LBM/HR @
90°F

These design figures are for 63.8 KWe and 60°F wetbulb.

General Description: The condenser is of all steel construction with one end welded and the other flanged for access. It makes use of direct contact heat transfer between isopentane and water, with the liquid isopentane that is condensed being sent to the boiler.

COOLING TOWER

Vendor: Baltimore Aircoil Company
Type: Single cell Ejector type (fanless)
Design Heat Load: 3.0 MMBTU/HR
Design Approach: 7°F
Design Range: 10°F
Design Wetbulb: 78°F

PUMPS

1. Brine Pump

Manufacturer: Worthington

Model: 10-11/10-12

Maximum Flow: 220 gpm @ 150 psig, 225^o F, 180 Ft. TDH

NOTE: This pump is driven by a 15 hp, 3 phase, 480 volt Baldour motor. Pump impeller material finally selected was Alloy 20.

2. Isopentane Pump

Manufacturer: Paco

Model: 1570-3 Single Stage Type LN

Maximum Flow: 22,600 LBM/HR @ 150 psig, 150^o F,
180 ft. TDH

NOTE: This pump is driven by a 7.5 hp motor.

3. Cooling Water Pump (water to condenser)

Manufacturer: Paco

Model: 4015-5

Maximum Flow: 900 gpm @ 150 psig, 150^o F, 50 ft. TDH

NOTE: This pump is driven by a 20 hp, 3 phase,
230 volt motor.

4. Ejector Pump (water out of condenser)

Manufacturer: Paco

Model: 4012-5

Maximum Flow: 900 gpm @ 150 psig, 150° F,
170 ft. TDH

NOTE: This pump is driven by a 40 hp, 3 phase,
230 volt motor.

**APPENDIX 3 - COMPUTER HEAT BALANCE PROGRAM LISTING WITH SAMPLE
RESULTS PRINTOUT**

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1  SJOB
2  REAL KVA,NET,LMTD1,LMTD3
3  DIMENSION IC1(20),IC2(20),IC3(20),IC4(20),IC5(20),IC6(20),IC7(20)
4  DIMENSION IC8(20)
5  DIMENSION IDATE(2),ITIME1(2),ITIME2(2)
6  READ(5,801)IDATE,ITIME1,ITIME2,DBULB1,DBULB2,WBULB1,WBULB2
7  801 FORMAT(2A4,2A4,2A4,4F5.1)
8  READ(5,802)BAROM1,BAROM2
9  802 FORMAT(2F5.2)
10 C
11 C**** THESE VARIABLES ARE READ IN FOR BOILER ANALYSIS-
12 C C1,Q1ISO,Q1B,T1ISO,T1B,T1DN,T1VAP,PB,M1,PBR,PISO,C2
13 READ(5,800)C1,Q1ISO,Q1B,T1ISO,T1B,T1DN,T1VAP,PB
14 800 FORMAT(8F10.3)
15 READ(5,800)M1,PBR,PISO,C2
16 C
17 C**** THESE VARIABLES ARE READ IN FOR TURBINE ANALYSIS-
18 C T2IN,P2IN,T2OUT,P2OUT,GROSKW,AUXKW,KVA
19 READ(5,600)T2IN,P2IN,T2OUT,P2OUT,GROSKW,AUXKW,KVA
20 C
21 C**** THESE VARIABLES ARE READ IN FOR CONDENSER ANALYSIS-
22 C C4,Q3L,P3VAP,T2OUT,T3ISO,P3W1,T3W1,T3W0,P3SHL,TSPACE
23 READ(5,800)C4,Q3L,P3VAP,T2OUT,T3ISO,P3W1,T3W1,T3W0
24 READ(5,800)P3SHL,TSPACE
25 C
26 C**** THESE VARIABLES ARE READ IN FOR COOLING TOWER ANALYSIS
27 C CTTIN,CTTOUT
28 READ(5,800)CTTIN,CTTOUT
29 C
30 C**** THESE ARE 4 COMMENT CARDS TO BE READ IN-
31 READ(5,803)IC1,IC2,IC3,IC4,IC5,IC6,IC7,IC8
32 803 FORMAT(20A4)
33 C
34 C**** DIRECT CONTACT BOILER ANALYSIS - GEOBER 100 KW PILOT PLANT.
35 C**** THIS ANALYSIS MAKES THE FOLLOWING ASSUMPTIONS-
36 C Q1ISO = ISOPENTANE FLOW FROM CONDENSER TO BOILER (ASSUME ALL
37 C ISOPENTANE) LBM/HR.
38 C Q1B = BRINE FLOW TO BOILER (ASSUME ALL BRINE) GPM
39 C Q1DN = BRINE FLOW OUT BOILER TO TAIL POND (ASSUME ALL BRINE)
40 C Q1VAP = VAPOR FLOW FROM BOILER TO TURBINE (ASSUME ISOPENTANE
41 C IN ACCORDANCE WITH DALTON MODEL OF MIXTURES) LBM/HR
42 C Q1VAP= PORTION OF STEAM FLOW IN Q1VAP. LBM/HR
43 C Q1VAP1= PORTION OF ISOPENTANE FLOW IN Q1VAP. LBM/HR
44 C Q1VAP= PORTION OF NONCONDENSABLES FLOW IN Q1VAP. LBM/HR
45 C C1 = WEIGHT PERCENT OF STEAM IN VAPOR FLOW TO TURBINE (%)
46 C C2 = WEIGHT PERCENT OF NONCONDENSABLES IN VAPOR TO TURBINE (%)
47 C M1 = HEIGHT OF BRINE IN BOILER (INCHES, ASSUME 60 ALWAYS)
48 C T1ISO = MEASURED TEMP OF ISOPENTANE INTO BOILER (F)
49 C T1B = MEASURED TEMP OF BRINE INTO BOILER (F)
50 C T1DN = MEASURED TEMP OF BRINE OUT BOILER (F)
51 C T1VAP = MEASURED TEMP OF VAPOR LEAVING BOILER (F)
52 C PB = MEASURED TOTAL VAPOR PRESSURE EXITING BOILER (PSIG)
53 C
54 C PBR = MEASURED BRINE PRESSURE IN (PSIG)
55 C PISO = MEASURED ISOPENTANE PRESSURE IN (PSIG)
56 C
57 C**** CALCULATE BRINE DENSITY (LBM/FT3, ASSUME 220,000 PPM SALT)
58 DENB=72.75796-.62338E-04*T1B*T1B
59 Q1VAP1=Q1ISO
60 Q1VAP=Q1VAP1/(1-C1/100-C2/100)

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21      Q1VAPW=C1/100*Q1VAP      00005200
22      Q1VAPW=Q1VAP-Q1VAP1-Q1VAPW      00005201
23      Q1B=Q1B*60.*.13368*DENB      00005300
24      Q1DN=Q1B-Q1VAPW-Q1VAPN      00005400
      C      00005500
C**** DETERMINE PARTIAL PRESSURES OF VAPOR OUT BOILER.      00005600
25      AMW=C1/100.      00005700
26      AMN=C2/100      00005701
27      AMI=1-(C1/100)-(C2/100)      00005800
28      ANTW=18.02      00005900
29      ANTA=29.0      00005901
30      ANTI=72.15      00006000
31      AMOLW=AMW/ANTW      00006100
32      AMOLN=AMN/ANTA      00006101
33      AMOLI=AMI/ANTI      00006200
34      AMOLM=AMOLW+AMOLI+AMOLN      00006300
      C      00006400
35      PB=PB*.4912*BAROM1      00006500
36      PBR=PBR*.4912*BAROM1      00006600
37      PISO=PISO*.4912*BAROM1      00006700
38      P1VAPW=AMOLW/AMOLM*PB      00006800
39      P1VAPN=AMOLN/AMOLM*PB*1.08767      00006801
40      P1VAPI=PB-P1VAPW-P1VAPN      00006900
41      CIA=100.-C1-C2      00007000
      C      00007100
C**** DETERMINE SATURATION PRESSURES CORRESPONDING TO T1VAP.      00007200
42      P1SATI=PSV(T1VAP)      00007300
43      P1SATW=PSL(T1VAP)      00007400
      C      00007500
C**** DETERMINE IF STEAM EXITING BOILER IS DRY SATURATED OR SUPERHEATED.      00007600
C**** THEN, DETERMINE BOILER EXITING VAPOR PROPERTIES.      00007700
44      IF (P1SATW-P1VAPW)>.5,6      00007800
45      5 P1VAPW=P1SATW      00007900
46      P1VAPI=PB-P1VAPW-P1VAPN      00008000
47      M1VAPW=MSV(P1VAPW,T1VAP,S1VAPW,V1VAPW)      00008100
48      N1=0      00008200
49      GO TO 7      00008300
50      6 M1VAPW=MSV(P1VAPW,T1VAP,S1VAPW,V1VAPW)      00008400
51      N1=1      00008500
52      7 S1VAPI=SSHV(P1VAPI,T1VAP)      00008600
53      M1VAPI=MSHV(P1VAPI,T1VAP)      00008700
54      M1ISO=MSF(T1ISO)      00008800
55      M1VAP=AMW*M1VAPW+AMI*M1VAPI      00008900
56      IF (P1SATI-P1VAPI)>17.17,16      00009000
57      17 N1A=0      00009100
58      GO TO 19      00009200
59      18 N1A=1      00009300
60      19 CONTINUE      00009400
      C      00009500
C**** DETERMINE H.T. IN BOILER BASED ON INLET BRINE FLOW, EXIT BRINE FLOW      00009600
C**** INLET ISOPENTANE FLOW. DETERMINE SPECIFIC HEAT (BTU/LBM-F) OF HRI      00009700
C**** ASSUMING 220,000 PPM SALT.      00009800
61      CPB=.7490137+1.08113E-04*T1B      00009900
62      HT1B1=Q1B*CPB*(T1B-T1DN)/1000000.      00010000
63      HT1B0=Q1DN*CPB*(T1B-T1DN)/1000000.      00010100
64      HT1ISO=(Q1VAPI*(M1VAPI-M1ISO)+Q1VAPW*(M1VAPW-T1VAP*32))/1000000.      00010200
      C      00010300
C**** CALCULATE VOLUMETRIC HEAT TRANSFER COEFFICIENT BASED ON ABOVE H.T.      00010400
C**** ASSUME LMTD = 37 DEGREES F.      00010500
      C      00010600

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65	V1=47.5**2*3.14159265/4.*M1/1728.	00010700
66	LMTD1=37.0	00010800
67	U181=MT181/(LMTD1*V1)*1000000.	00010900
68	U180=MT180/(LMTD1*V1)*1000000.	00011000
69	U1150=MT1150/(LMTD1*V1)*1000000.	00011100
C		00011200
C****	TURBINE ANALYSIS - GEORGE 100 KW PILOT PLANT.	00011300
C****	THIS ANALYSIS MAKES THE FOLLOWING ASSUMPTIONS-	00011400
C	Q1VAP = VAPOR FLOW INTO TURBINE = VAPOR FLOW OUT TURBINE (LBM/HR)	00011500
C	Q1VAPW = LBM/HR STEAM IN Q1VAP	00011600
C	Q1VAPI = LBM/HR ISOPENTANE IN Q1VAP	00011700
C	Q1VAPN = LBM/HR NONCONDENSABLES IN Q1VAP	00011701
C	Q1VAP = Q1VAPI + Q1VAPW + Q1VAPN	00011800
C		00011900
C	T2IN = VAPOR TEMPERATURE ENTERING TURBINE (DEGREES F)	00012000
C	P2IN = TOTAL VAPOR PRESSURE ENTERING TURBINE (PSIG)	00012100
C	P2INW = WATER VAPOR PRESSURE ENTERING TURBINE (PSIG)	00012200
C	P2INI = ISOPENTANE VAPOR PRESSURE ENTERING TURBINE (PSIG)	00012300
C	P2INN = NONCONDENSABLES VAPOR PRESSURE ENTERING TURBINE (PSIG)	00012301
C	P2IN = P2INW + P2INI + P2INN	00012400
C	ASSUME ISOPENTANE IN SUPERHEATED OR DRY SATURATED	00012500
C	ASSUME WATER IN SUPERHEATED OR DRY SATURATED	00012501
C		00012600
C	T2OUT = VAPOR TEMPERATURE EXITING TURBINE (DEGREES F)	00012700
C	P2OUT = TOTAL VAPOR PRESSURE EXITING TURBINE (PSIG)	00012800
C	P2OUTW = WATER VAPOR PRESSURE EXITING TURBINE (PSIG)	00012900
C	P2OUTI = ISOPENTANE VAPOR PRESSURE EXITING TURBINE (PSIG)	00013000
C	P2OUTN = NONCONDENSABLES VAPOR PRESSURE EXITING TURBINE (PSIG)	00013001
C	P2OUT = P2OUTW + P2OUTI + P2OUTN	00013100
C	ASSUME ISOPENTANE OUT SUPERHEATED OR DRY SATURATED	00013200
C	ASSUME WATER OUT SUPERHEATED OR DRY SATURATED	00013201
C		00013300
C	ISENTROPICALLY, ISOPENTANE OUT SUPERHEATED OR DRY SATURATED	00013400
C	ISENTROPICALLY, WATER OUT SUPERHEATED OR SATURATED (WITH LIQUID)	00013500
C		00013600
C	GROSSW = GROSS GENERATION FOR 1 HOUR PERIOD (KWH)	00013700
C	AUXKW = AUXILIARY LOAD FOR 1 HOUR PERIOD (KWH)	00013800
C	KVA = APPARENT POWER AT GENERATOR TERMINALS (KVA)	00013900
70	P2IN=P2IN*.4912*BAROM1	00014000
71	P2OUT=P2OUT*.4912*BAROM1	00014100
C		00014200
C****	CALCULATE PRESSURE DROP OF VAPOR FROM BOILER TO TURBINE INLET.	00014300
72	PDROP1=PB-P2IN	00014400
C		00014401
C****	CALCULATE TEMPERATURE CHANGE OF VAPOR FROM BOILER TO TURBINE INLET	00014402
73	TDROP1=T1VAP-T2IN	00014403
C		00014500
C****	CALCULATE P2INW, P2INI, & P2INN; P2OUTW, P2OUTI, & P2OUTN	00014600
74	P2INW=AMOLW/AMOLH*P2IN	00014700
75	P2INN=AMOLN/AMOLH*P2IN*1.08767	00014701
76	P2INI=P2IN-P2INW-P2INN	00014800
77	P2OUTW=AMOLW/AMOLH*P2OUT	00014900
78	P2OUTN=AMOLN/AMOLH*P2OUT*1.08767	00014901
79	P2OUTI=P2OUT-P2OUTW-P2OUTN	00015000
C		00015100
C****	DETERMINE STEAM SATURATION PRESSURES AT INLET AND EXIT.	00015200
80	P2SATW=PSL(T2IN)	00015300
81	P2SATI=PSL(T2OUT)	00015400
C		00015500
C****	DETERMINE IF STEAM INTO TURBINE IS DRY SATURATED OR SUPERHEATED.	00015600

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82 C**** THEN, DETERMINE INLET FLUID PROPERTIES. 00015700
83 IF (P2SATW-P2INW)8.0,9 00015800
84 P2INW=P2SATW 00015900
85 P2INI=P2IN-P2INW-P2INN 00016000
86 H2INW=HSV(P2INW,T2IN,S2INW,V2INW) 00016100
87 N2=0 00016200
88 GO TO 10 00016300
89 9 H2INW=HSS(P2INW,T2IN,S2INW,V2INW) 00016400
90 N2=1 00016500
91 10 S2INI=SSHV(P2INI,T2IN) 00016600
92 H2INI=MSHV(P2INI,T2IN) 00016700
93 V2INI=VSHV(P2INI,T2IN) 00016800
94 H2IN=AMW*H2INW+AMI*H2INI 00016900
95 S2IN=AMW*S2INW+AMI*S2INI 00017000
96 P2SATI=PSV(T2IN) 00017100
97 IF (P2SATI-P2INI)20.20,21 00017200
98 20 N2A=0 00017300
99 GO TO 22 00017400
100 21 N2A=1 00017500
22 CONTINUE 00017600
C 00017700
C**** DETERMINE IF STEAM EXITING TURBINE IS SUPERHEATED OR DRY SATURATED 00017800
C**** THEN, DETERMINE EXIT FLUID PROPERTIES. 00017900
101 IF (P2SATW-P2OUTW)11.11,12 00018000
102 11 P2OUTW=P2SATW 00018100
103 P2OUTI=P2OUT-P2OUTW-P2OUTN 00018200
104 H2OUTW=HSV(P2OUTW,T2OUT,S2OUTW,V2OUTW) 00018300
105 N3=0 00018400
106 GO TO 13 00018500
107 12 H2OUTW=HSS(P2OUTW,T2OUT,S2OUTW,V2OUTW) 00018600
108 N3=1 00018700
109 13 S2OUTI=SSHV(P2OUTI,T2OUT) 00018800
110 H2OUTI=MSHV(P2OUTI,T2OUT) 00018900
111 V2OUTI=VSHV(P2OUTI,T2OUT) 00019000
112 H2OUT=AMW*H2OUTW+AMI*H2OUTI 00019100
113 P2SATO=PSV(T2OUT) 00019200
114 IF (P2SATO-P2OUTI)23.23,24 00019300
115 23 N3A=0 00019400
116 GO TO 25 00019500
117 24 N3A=1 00019600
118 25 CONTINUE 00019700
C 00019800
C**** DETERMINE ISENTROPIC EXIT PROPERTIES OF ISOPENTANE AND STEAM, 00019900
C**** ASSUMING STEAM IS SATURATED, ISOPENTANE IS SUPERHEATED. 00020000
119 T2ISEN=T2IN-20. 00020100
120 3 PISENW=PSL(T2ISEN) 00020200
121 PISENI=P2OUT-PISENW-P2OUTN 00020300
122 SISENI=SSHV(PISENI,T2ISEN) 00020400
123 VISENI=VSHV(PISENI,T2ISEN) 00020500
124 HISENI=MSHV(PISENI,T2ISEN) 00020600
125 HISENV=HSV(PISENW,TISENW,SISENV,VISENV) 00020700
126 HISENL=HCL(PISENW,T2ISEN,SISENL) 00020800
127 VISENL=VCL(PISENW,T2ISEN) 00020900
C 00021000
X = QUALITY OF STEAM IN ISENTROPIC EXIT. 00021100
128 X=((1.-100./C1)*(S2INI-SISENI)-S2INW-SISENL)/(SISENL-SISENV) 00021200
129 Y=((VISENL*X*(VISENV-VISENL))/V2INW)-(VISENI/V2INI) 00021300
130 Y=ABS(Y) 00021400
131 IF (Y-.01)1.1,2 00021500
132 2 T2ISEN=T2ISEN-.1 00021600
133 GO TO 3

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134      1 H2ISEN=( AM1 )*(HISENI+( ANW )*(HISENL+X*(HISENV-HISENL)) 00021700
135      HISENW=HISENL+X*(HISENV-HISENL) 00021800
136      SISENW=SISENL+X*(SISENV-SISENL) 00021900
137      VISENW=VISENL+X*(VISENV-VISENL) 00022000
138      IF(X.LT.1.0) GO TO 4 00022100
      C 00022200
C**** DETERMINE ISENTROPIC EXIT PROPERTIES OF ISOPENTANE AND STEAM. 00022300
C**** ASSUMING STEAM IS SUPERHEATED, ISOPENTANE IS SUPERHEATED. 00022400
139      T2ISEN=T2IN-20. 00022500
140      PISENW=AMOLW/AMOLM*P2OUT 00022600
141      PISENI=P2OUT-PISENW-P2OUTN 00022700
142      55 SISENI=SSMV(PISENI,T2ISEN) 00022800
143      VISENI=VSMV(PISENI,T2ISEN) 00022900
144      HISENI=HSMV(PISENI,T2ISEN) 00023000
145      HISENW=HSS(PISENW,T2ISEN+SISENW-VISENW) 00023100
146      H2ISEN=AMI*(HISENI+AMW*(HISENW 00023200
147      S2ISEN=AMI*(SISENI+AMW*(SISENW 00023300
148      Z=S2IN-S2ISEN 00023400
149      Z1=ABS(Z) 00023500
150      IF(Z1.LE.0.0001) GO TO 4 00023600
151      IF(Z)53.4+.54 00023700
152      53 T2ISEN=T2ISEN-.1 00023800
153      GO TO 55 00023900
154      54 T2ISEN=T2ISEN+.1 00024000
155      GO TO 55 00024100
      C 00024200
C**** CALCULATE ACTUAL ENTHALPY DROP THROUGH TURBINE. 00024300
156      4 HDROPA=H2IN-H2OUT 00024400
      C 00024500
C**** CALCULATE ISENTROPIC ENTHALPY DROP THROUGH TURBINE. 00024600
157      HDROPS=H2IN-H2ISEN 00024700
      C 00024800
C**** CALCULATE TURBINE EFFICIENCY, STEAM RATE, POWER FACTOR 00024900
158      TEFF=HDROPA/HDROPS*100. 00025000
159      SR=Q1VAP/(GROSKW-AUXKW) 00025100
160      PF=GROSKW/KVA 00025200
161      NET=GROSKW-AUXKW 00025300
      C 00025400
C**** CALCULATE % OF TURBINE WORK DUE TO EACH COMPONENT. 00025500
162      EFFI=AMI*(H2INI-H2OUTI)/HDROPS*100. 00025600
163      EFFW=AMW*(H2INW-H2OUTW)/HDROPS*100. 00025700
      C 00025800
C**** DIRECT CONTACT CONDENSER ANALYSIS - GEORGE 100 KW PILOT PLANT. 00025900
C**** THIS ANALYSIS MAKES THE FOLLOWING ASSUMPTIONS- 00026000
      C Q1VAP,Q1VAPI,Q1VAPW,Q1VAPN - SAME AS FOR TURBINE 00026100
      C P3VAP = PRESSURE OF VAPOR INTO CONDENSER (PSIG) 00026200
      C T2OUT = TEMPERATURE OF VAPOR INTO CONDENSER (F) 00026300
      C TSPACE= VAPOR SPACE TEMPERATURE IN SHELL (F) 00026301
      C 00026400
      C T3ISO = TEMPERATURE OF ISOPENTANE FROM CONDENSER TO BOILER (F) 00026500
      C 00026600
      C P3WI = PRESSURE OF CIRC WATER INTO CONDENSER (PSIG) 00026700
      C T3WI = TEMPERATURE OF CIRC WATER INTO CONDENSER (F) 00026800
      C T3WO = TEMPERATURE OF CIRC WATER MIXTURE EXITING CONDENSER (F) 00026900
      C 00027000
      C Q3L = CIRC WATER MIXTURE FLOW EXITING CONDENSER (GPM) 00027100
      C C4 = WEIGHT PERCENT OF ISOPEN IN CIRC WATER OUT CONDENSER (%) 00027200
      C P3SHL = SHELL PRESSURE (PSIG) 00027300
      C 00027400
      C 00027500

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164	P3VAP=P3VAP*.4912*BAROM1	00027600
165	P3WI=P3WI*.4912*BAROM1	00027700
166	P3SHL=P3SHL*.4912*BAROM1	00027800
167	C4A=100.-C4	00027900
168	BMW=C4A/100.	00028000
169	BMI=1-BMW	00028100
170	BMOLW=BMW/AMTW	00028200
171	BMOLI=BMW/AMTI	00028300
172	BMOLM=BMOLW*BMOLI	00028400
173	P3VAPW=AMOLW/AMOLM*P3VAP	00028500
174	P3VAPN=AMOLN/AMOLM*P3VAP*1.08767	00028501
175	P3VAPI=P3VAP-P3VAPW-P3VAPN	00028600
	C	00028700
	C**** DETERMINE STEAM SATURATION PRESSURE AT CONDENSER INLET.	00028800
176	P3SATW=PSL(T2OUT)	00028900
	C	00029000
	C**** DETERMINE IF STEAM INTO CONDENSER IS SUPERHEATED OR SATURATED.	00029100
	C**** THEN, DETERMINE CONDENSEM VAPOR INLET PROPERTIES.	00029200
177	IF(P3SATW-P3VAPW)14,14,15	00029300
178	14 P3VAPW=P3SATW	00029400
179	P3VAPI=P3VAP-P3VAPW-P3VAPN	00029500
180	H3VAPW=HSV(P3VAPW,T2OUT,S3VAPW,V3VAPW)	00029600
181	N4=0	00029700
182	GO TO 16	00029800
183	15 H3VAPW=HSS(P3VAPW,T2OUT,S3VAPW,V3VAPW)	00029900
184	N4=1	00030000
185	16 H3VAPI=HSV(P3VAPI,T2OUT)	00030100
186	S3VAPI=SSHV(P3VAPI,T2OUT)	00030200
187	V3VAPI=VSHV(P3VAPI,T2OUT)	00030300
188	H3VAP=AMW*H3VAPW+AMI*H3VAPI	00030400
189	P3SATI=PSV(T2OUT)	00030500
190	IF(P3SATI-P3VAPI)26,26,27	00030600
191	26 N4=0	00030700
192	GO TO 28	00030800
193	27 N4=1	00030900
194	28 CONTINUE	00031000
	C	00031100
195	H3LI=MSF(T3W0)	00031200
196	H3LW=MSL(T3W0)	00031300
197	H3L=BMW*H3LW+BMI*H3LI	00031400
198	V3LW=VSL(T3W0)	00031500
	C	00031600
199	H3WI=MSL(T3WI)	00031700
	C	00031800
200	H3ISO=MSF(T3ISO)	00031900
	C	00032000
201	HIMUP=MSF(DBUL81)	00032100
	C	00032200
	C**** CALCULATE FLOWS ABOUT CONDENSER.	00032300
202	Q3L=Q3L*8.0208*(1/V3LW)	00032400
203	Q3LW=Q3L*BMW	00032500
204	Q3LI=Q3L*BMI	00032600
205	QIMUP=Q3LI	00032700
206	Q3IN=Q3LW-Q1VAPW	00032800
	C	00032801
	C**** CALCULATE SUBCOOLING OF ISOPENTANE OUT	00032802
207	SUBC3=TSPACE-T3ISO	00032803
	C	00032900
	C**** CALCULATE HEAT GAINED BY CIRC WATER, LOST BY ISOPENTANE.	00033000
208	HT3ISO=(Q1VAPI*H3VAPI-Q1ISO*H3ISO+Q1VAPW*(H3VAPW-H3LW))/1000000.	00033100

209	C	MT3CW=(Q3IN*H3WI-Q3LW*H3LW)/(-1000000.)	00033200
	C***	CALCULATE VOLUMETRIC HEAT TRANSFER COEFFICIENTS BASED ON ABOVE.	00033300
210		T3SATI=TSV(P3SHL)	00033400
211		LMTD3=(T3W0-T3WI)/ALOG((T3SATI-T3WI)/(T3SATI-T3W0))	00033500
212		V3=64.	00033600
	C		00033700
213		U3ISO=MT3ISO/(V3*LMTD3)*1000000.	00033800
214		U3CW=MT3CW/(V3*LMTD3)*1000000.	00033900
	C		00034000
215	C***	CALCULATE PRESSURE DROP FROM TURBINE EXHAUST TO CONDENSER.	00034100
		PDR0P2=P2OUT-P3VAP	00034200
	C		00034300
	C***	COOLING TOWER - GEOMER 100 KW PILOT PLANT.	00034400
	C		00034500
216		CTDROP=CTTIN-CTTOUT	00034600
217		CTAPP=CTTOUT-WBULB1	00034700
	C		00034800
218		HCTI=HSL(CTTIN)	00034900
219		HCTO=HSL(CTTOUT)	00035000
220		CTLOAD=(HCTI-HCTO)*Q3L/1000000.	00035100
	C		00035200
	C***	CALCULATE GROSS AND NET CYCLE EFFICIENCIES, BASED ON BRINE	00035300
	C***	AND ISOPENTANE FLOWS IN BOILER.	00035400
221		GETAB=GROSKW*3412.75/(HT1BI*1000000.)*100.	00035500
222		ETAB=NET*3412.75/(HT1BI*1000000.)*100.	00035600
223		GETAI=GROSKW*3412.75/(HT1ISO*1000000.)*100.	00035700
224		ETAI=NET*3412.75/(HT1ISO*1000000.)*100.	00035800
225		X=X*100.	00035900
226		WRITE(6,900)	00036000
227	900	FORMAT(1H1,47X,38(''))	00036100
228		WRITE(6,902)	00036200
229	902	FORMAT(48X,'',15X,'GEOMER',15X,'')	00036300
230		WRITE(6,903)	00036400
231	903	FORMAT(48X,'',2X,'GEOTHERMAL BRINE ENERGY RECOVERY',2X,'')	00036500
232		WRITE(6,904)	00036600
233	904	FORMAT(48X,'',2X,'100 KWH PILOT PLANT HEAT BALANCE',2X,'')	00036700
234		WRITE(6,910)	00036800
235	910	FORMAT(48X,38(''))	00036900
236		WRITE(6,905)	00037000
237	905	FORMAT(//46X,42(''))	00037100
238		WRITE(6,907)	00037200
239	907	FORMAT(46X,'',5X,'ARKANSAS POWER & LIGHT COMPANY',5X,'')	00037300
240		WRITE(6,908)	00037400
241	908	FORMAT(46X,'',2X,'PLANT PERFORMANCE EVALUATION SECTION',2X,'')	00037500
242		WRITE(6,909)	00037600
243	909	FORMAT(46X,42(''))//)	00037700
244		WRITE(6,915)	00037800
245	915	FORMAT(10X,114(''-'))/)	00037900
246		WRITE(6,911)	00038000
247	911	FORMAT(38X,'TEST CONDITIONS - ')	00038100
248		WRITE(6,912)	00038200
249	912	FORMAT(75X,'START',8X,'FINISH')	00038300
250		WRITE(6,913)IDATE	00038400
251	913	FORMAT(40X,'DATE',T74,2A4)	00038500
252		WRITE(6,914)ITIME1,ITIME2	00038600
253	914	FORMAT(40X,'TIME',T74,2A4,T88,2A4)	00038700
254		WRITE(6,915)WBULB1,WBULB2	00038800
255	915	FORMAT(40X,'DRY BULB TEMPERATURE (F)',11X,F4.1,10X,F4.1)	00038900
256		WRITE(6,916)WBULB1,WBULB2	00039000
			00039100

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257 916 FORMAT(40X,'WET BULB TEMPERATURE (F)',11X,F4.1,10X,F4.1) 00039200
258 WRITE(6,917)BAROM1,BAROM2 00039300
259 917 FORMAT(40X,'BAROMETRIC PRESSURE (IN HG)',8X,F5.2,8X,F5.2/) 00039400
260 WRITE(6,918) 00039500
261 WRITE(6,919) 00039600
262 919 FORMAT(T40.44('**')) 00039700
263 WRITE(6,920) 00039800
264 920 FORMAT(T40.1* DIRECT CONTACT BOILER PERFORMANCE DATA **) 00039900
265 WRITE(6,919) 00040000
266 WRITE(6,921) 00040100
267 921 FORMAT(/T49,'FLOW',T58,'PRESSURE',T68,'TEMPERATURE',T81,'ENTHALPY',T92,'MASS FRACTION',T107,'SPECIFIC HEAT',T122,'DENSITY') 00040200
268 WRITE(6,922) 00040300
269 922 FORMAT(T48,'LBM/HR',T60,'PSIA',T70,'DEG. F',T82,'BTU/LBM',T98,'%',00040400
270 1T109,'BTU/LBM-F',T122,'LBM/FT3'//) 00040500
271 WRITE(6,923)Q18,PBR,T18,CPB,DENB 00040600
272 923 FORMAT(T6,'BRINE IN',T46,F10.3,T59,F5.1,T71,F5.1,T84,'-',T98,'-',T00040700
273 1110,F6.4,T123,F5.2) 00040800
274 WRITE(6,924)Q10N,T10N 00040900
275 924 FORMAT(T6,'BRINE OUT',T46,F10.3,T61,'-',T71,F5.1,T84,'-',T98,'-',T00041000
276 1113,'-',T125,'-') 00041100
277 WRITE(6,925)Q1ISO,PISO,T1ISO,H1ISO 00041200
278 925 FORMAT(T6,'ISOPENTANE IN',T46,F10.3,T59,F5.1,T71,F5.1,T81,F9.4,T9800041300
279 1,'-',T113,'-',T125,'-') 00041400
280 WRITE(6,926)Q1VAP,PB,T1VAP,H1VAP 00041500
281 926 FORMAT(T6,'VAPOR MIXTURE OUT - TOTAL',T46,F10.3,T59,F5.1,T71,F5.1,00041600
282 1T81,F9.4,T98,'-',T113,'-',T125,'-') 00041700
283 WRITE(6,927)Q1VAP1,P1VAP1,T1VAP,H1VAP1,C1A 00041800
284 927 FORMAT(T24,'- ISOPENTANE PART',T46,F10.3,T59,F5.1,T71,F5.1,T81,F9.00041900
285 1,T95,F7.4,T113,'-',T125,'-') 00042000
286 WRITE(6,928)Q1VAPN,P1VAPN,T1VAP,H1VAPN,C1 00042100
287 928 FORMAT(T24,'- STEAM PART',T46,F10.3,T59,F5.1,T71,F5.1,T81,F9.4,T9500042200
288 1,F7.4,T113,'-',T125,'-') 00042300
289 WRITE(6,1018)Q1VAPN,P1VAPN,T1VAP,C2 00042400
290 1018 FORMAT(T24,'- NONCONDENSABLES',T46,F10.3,T59,F5.1,T71,F5.1,T84,'-',00042500
291 1,T95,F7.4,T113,'-',T125,'-') 00042600
292 IF(N1-1)29,30,30 00042700
293 29 WRITE(6,992) 00042800
294 992 FORMAT(T46,'NOTE : STEAM EXITING BOILER IS DRY SATURATED.') 00042900
295 GO TO 31 00043000
296 30 WRITE(6,993) 00043100
297 993 FORMAT(T46,'NOTE : STEAM EXITING BOILER IS SUPERHEATED.') 00043200
298 31 IF(N1A-1)32,33,33 00043300
299 32 WRITE(6,994) 00043400
300 994 FORMAT(T53,'ISOPENTANE EXITING BOILER IS DRY SATURATED.') 00043500
301 GO TO 34 00043600
302 33 WRITE(6,995) 00043700
303 995 FORMAT(T53,'ISOPENTANE EXITING BOILER IS SUPERHEATED.') 00043800
304 34 CONTINUE 00043900
305 WRITE(6,929)H1 00044000
306 929 FORMAT(T6,'HEIGHT OF BRINE IN BOILER (INCHES) = ',T44,F5.1//) 00044100
307 WRITE(6,930) 00044200
308 930 FORMAT(T44.48('**')) 00044300
309 WRITE(6,931) 00044400
310 931 FORMAT(T44.1* DIRECT CONTACT BOILER PERFORMANCE ANALYSIS **) 00044500
311 WRITE(6,930) 00044600
312 WRITE(6,985) 00044700
313 985 FORMAT(/T90,'BASED ON') 00044800
314 WRITE(6,939) 00044900
315 939 FORMAT(T65,'BRINE FLOW IN',T88,'BRINE FLOW OUT',T112,'ISOPENTANE VU00045000

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308      1APOP(//)                                00044900
309      WRITE(6,932)MT1BI,MT1BO,MT1ISU          00045000
309      932 FORMAT(T6,'HEAT TRANSFER IN BOILER (MMB(U/MH))',T6B,F7.5,T91,F7.5,T00045100
310      1116,F7.5)                                00045200
310      WRITE(6,933)U1BI,U1BO,U1ISU             00045300
311      933 FORMAT(T6,'VOLUMETRIC HEAT TRANSFER COEFFICIENT (BTU/MH-FT3-F)',T600045400
311      1B,F6.1,T91,F6.1,T116,F6.1)             00045500
312      WRITE(6,934)                             00045600
313      934 FORMAT(1H1,T53,30('**'))             00045700
314      WRITE(6,935)                             00045800
315      935 FORMAT(T53,'* TURBINE PERFORMANCE DATA *') 00045900
316      WRITE(6,984)                             00046000
317      984 FORMAT(T53,30('**'))                 00046100
318      WRITE(6,936)                             00046200
319      936 FORMAT(/T49,'FLOW',T58,'PRESSURE',T6B,'TEMPERATURE',T81,'ENTHALPY',T00046300
319      1,T93,'ENTROPY',T103,'SPECIFIC VOLUME')    00046400
320      WRITE(6,937)                             00046500
321      937 FORMAT(T4B,'LBM/MH',T60,'PSIA',T70,'DEG. F',T82,'BTU/LBM',T92,'BTU00046600
321      1/LBM-R',T107,'FT3/LBM'/)                00046700
322      WRITE(6,938) Q1VAP,P2IN,T2IN,M2IN         00046800
323      938 FORMAT(T6,'VAPOR MIXTURE IN -TOTAL',T4B,F10.3,T59,F5.1,T71,F5.1,T00046900
323      1B1,F9.4,T96,'-',T110,'-')              00047000
324      WRITE(6,940)Q1VAPI,P2INI,T2IN,M2INI,S2INI,V2INI 00047100
325      940 FORMAT(T24,'- ISOPENTANE PART',T46,F10.3,T59,F5.1,T71,F5.1,T81,F9.00047200
325      14,T93,F6.4,T107,F6.4)                  00047300
326      WRITE(6,941)Q1VAPW,P2INW,T2INW,M2INW,S2INW,V2INW 00047400
327      941 FORMAT(T24,'- STEAM PART',T46,F10.3,T59,F5.1,T71,F5.1,T81,F9.4,T9300047500
327      1,F6.4,T107,F6.4)                      00047600
328      WRITE(6,1019)Q1VAPN,P2INN,T2IN           00047601
329      1019 FORMAT(T24,'- NONCONDENSABLES',T46,F10.3,T59,F5.1,T71,F5.1/) 00047602
330      IF(N2-1)35,36,36                        00047700
331      35 WRITE(6,996)                          00047800
332      996 FORMAT(T46,'NOTE : STEAM ENTERING TURBINE IS DRY SATURATED.') 00047900
333      GO TO 37                                00048000
334      36 WRITE(6,997)                          00048100
335      997 FORMAT(T46,'NOTE : STEAM ENTERING TURBINE IS SUPERHEATED.') 00048200
336      37 IF(N2A-1)38,39,39                    00048300
337      38 WRITE(6,998)                          00048400
338      998 FORMAT(T53,'ISOPENTANE ENTERING TURBINE IS DRY SATURATED.') 00048500
339      GO TO 40                                00048600
340      39 WRITE(6,999)                          00048700
341      999 FORMAT(T53,'ISOPENTANE ENTERING TURBINE IS SUPERHEATED.') 00048800
342      40 CONTINUE                             00048900
343      WRITE(6,942)Q1VAP,P2OUT,T2OUT,M2OUT       00049000
344      942 FORMAT(T6,'VAPOR MIXTURE OUT - TOTAL',T46,F10.3,T59,F5.1,T71,F5.1,00049100
344      1T81,F9.4,T96,'-',T110,'-')             00049200
345      WRITE(6,940)Q1VAPI,P2OUTI,T2OUTI,M2OUTI,S2OUTI,V2OUTI 00049300
346      WRITE(6,941)Q1VAPW,P2OUTW,T2OUTW,M2OUTW,S2OUTW,V2OUTW 00049400
347      WRITE(6,1019)Q1VAPN,P2OUTN,T2OUT         00049401
348      IF(N3-1)41,42,42                        00049500
349      41 WRITE(6,1000)                         00049600
350      1000 FORMAT(T46,'NOTE : STEAM EXITING TURBINE IS DRY SATURATED.') 00049700
351      GO TO 43                                00049800
352      42 WRITE(6,1001)                         00049900
353      1001 FORMAT(T46,'NOTE : STEAM EXITING TURBINE IS SUPERHEATED.') 00050000
354      43 IF(N3A-1)44,45,45                    00050100
355      44 WRITE(6,1002)                         00050200
356      1002 FORMAT(T53,'ISOPENTANE EXITING TURBINE IS DRY SATURATED.') 00050300
357      GO TO 46                                00050400
358      45 WRITE(6,1003)                         00050500

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359 1003 FORMAT(T53,'ISOPENTANE EXITING TURBINE IS SUPERHEATED.'/) 00050600
360 46 CONTINUE 00050700
361 WRITE(6,943) 00050800
362 943 FORMAT(T6,'EXIT CONDITIONS FOR ISENTROPIC EXPANSION OF VAPOR- ') 00050900
363 IF(X=100.) 987,986,986 00051000
364 986 WRITE(6,948) 00051100
365 988 FORMAT(T6,'STEAM IS SUPERHEATED') 00051200
366 GO TO 989 00051300
367 987 WRITE(6,944)X 00051400
368 944 FORMAT(T6,'STEAM IS SATURATED. QUALITY = ',F6.2,' %') 00051500
369 989 WRITE(6,942)Q1VAP,P2OUT,T2ISEN,H2ISEN 00051600
370 WRITE(6,940)Q1VAPI,P1SENI,T2ISEN,H1SENI,S1SENI,V1SENI 00051700
371 WRITE(6,945)Q1VAPM,P1SENM,T2ISENM,H1SENM,S1SENM,V1SENM 00051800
372 945 FORMAT(T24,'- STEAM PART-TOT',T46,F10.3,T59,F5.1,T71,F5.1,T81,F9.4, 00051900
1,T93,F6.4,T105,F8.4) 00052000
373 IF(X=100.) 990,991,991 00052100
374 990 WRITE(6,946)HISENV,SISENV,VISENV 00052200
375 946 FORMAT(T36,'-VAP',T50,'-',T61,'-',T73,'-',T81,F9.4,T93,F6.4,T105,F 00052300
18.4) 00052400
376 WRITE(6,947)HISENL,SISENL,VISENL 00052500
377 947 FORMAT(T36,'-LIQ',T50,'-',T61,'-',T73,'-',T81,F9.4,T93,F6.4,T107,F 00052600
16.4) 00052700
378 991 WRITE(6,1019)Q1VAPN,P2OUTN,T2ISEN 00052701
379 WRITE(6,948) 00052800
380 948 FORMAT(T51,34('')) 00052900
381 WRITE(6,950) 00053000
382 950 FORMAT(T51,'* TURBINE PERFORMANCE ANALYSIS *') 00053100
383 WRITE(6,948) 00053200
384 WRITE(6,951) 00053300
385 951 FORMAT(/T31,'GROSS GENERATION',T49,'AUXILIARY LOAD',T65,'NET GENER 00053400
1ATION',T81,'POWER FACTOR',T95,'VAPOR RATE') 00053500
386 WRITE(6,952) 00053600
387 952 FORMAT(T37,'KWH',T54,'KWH',T70,'KWH',T95,'LHM/NET KWH/') 00053700
388 WRITE(6,953)GROSSK,AUXK,NET,PF,SR 00053800
389 953 FORMAT(T36,F5.1,T53,F5.1,T69,F5.1,T84,F5.2,T96,F7.2//) 00053900
390 WRITE(6,954)PDROPI 00054000
391 954 FORMAT(T6,'PRESSURE DROP FROM BOILER TO TURBINE INLET = ',F4.2,' P 00054100
1SIA.') 00054200
392 WRITE(6,1015)TDROPI 00054201
393 1015 FORMAT(T6,'TEMPERATURE DROP FROM BOILER TO TURBINE INLET = ',F5.2, 00054202
1' F') 00054203
394 WRITE(6,955)MDROPA,MDROPS 00054300
395 955 FORMAT(T6,'ENTHALPY DROP THROUGH TURBINE - ACTUAL = ',F8.4,' BT 00054400
1U/LBM',/T36,'- ISENTROPIC =',F8.4,' BTU/LBM') 00054500
396 WRITE(6,956)TEFF 00054600
397 956 FORMAT(T6,'TURBINE EFFICIENCY =',F6.2,' %') 00054700
398 WRITE(6,957)EFFI 00054800
399 957 FORMAT(T26,F6.2,' % DUE TO EXPANSION OF ISOPENTANE FRACTION') 00054900
400 WRITE(6,958)EFFW 00055000
401 958 FORMAT(T26,F6.2,' % DUE TO EXPANSION OF STEAM FRACTION'//) 00055100
402 WRITE(6,959) 00055200
403 959 FORMAT(1H1,T44,47('')) 00055300
404 WRITE(6,960) 00055400
405 960 FORMAT(T44,'* DIRECT CONTACT CONDENSER PERFORMANCE DATA *') 00055500
406 WRITE(6,973) 00055600
407 WRITE(6,961) 00055700
408 961 FORMAT(/T63,'FLOW',T72,'PRESSURE',T82,'TEMPERATURE',T95,'ENTHALPY' 00055800
1,T106,'MASS FRACTION') 00055900
409 WRITE(6,962) 00056000
410 962 FORMAT(T62,'LHM/HR',T74,'PSIA',T84,'DEG. F',T96,'BTU/LBM',T112,'%' 00056100

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411 WRITE(6,963)Q1VAP,P3VAP,T2OUT,M3VAP 00056200
412 963 FORMAT(T18,'VAPOR MIXTURE IN - TOTAL',T60,F10.3,T73,F5.1,T85,F5.1,00056300
1T95,F9.4,T112,'-') 00056400
413 WRITE(6,964)Q1VAPI,P3VAPI,T2OUT,M3VAPI,C1A 00056500
414 964 FORMAT(T35,'- ISOPENTANE PART',T60,F10.3,T73,F5.1,T85,F5.1,T95,F9.4,00056600
14,T109,F7.4) 00056700
415 WRITE(6,965)Q1VAPW,P3VAPW,T2OUT,M3VAPW,C1 00056800
416 965 FORMAT(T35,'- STEAM PART',T60,F10.3,T73,F5.1,T85,F5.1,T95,F9.4,T1000057000
18,F8.4) 00057100
417 WRITE(6,1020)Q1VAPN,P3VAPN,T2OUT,C2 00057101
418 1020 FORMAT(T35,'- NONCONDENSABLES',T60,F10.3,T73,F5.1,T85,F5.1,T108,F800057102
1.4) 00057103
419 WRITE(6,966)Q1ISO,T3ISO,M3ISO 00057200
420 966 FORMAT(T18,'LIQUID ISOPENTANE OUT',T60,F10.3,T75,'-',T85,F5.1,T95,00057300
1F9.4,T112,'-') 00057400
421 WRITE(6,1017)Q1MUP,DBULB1,H1MUP 00057401
422 1017 FORMAT(T18,'ISOPENTANE MAKEUP IN',T60,F10.3,T75,'-',T85,F5.1,T95,F00057402
19.4,T112,'-') 00057403
423 WRITE(6,967)Q3IN,M3WI,T3WI,M3WI 00057500
424 967 FORMAT(T18,'CIRC WATER IN',T60,F10.3,T73,F5.1,T85,F5.1,T95,F9.4,T100057600
112,'-') 00057700
425 WRITE(6,968)Q3L,T3W0,M3L 00057800
426 968 FORMAT(T18,'CIRC WATER MIXTURE OUT - TOTAL',T60,F10.3,T75,'-',T85,00057900
1F5.1,T95,F9.4,T112,'-') 00058000
427 WRITE(6,969)Q3LI,T3W0,M3LI,C4 00058100
428 969 FORMAT(T41,'- ISOPENTANE PART',T60,F10.3,T75,'-',T85,F5.1,T95,F9.4,00058200
1,T109,F7.4) 00058300
429 WRITE(6,970)Q3LW,T3W0,M3LW,C4A 00058400
430 970 FORMAT(T41,'- CIRC WATER PART',T60,F10.3,T75,'-',T85,F5.1,T95,F9.4,00058500
1,T108,F8.4) 00058600
431 IF(N4-1)47,48,48 00058700
432 47 WRITE(6,1004) 00058800
433 1004 FORMAT(T60,'NOTE : STEAM ENTERING CONDENSER IS DRY SATURATED.') 00058900
434 GO TO 49 00059000
435 48 WRITE(6,1005) 00059100
436 1005 FORMAT(T60,'NOTE : STEAM ENTERING CONDENSER IS SUPERHEATED.') 00059200
437 49 IF(N4A-1)50,51,51 00059300
438 50 WRITE(6,1006) 00059400
439 1006 FORMAT(T67,'ISOPENTANE ENTERING CONDENSER IS DRY SATURATED.') 00059500
440 GO TO 52 00059600
441 51 WRITE(6,1007) 00059700
442 1007 FORMAT(T67,'ISOPENTANE ENTERING CONDENSER IS SUPERHEATED.') 00059800
443 52 CONTINUE 00059900
444 WRITE(6,971) 00060000
445 971 FORMAT(T42,51('')) 00060100
446 WRITE(6,972) 00060200
447 972 FORMAT(T42,'* DIRECT CONTACT CONDENSER PERFORMANCE ANALYSIS *') 00060300
448 WRITE(6,971) 00060400
449 973 FORMAT(T44,47('')) 00060500
450 WRITE(6,974) 00060600
451 974 FORMAT(/T75,'BASED ON CIRC WATER',2X,'BASED ON ISOPENTANE') 00060700
452 WRITE(6,975)HT3C,M3T3ISO 00060800
453 975 FORMAT(T20,'HEAT TRANSFER IN CONDENSER (MMBTU/HR)',T81,F7.5,T102,F00060900
17.5) 00061000
454 WRITE(6,976)U3CW,U3ISO 00061100
455 976 FORMAT(T20,'VOLUMETRIC HEAT TRANSFER COEFFICIENT (BTU/HR-FT3-F)',T00061200
182,F6.1,T103,F6.1) 00061300
456 WRITE(6,1016)SUBC3 00061301
457 1016 FORMAT(T20,'SUBCOOLING OF ISOPENTANE OUT = ',F4.1,' F') 00061302

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458      WRITE(6,977)PDROP2                                00061400
459      977 FORMAT(T20,'PRESSURE DROP FROM TURBINE EXHAUST TO CONDENSER = ',F4,00061500
        1.1,' PSIA'//)                                     00061600
460      WRITE(6,978)                                       00061700
461      978 FORMAT(T49,37('**'))                          00061800
462      WRITE(6,979)                                       00061900
463      979 FORMAT(T49,'* COOLING TOWER DATA AND ANALYSIS *') 00062000
464      WRITE(6,978)                                       00062100
465      WRITE(6,980)                                       00062200
466      980 FORMAT(/T54,'TEMP IN',T68,'TEMP OUT',T78,'TEMP DROP',T89,'APPROACH'00062300
        1')                                               00062400
467      WRITE(6,981)CTTIN,CTTOUT,CTDROP,CTAPP             00062500
468      981 FORMAT(T38,'CIRCULATING WATER',T60,F4.1,T70,F4.1,T80,F4.1,T91,F4.1)00062600
        1//                                              00062700
469      WRITE(6,982)CTLOAD                                00062800
470      982 FORMAT(T38,'COOLING TOWER HEAT LOAD = ',F7.5,' MMBTU/MH') 00062900
471      WRITE(6,1008)                                     00063000
472      1008 FORMAT(/T53,27('**'))                       00063100
473      WRITE(6,1009)                                     00063200
474      1009 FORMAT(T53,'* OVERALL PLANT SUMMARY *')      00063300
475      WRITE(6,1010)                                     00063400
476      1010 FORMAT(T53,27('**'))                         00063500
477      WRITE(6,1011)                                     00063600
478      1011 FORMAT(T82,'BASED ON')                       00063700
479      WRITE(6,1012)                                     00063800
480      1012 FORMAT(T71,'BRINE FLOW',T85,' ISOPENTANE FLOW') 00063900
481      WRITE(6,1013)GETAB,GETAI                          00064000
482      1013 FORMAT(T33,'OVERALL GROSS CYCLE EFFICIENCY (%)',T73,F8.4,T88,F8.4)00064100
483      WRITE(6,1014)ETAB,ETAI                           00064200
484      1014 FORMAT(T33,'OVERALL NET CYCLE EFFICIENCY (%)',T73,F8.4,T88,F8.4//)00064300
485      WRITE(6,1021)IC1,IC2,IC3,IC4,IC5,IC6,IC7,IC8     00064310
486      1021 FORMAT(T20,20A4)                             00064311
487      WRITE(6,983)                                       00064400
488      983 FORMAT(1H1,T50,'FINISHED'////)               00064500
489      STOP                                              00064600
490      END                                              00064700

491      REAL FUNCTION SSHV*(PSHV,TSHV)                    00064800
492      IMPLICIT REAL*8(A-H,O-Z)                          00064900
493      REAL*4 PSHV,TSHV                                  00065000
C*** FUNCTION SSHV(PSHV,TSHV) YIELDS ENTROPY OF SUPERHEATED ISOPENTANE 00065100
C*** AS A FUNCTION OF PRESSURE AND TEMPERATURE.          00065200
C      PSHV = PSIA, TSHV = DEGREES F.                    00065300
494      PI=PSHV                                           00065400
495      TI=TSHV                                           00065500
496      A=1.158877+.00077223*T1                          00065600
497      B=-.030535-.000008615*T1                        00065700
498      SSHV=A*(B*DLOG(PI))                               00065800
499      RETURN                                           00065900
500      END                                              00066000

501      REAL FUNCTION MSHV*(PSHV,TSHV)                    00066100
502      IMPLICIT REAL*8(A-H,O-Z)                          00066200
503      REAL*4 PSHV,TSHV                                  00066300
C*** FUNCTION MSHV(PSHV,TSHV) YIELDS ENTHALPY OF SUPERHEATED ISOPENTANE 00066400
C*** AS A FUNCTION OF PRESSURE AND TEMPERATURE.          00066500
C      PSHV = PSIA, TSHV = DEGREES F.                    00066600
504      PI=PSHV                                           00066700
505      TI=TSHV                                           00066800
506      A=380.8416+.421425*T1                            00066900

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507      H=.00000145*T1-.0004906          00067000
508      D=DABS(T1-120.)/57.2957795131    00067100
509      E=DCOS(D)                          00067200
510      C=1+((.88-E)/200.)                00067300
511      HSHV=A*C*DEXP(H*P1)-1000.         00067400
512      RETURN                              00067500
513      END                                00067600

514      REAL FUNCTION VSHV** (PSHV,TSHV)    00067700
515      IMPLICIT REAL*8(A-H,O-Z)            00067800
516      REAL*4 PSHV,TSHV                    00067900
C**** FUNCTION VSHV(PSHV,TSHV) YIELDS SPECIFIC VOLUME OF SUPERHEATED ISO
C**** TSHV = DEGREES F, PSHV = PSIA.        00068100
517      T1=TSHV                             00068200
518      P1=PSHV                             00068300
C**** DETERMINE WHICH CURVE FIT TO USE.    00068400
519      IF (T1-150.)1,1,2                   00068500
520      1 V1=((P1*.05463)-106.716469)/(1-1.340181*P1) 00068600
521      V2= (-45.565887-(.042392*P1))/(1-1.140752*P1) 00068700
522      VSHV=((T1-120.)/40.)*(V2-V1)+V1     00068800
523      GO TO 3                             00068900
524      2 V1=(1085.520852-(2.596808*P1))/(1+12.046124*P1) 00069000
525      V2=(1312.034919-(2.466776*P1))/(1+13.684444*P1) 00069100
526      VSHV=((T1-140.)/40.)*(V2-V1)+V1     00069200
527      3 RETURN                           00069300
528      END                                00069400

529      REAL FUNCTION TSHV** (SSHV,PSHV)    00069500
530      IMPLICIT REAL*8(A-H,O-Z)            00069600
531      REAL*4 SSHV,PSHV                    00069700
C**** FUNCTION TSHV(SSHV,PSHV) YIELDS TEMPERATURE OF SUPERHEATED
C**** ISOPENTANE, GIVEN ENTROPY AND PRESSURE. 00069800
C**** ASSUME TSHV = T1 = 100 F.           00069900
532      T1=100.                             00070000
533      S1=SSHV                              00070100
534      P1=PSHV                              00070200
535      2 A=1.158877+.00077223*T1          00070300
536      B=-.030535-.000008815*T1          00070400
537      S2=A*(B*DLOG(P1))                  00070500
538      DIFF=S2-S1                          00070600
539      DIFF=DABS(DIFF)                      00070700
540      IF (DIFF .LE. .0001) GO TO 1        00070800
541      IF (DIFF .LT. 0.) GO TO 3           00070900
542      T1=T1-.2                            00071000
543      GO TO 2                             00071100
544      3 T1=T1+.2                          00071200
545      GO TO 2                             00071300
546      1 TSHV=T1                           00071400
547      RETURN                              00071500
548      END                                00071600

549      REAL FUNCTION TSV** (PSL)           00071700
550      IMPLICIT REAL*8(A-H,O-Z)            00071800
551      REAL*4 PSL                          00071900
C**** FUNCTION TSV(PSL) YIELDS TEMPERATURE AS A FUNCTION OF PRESSURE FOR
C**** SATURATED ISOPENTANE.              00072000
C      TSV = DEGREES F, PSL = PSIA.        00072100
C      RANGE = .197 LE PSL LE 453.        00072200
552      P1=PSL                             00072300
553      P2=PSL**2                          00072400

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554      PJ=DLOG(P1)                                00072700
555      P4=USQRT(P1)                                00072800
C**** DETERMINE WHICH CURVE FIT RANGE TO USE.      00072900
556      IF(P1-.43+.11.1.2)                          00073000
557      2 IF(P1-1.63+.3.3.4)                        00073100
558      4 IF(P1-6.05+.5.5.6)                        00073200
559      6 IF(P1-28.80+.7.7.8)                        00073300
560      8 IF(P1-218.97+.9.9.10)                     00073400
C**** CURVE FITS FOR TSV = F(PSL).                00073500
561      1 TSV=-96.92259224+160.39129138*P1-120.44866200*P2 00073600
562      GO TO 12                                       00073700
563      3 TSV=-31.64877901+.5.7422593*P1+25.00900837*P3 00073800
564      GO TO 12                                       00073900
565      5 TSV=-28.78768152+.2.21655896*P1+30.78587033*P3 00074000
566      GO TO 12                                       00074100
567      7 TSV=-36.9733429+.78476020*P1+.40.02068337*P3 00074200
568      GO TO 12                                       00074300
569      9 TSV=-48.85441589+-.07635143*P1+11.51090826*P4+32.5169599*P3 00074400
570      GO TO 12                                       00074500
571      10 TSV=-158.33742927+.1018604*P1+77.20775356*P3 00074600
572      12 RETURN                                     00074700
573      END                                           00074800

574      REAL FUNCTION PSV*4(TSL)                     00074900
575      IMPLICIT REAL*8(A-M,O-Z)                     00075000
576      REAL*4 TSL                                    00075100
C**** FUNCTION PSV(TSL) YIELDS PRESSURE AS A FUNCTION OF TEMPERATURE FOR 00075200
C**** SATURATED ISOPENTANE.                         00075300
C      TSL = DEGREES F, PSV = PSIA.                  00075400
C      RANGE = -70 LE TSL LE 240.                   00075500
577      TR=TSL+.459.67                               00075600
578      T1=TSL                                        00075700
579      T2=TSL*TSL                                    00075800
580      T3=T2*TSL                                    00075900
581      T4=DLOG(TR)                                  00076000
C**** DETERMINE WHICH CURVE FIT RANGE TO USE.      00076100
582      IF(T1-40.)1.1.2                              00076200
583      2 IF(T1-80.)3.3.4                             00076300
584      4 IF(T1-120.)5.5.6                           00076400
585      6 IF(T1-160.)7.7.8                           00076500
C**** CURVE FITS FOR PSV = F(TSL).                 00076600
586      1 PSV=2.177618+.62165020-.01*T1+.72204880-.03*T2+.34348750-.05*T3 00076700
587      GO TO 9                                        00076800
588      3 PSV=DEXP(.47.18563-(8136.939/TR)-(4.68329*T4)) 00076900
589      GO TO 9                                        00077000
590      5 PSV=DEXP(.29.20941-(6825.564/TR)-(2.2121*T4)) 00077100
591      GO TO 9                                        00077200
592      7 PSV=DEXP(.19.93808-(6051.937/TR)-(.96463*T4)) 00077300
593      GO TO 9                                        00077400
594      8 PSV=-6.40200001+.25080952*T1-.00088036*T2+.00001021*T3 00077500
595      9 RETURN                                     00077600
596      END                                           00077700

597      REAL FUNCTION MSF*4(TSL)                     00077800
598      IMPLICIT REAL*8(A-M,O-Z)                     00077900
599      REAL*4 TSL                                    00078000
C**** FUNCTION MSF(TSL) YIELDS ENTHALPY OF SATURATED LIQUID ISOPENTANE 00078100
C**** AS A FUNCTION OF TEMPERATURE.                 00078200
C      TSL = DEGREES F,                               00078300
C      RANGE = -70 LE TSL LE 240.                   00078400

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600      T1=TSL                                00078500
601      T2=TSL*TSL                            00078600
602      T3=TSL*T2                            00078700
603      T4=TSL*T3                            00078800
C**** DETERMINE WHICH CURVE FIT RANGE TO USE AND DETERMINE CONSTANTS. 00078900
604      A=220.367*.55*T1-1000.                00079000
605      B=-.4896320D-01*T1+.3598351D-03*T2+.1430494D-05*T3+.3801643D-07*T4 00079100
        1.1.718605                            00079200
606      IF(T1-30.)1,1,2                        00079300
607      2 IF(T1-140.)3,3,4                      00079400
C**** CURVE FITS FOR MSF = F(TSL).              00079500
608      1 MSF=A*B                              00079600
609      GO TO 5                                00079700
610      3 MSF=A                                00079800
611      GO TO 5                                00079900
612      4 MSF=-779.1412698+.54276455*T1-.00004563*T2+.00000093*T3 00080000
613      5 RETURN                              00080100
614      END                                    00080200

615      REAL FUNCTION MSG*(TSV)                00080300
616      IMPLICIT REAL*8(A-H,O-Z)              00080400
617      REAL*4 TSV                            00080500
C**** FUNCTION MSG(TSV) YIELDS ENTHALPY OF DRY SATURATED VAPOR ISOPENTAN 00080600
C**** GIVEN TEMPERATURE.                      00080700
C      RANGE = -70 LE TSV LE 300 F            00080800
C      TSV = DEGREES F                        00080900
618      T1=TSV                                00081000
619      T2=TSV*TSV                            00081100
620      T3=T2*TSV                            00081200
C**** DETERMINE WHICH CURVE FIT RANGE TO USE. 00081300
621      IF(T1-100.)1,1,2                      00081400
622      2 IF(T1-260.)3,3,4                    00081500
C**** CURVE FITS FOR MSG = F(TSV).            00081600
623      1 MSG=-615.34871861+.33417283*T1+.00022227*T2-.00000041*T3 00081700
624      GO TO 5                                00081800
625      3 MSG=-614.29220779+.31136724*T1+.00037906*T2-.00000073*T3 00081900
626      GO TO 5                                00082000
627      4 MSG=-271.57936483-3.34576059*T1+.0133998*T2-.0000162*T3 00082100
628      5 RETURN                              00082200
629      END                                    00082300

C$OPTIONS NOWARN,NOLIST                        00000050

SENTRY

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 * GEOBER *
 * GEOTHERMAL BRINE ENERGY RECOVERY *
 * 100 KWH PILOT PLANT HEAT BALANCE *

 * ARKANSAS POWER & LIGHT COMPANY *
 * PLANT PERFORMANCE EVALUATION SECTION *

 TEST CONDITIONS -

	START	FINISH
DATE	7/22/80	
TIME	4:20 AM	5:00 AM
DRY BULB TEMPERATURE (F)	78.0	78.0
WET BULB TEMPERATURE (F)	77.0	75.0
BAROMETRIC PRESSURE (IN HG)	29.88	29.88

 * DIRECT CONTACT BOILER PERFORMANCE DATA *

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	MASS FRACTION %	SPECIFIC HEAT BTU/LBM-F	DENSITY LBM/FT3
BRINE IN	79413.000	55.0	203.0	-	-	0.7710	70.22
BRINE OUT	77756.500	-	157.8	-	-	-	-
ISOPENTANE IN	17500.000	74.7	96.9	-726.3213	-	-	-
VAPOR MIXTURE OUT - TOTAL	19156.450	53.0	159.0	-415.9812	-	-	-
- ISOPENTANE PART	17500.000	47.9	159.0	-557.4719	91.3530	-	-
- STEAM PART	1581.748	4.6	159.0	1129.7800	8.2570	-	-
- NONCONDENSABLES	74.709	0.4	159.0	-	0.3900	-	-

NOTE : STEAM EXITING BOILER IS DRY SATURATED.
 ISOPENTANE EXITING BOILER IS SUPERHEATED.

HEIGHT OF BRINE IN BOILER (INCHES) = 60.0

 * DIRECT CONTACT BOILER PERFORMANCE ANALYSIS *

	BRINE FLOW IN	BASED ON BRINE FLOW OUT	ISOPENTANE VAPOR
HEAT TRANSFER IN BOILER (MMBTU/HR)	2.76734	2.70961	4.54101
VOLUMETRIC HEAT TRANSFER COEFFICIENT (BTU/HR-FT3-F)	1215.6	1190.2	1994.6

 • TURBINE PERFORMANCE DATA •

		FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	ENTROPY BTU/LBM-R	SPECIFIC VOLUME FT ³ /LBM
VAPOR MIXTURE IN	-TOTAL	19156.450	51.0	159.0	-415.7727	-	-
	- ISOPENTANE PART	17500.000	45.9	159.0	-557.2437	1.1594	1.8189
	- STEAM PART	1581.748	4.6	159.0	1129.7800	1.8506	79.0356
	- NONCONDENSABLES	74.709	0.4	159.0			

NOTE : STEAM ENTERING TURBINE IS DRY SATURATED.
 ISOPENTANE ENTERING TURBINE IS SUPERHEATED.

VAPOR MIXTURE OUT	- TOTAL	19156.450	28.7	139.4	-422.4116	-	-
	- ISOPENTANE PART	17500.000	25.6	139.4	-563.7827	1.1635	3.2917
	- STEAM PART	1581.748	2.8	139.4	1121.7220	1.8907	124.7949
	- NONCONDENSABLES	74.709	0.2	139.4			

NOTE : STEAM EXITING TURBINE IS DRY SATURATED.
 ISOPENTANE EXITING TURBINE IS SUPERHEATED.

EXIT CONDITIONS FOR ISENTROPIC EXPANSION OF VAPOR-

STEAM IS SATURATED, QUALITY = 97.25 %

VAPOR MIXTURE OUT	- TOTAL	19156.450	28.7	133.9	-427.1885	-	-
	- ISOPENTANE PART	17500.000	26.0	133.9	-566.2800	1.1590	3.2059
	- STEAM PART-TOT	1581.748	2.5	133.9	1091.4990	1.8555	138.8454
	-VAP	-	-	-	1119.4300	1.9026	142.7648
	-L10	-	-	-	102.1497	0.1880	0.0163
	- NONCONDENSABLES	74.709	0.2	133.9			

 • TURBINE PERFORMANCE ANALYSIS •

GROSS GENERATION KWH	AUXILIARY LOAD KWH	NET GENERATION KWH	POWER FACTOR	VAPOR RATE LBM/NET KWH
18.3	55.3	-36.9	0.54	-518.86

PRESSURE DROP FROM BOILER TO TURBINE INLET = 2.00 PSIA.

TEMPERATURE DROP FROM BOILER TO TURBINE INLET = 0.00 F

ENTHALPY DROP THROUGH TURBINE - ACTUAL = 6.6389 BTU/LBM

- ISENTROPIC = 11.4158 BTU/LBM

TURBINE EFFICIENCY = 58.16 %

52.33 % DUE TO EXPANSION OF ISOPENTANE FRACTION

5.83 % DUE TO EXPANSION OF STEAM FRACTION

 * DIRECT CONTACT CONDENSER PERFORMANCE DATA *

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	MASS FRACTION %
VAPOR MIXTURE IN - TOTAL	19156.450	27.0	139.4	-422.2212	-
- ISOPENTANE PART	17500.000	23.9	139.4	-563.5742	91.3530
- STEAM PART	1581.748	2.8	139.4	1121.7220	8.2570
- NONCONDENSABLES	74.709	0.2	139.4		0.3900
LIQUID ISOPENTANE OUT	17500.000	-	95.3	-727.2014	-
ISOPENTANE MAKEUP IN	234.541	-	78.0	-736.7329	-
CIRC WATER IN	348236.300	39.3	85.1	53.4772	-
CIRC WATER MIXTURE OUT - TOTAL	350052.600	-	95.5	63.2716	-
- ISOPENTANE PART	234.541	-	95.5	-727.0913	0.0670
- CIRC WATER PART	349818.000	-	95.5	63.8015	99.9330

NOTE : STEAM ENTERING CONDENSER IS DRY SATURATED.
 ISOPENTANE ENTERING CONDENSER IS SUPERHEATED.

 * DIRECT CONTACT CONDENSER PERFORMANCE ANALYSIS *

	BASED ON CIRC WATER	BASED ON ISOPENTANE
HEAT TRANSFER IN CONDENSER (MMBTU/HR)	3.69619	4.53684
VOLUMETRIC HEAT TRANSFER COEFFICIENT (BTU/HR-FT ³ -F)	2267.0	2782.6

SUBCOOLING OF ISOPENTANE OUT = -0.5 F
 PRESSURE DROP FROM TURBINE EXHAUST TO CONDENSER = 1.7 PSIA

 * COOLING TOWER DATA AND ANALYSIS *

	TEMP IN	TEMP OUT	TEMP DROP	APPROACH
CIRCULATING WATER	95.5	85.1	10.5	8.1

COOLING TOWER HEAT LOAD = 3.61404 MMBTU/HR

 * OVERALL PLANT SUMMARY *

	BRINE FLOW	ISOPENTANE FLOW
OVERALL GROSS CYCLE EFFICIENCY (%)	2.2617	1.3783
OVERALL NET CYCLE EFFICIENCY (%)	-4.5531	-2.7747

THIS TESTING WAS DONE DURING THE EARLY MORNING SO AS TO BENEFIT FROM LOW WET AND DRY BULB AMBIENT TEMPERATURES. THE ELECTRICAL MEASUREMENTS WERE OBTAINED BY THE TIMED DISK CHECK METHOD. SAMPLE ANALYSES USED ARE ACTUAL, NOT ASSUMED. ISOPENTANE FLOW ASSUMED BECAUSE OF OSCILLATIONS IN MANOMETER ACROSS ORIFICE PLATE DUE TO ISOPENTANE PUMP CAVITATION.

APPROXIMATELY 10 INCH ISOPENTANE LOSS FROM STORAGE TANKS OVER 1.25 HR PERIOD.
 POWER FACTOR OF PLANT USAGE FROM GRID SYSTEM = .91 LAGGING.

APPENDIX 4 - COMPUTER HEAT BALANCE PROGRAM RESULTS USING AP&L DATA

 * GEUBER *
 * GEOTHERMAL BRINE ENERGY RECOVERY *
 * 100 KWH PILOT PLANT HEAT BALANCE *

 * ARKANSAS POWER & LIGHT COMPANY *
 * PLANT PERFORMANCE EVALUATION SECTION *

TEST CONDITIONS -

	START	FINISH
DATE	6/9/80	
TIME	12:20 PM	1:20 PM
DRY BULB TEMPERATURE (F)	76.0	80.0
WET BULB TEMPERATURE (F)	66.0	68.0
BAROMETRIC PRESSURE (IN HG)	30.04	30.04

 * DIRECT CONTACT BOILER PERFORMANCE DATA *

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	MASS FRACTION %	SPECIFIC HEAT BTU/LBM-F	DENSITY LBM/FT3
BRINE IN	86005.000	51.3	199.3	-	-	0.7706	70.31
BRINE OUT	84159.180	-	152.3	-	-	-	-
ISOPENTANE IN	19500.000	58.3	95.0	-727.3828	-	-	-
VAPOR MIXTURE OUT - TOTAL	21345.760	49.8	157.8	-416.2344	-	-	-
- ISOPENTANE PART	19500.000	44.8	157.8	-557.7034	91.3530	-	-
- STEAM PART	1762.519	4.5	157.8	1129.2710	8.2570	-	-
- NONCONDENSABLES	83.247	0.4	157.8	-	0.3900	-	-

NOTE : STEAM EXITING BOILER IS DRY SATURATED.
 ISOPENTANE EXITING BOILER IS SUPERHEATED.

HEIGHT OF BRINE IN BOILER (INCHES) = 60.0

 * DIRECT CONTACT BOILER PERFORMANCE ANALYSIS *

	BRINE FLOW IN	BASED ON BRINE FLOW OUT	ISOPENTANE VAPOR
HEAT TRANSFER IN BOILER (MMBTU/HR)	3.11476	3.04792	5.07747
VOLUMETRIC HEAT TRANSFER COEFFICIENT (BTU/HR-FT3-F)	1368.2	1338.8	2230.3

 * TURBINE PERFORMANCE DATA *

	FLOW LBM/HK	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	ENTROPY BTU/LBM-R	SPECIFIC VOLUME FT ³ /LBM
VAPOR MIXTURE IN - TOTAL	21345.760	47.5	156.3	-416.7063	-	-
- ISOPENTANE PART	14500.000	42.8	156.3	-558.1646	1.1597	1.4567
- STEAM PART	1762.519	4.3	156.3	1120.6600	1.8561	84.0947
- NONCONDENSABLES	83.247	0.4	156.3			

NOTE : STEAM ENTERING TURBINE IS DRY SATURATED.
 ISOPENTANE ENTERING TURBINE IS SUPERHEATED.

	FLOW LBM/HK	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	ENTROPY BTU/LBM-R	SPECIFIC VOLUME FT ³ /LBM
VAPOR MIXTURE OUT - TOTAL	21345.760	26.0	134.5	-424.3030	-	-
- ISOPENTANE PART	14500.000	23.3	134.5	-565.6687	1.1629	3.5950
- STEAM PART	1762.519	2.5	134.5	1119.6810	1.9013	140.6639
- NONCONDENSABLES	83.247	0.2	134.5			

NOTE : STEAM EXITING TURBINE IS DRY SATURATED.
 ISOPENTANE EXITING TURBINE IS SUPERHEATED.

EXIT CONDITIONS FOR ISENTROPIC EXPANSION OF VAPOR-
 STEAM IS SATURATED, QUALITY = 96.46 %

	FLOW LBM/HK	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	ENTROPY BTU/LBM-R	SPECIFIC VOLUME FT ³ /LBM
VAPOR MIXTURE OUT - TOTAL	21345.760	26.0	130.4	-428.6653	-	-
- ISOPENTANE PART	14500.000	23.5	130.4	-567.4885	1.1595	3.5259
- STEAM PART-TOT	1762.519	2.2	130.4	1086.9830	1.8576	150.8355
- VAP	-	-	-	1117.9870	1.9102	155.5669
- LIQ	-	-	-	98.7281	0.1824	0.0162
- NONCONDENSABLES	83.247	0.2	130.4			

 * TURBINE PERFORMANCE ANALYSIS *

GROSS GENERATION KWH	AUXILIARY LOAD KWH	NET GENERATION KWH	POWER FACTOR	VAPOR RATE LBM/NET KWH
16.8	53.3	-36.6	0.55	-583.54

PRESSURE DROP FROM BOILER TO TURBINE INLET = 2.25 PSIA.
 TEMPERATURE DROP FROM BOILER TO TURBINE INLET = 1.50 F
 ENTHALPY DROP THROUGH TURBINE - ACTUAL = 7.5967 BTU/LBM
 - ISENTROPIC = 11.9590 BTU/LBM

TURBINE EFFICIENCY = 63.52 %
 57.32 % DUE TO EXPANSION OF ISOPENTANE FRACTION
 6.20 % DUE TO EXPANSION OF STEAM FRACTION

 * DIRECT CONTACT CONDENSER PERFORMANCE DATA *

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	MASS FRACTION %
VAPOR MIXTURE IN - TOTAL	21345.760	25.0	134.5	-424.1868	-
- ISOPENTANE PART	19500.000	22.3	134.5	-565.5415	91.3530
- STEAM PART	1762.519	2.5	134.5	1119.6810	8.2570
- NONCONDENSABLES	83.247	0.2	134.5		0.3900
LIQUID ISOPENTANE OUT	19500.000	-	93.8	-728.0703	-
ISOPENTANE MAKEUP IN	203.865	-	76.0	-737.8328	-
CIRC WATER IN	302303.000	41.8	83.0	51.3574	-
CIRC WATER MIXTURE OUT - TOTAL	304269.500	-	94.8	62.5375	-
- ISOPENTANE PART	203.865	-	94.8	-727.5203	0.0670
- CIRC WATER PART	304065.600	-	94.8	63.0672	99.9330

NOTE : STEAM ENTERING CONDENSER IS DRY SATURATED.
 ISOPENTANE ENTERING CONDENSER IS SUPERHEATED.

 * DIRECT CONTACT CONDENSER PERFORMANCE ANALYSIS *

	BASED ON CIRC WATER	BASED ON ISOPENTANE
HEAT TRANSFER IN CONDENSER (MMBTU/HR)	3.65107	5.03161
VOLUMETRIC HEAT TRANSFER COEFFICIENT (BTU/HR-FT ³ -F)	2582.8	3559.5

SUBCOOLING OF ISOPENTANE OUT = 1.0 F
 PRESSURE DROP FROM TURBINE EXHAUST TO CONDENSER = 1.0 PSIA

 * COOLING TOWER DATA AND ANALYSIS *

	TEMP IN	TEMP OUT	TEMP DROP	APPROACH
CIRCULATING WATER	94.8	83.0	11.8	17.0

COOLING TOWER HEAT LOAD = 3.56294 MMBTU/HR

 * OVERALL PLANT SUMMARY *

	BRINE FLOW	ISOPENTANE FLOW
OVERALL GROSS CYCLE EFFICIENCY (%)	1.8352	1.1258
OVERALL NET CYCLE EFFICIENCY (%)	-4.0080	-2.4587

FLUID SAMPLES USED HEREIN ARE ASSUMED, BASED ON 7/22/80 SAMPLES.
 BOILER LMTD ASSUMED = 37 F; BRINE HEIGHT ASSUMED = 60 INCHES.
 CONDENSER H.T. VOLUME ALWAYS ASSUMED = 64 FT³.

 • GEOTHERMAL BRINE ENERGY RECOVERY •
 • 100 KWH PILOT PLANT HEAT BALANCE •

 • ARKANSAS POWER & LIGHT COMPANY •
 • PLANT PERFORMANCE EVALUATION SECTION •

TEST CONDITIONS -

	START	FINISH
DATE	6/9/80	
TIME	2:25 PM	3:00 PM
DRY BULB TEMPERATURE (F)	81.0	79.0
WET BULB TEMPERATURE (F)	69.0	67.0
BAROMETRIC PRESSURE (IN HG)	30.00	30.00

 • DIRECT CONTACT BOILER PERFORMANCE DATA •

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	MASS FRACTION %	SPECIFIC HEAT BTU/LBM-F	DENSITY LBM/FT3
BRINE IN	100323.800	52.7	201.0	-	-	0.7707	70.27
BRINE OUT	98430.620	-	151.0	-	-	-	-
ISOPENTANE IN	20000.000	59.7	91.3	-729.4014	-	-	-
VAPOR MIXTURE OUT - TOTAL	21893.090	51.1	156.7	-416.8838	-	-	-
- ISOPENTANE PART	20000.000	46.3	156.7	-558.3743	91.3530	-	-
- STEAM PART	1807.712	4.4	156.7	1128.8320	8.2570	-	-
- NONCONDENSABLES	85.382	0.4	156.7	-	0.3900	-	-

NOTE : STEAM EXITING BOILER IS DRY SATURATED.
 ISOPENTANE EXITING BOILER IS SUPERHEATED.

HEIGHT OF BRINE IN BOILER (INCHES) = 60.0

 • DIRECT CONTACT BOILER PERFORMANCE ANALYSIS •

	BRINE FLOW IN	BASED ON BRINE FLOW OUT	ISOPENTANE VAPOR
HEAT TRANSFER IN BOILER (MMBTU/HR)	3.86620	3.79324	5.23578
VOLUMETRIC HEAT TRANSFER COEFFICIENT (BTU/HR-FT3-F)	1698.2	1660.2	2299.8

 * TURBINE PERFORMANCE DATA *

		FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	ENTROPY BTU/LBM-R	SPECIFIC VOLUME FT ³ /LBM
VAPOR MIXTURE IN	-TOTAL	21893.090	49.4	155.7	-417.1812	-	-
	- ISOPENTANE PART	20000.000	44.7	155.7	-558.6828	1.1578	1.8606
	- STEAM PART	1807.712	4.3	155.7	1128.4240	1.8572	85.2097
	- NONCONDENSABLES	85.382	0.4	155.7			

NOTE : STEAM ENTERING TURBINE IS DRY SATURATED.
 ISOPENTANE ENTERING TURBINE IS SUPERHEATED.

VAPOR MIXTURE OUT	- TOTAL	21893.090	26.7	134.7	-424.3120	-	-
	- ISOPENTANE PART	20000.000	24.0	134.7	-565.6848	1.1621	3.4854
	- STEAM PART	1807.712	2.5	134.7	1119.7520	1.9009	140.0759
	- NONCONDENSABLES	85.382	0.2	134.7			

NOTE : STEAM EXITING TURBINE IS DRY SATURATED.
 ISOPENTANE EXITING TURBINE IS SUPERHEATED.

EXIT CONDITIONS FOR ISENTROPIC EXPANSION OF VAPOR-

STEAM IS SATURATED, QUALITY = 96.89 %

VAPOR MIXTURE OUT	- TOTAL	21893.090	26.7	129.4	-429.2869	-	-
	- ISOPENTANE PART	20000.000	24.3	129.4	-568.0664	1.1577	3.3997
	- STEAM PART-TOT	1807.712	2.2	129.4	1085.8500	1.8588	154.0800
	-VAP	-	-	-	1117.5340	1.9126	159.8456
	-LIQ	-	-	-	97.7137	0.1809	0.0162
	- NONCONDENSABLES	85.382	0.2	129.4			

 * TURBINE PERFORMANCE ANALYSIS *

GROSS GENERATION KWH	AUXILIARY LOAD KWH	NET GENERATION KWH	POWER FACTOR	VAPOR RATE LBM/NET KWH
23.0	53.3	-30.4	0.58	-720.88

PRESSURE DROP FROM BOILER TO TURBINE INLET = 1.66 PSIA.
 TEMPERATURE DROP FROM BOILER TO TURBINE INLET = 1.00 F
 ENTHALPY DROP THROUGH TURBINE - ACTUAL = 7.1309 BTU/LBM
 - ISENTROPIC = 12.1057 BTU/LBM

TURBINE EFFICIENCY = 58.90 %
 52.99 % DUE TO EXPANSION OF ISOPENTANE FRACTION
 5.91 % DUE TO EXPANSION OF STEAM FRACTION

 * DIRECT CONTACT CONDENSER PERFORMANCE DATA *

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	MASS FRACTION %
VAPOR MIXTURE IN - TOTAL	21893.090	26.1	134.7	-424.2341	-
- ISOPENTANE PART	20000.000	23.3	134.7	-565.5996	91.3530
- STEAM PART	1807.712	24.5	134.7	1114.7520	8.2570
- NONCONDENSABLES	85.382	0.2	134.7	-	0.3900
LIQUID ISOPENTANE OUT	20000.000	-	90.0	-730.1328	-
ISOPENTANE MAKEUP IN	231.446	-	81.0	-735.0828	-
CIRC WATER IN	343394.800	38.7	80.0	48.3961	-
CIRC WATER MIXTURE OUT - TOTAL	345434.000	-	90.0	57.8199	-
- ISOPENTANE PART	231.446	-	90.0	-730.1328	0.0670
- CIRC WATER PART	345202.500	-	90.0	58.3482	99.9330

NOTE : STEAM ENTERING CONDENSER IS DRY SATURATED.
 ISOPENTANE ENTERING CONDENSER IS SUPERHEATED.

 * DIRECT CONTACT CONDENSER PERFORMANCE ANALYSIS *

	BASED ON CIRC WATER	BASED ON ISOPENTANE
HEAT TRANSFER IN CONDENSER (MMBTU/HR)	3.52298	5.20938
VOLUMETRIC HEAT TRANSFER COEFFICIENT (BTU/HR-FT ³ -F)	1919.0	2837.6

SUBCOOLING OF ISOPENTANE OUT = -0.3 F
 PRESSURE DROP FROM TURBINE EXHAUST TO CONDENSER = 0.7 PSIA

 * COOLING TOWER DATA AND ANALYSIS *

	TEMP IN	TEMP OUT	TEMP DROP	APPROACH
CIRCULATING WATER	90.0	80.0	10.0	11.0

COOLING TOWER HEAT LOAD = 3.43780 MMBTU/HR

 * OVERALL PLANT SUMMARY *

	BRINE FLOW	ISOPENTANE FLOW
OVERALL GROSS CYCLE EFFICIENCY (%)	2.0267	1.4966
OVERALL NET CYCLE EFFICIENCY (%)	-2.6808	-1.9796

FLUID SAMPLES USED HEREIN ARE ASSUMED, BASED ON 7/22/80 SAMPLES.
 ISOPENTANE FLOW ASSUMED = 20000 LBM/HR (METER PEGGED OUT).
 BOILER LMTD ASSUMED = 37 F; BRINE HEIGHT ASSUMED = 60 INCHES.
 CONDENSER H.T. VOLUME ALWAYS ASSUMED = 64 FT³.

 * GEOMER *
 * GEOTHERMAL BRINE ENERGY RECOVERY *
 * 100 KWH PILOT PLANT HEAT BALANCE *

 * ARKANSAS POWER & LIGHT COMPANY *
 * PLANT PERFORMANCE EVALUATION SECTION *

 TEST CONDITIONS -

	START	FINISH
DATE	7/22/80	
TIME	3:45 AM	3:45 AM
DRY BULB TEMPERATURE (F)	78.0	78.0
WET BULB TEMPERATURE (F)	77.0	77.0
BAROMETRIC PRESSURE (IN HG)	29.88	29.88

 * DIRECT CONTACT BOILER PERFORMANCE DATA *

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	MASS FRACTION %	SPECIFIC HEAT BTU/LBM-F	DENSITY LBM/FT3
BRINE IN	81073.310	54.7	200.0	-	-	0.7711	70.19
BRINE OUT	79511.500	-	155.0	-	-	-	-
ISOPENTANE IN	16500.000	79.7	91.8	-729.1428	-	-	-
VAPOR MIXTURE OUT - TOTAL	18061.800	50.7	157.2	-416.5918	-	-	-
- ISOPENTANE PART	16500.000	45.8	157.2	-558.0742	91.3530	-	-
- STEAM PART	1491.362	4.4	157.2	1129.0480	8.2570	-	-
- NONCONDENSABLES	70.439	0.4	157.2	-	0.3900	-	-

NOTE : STEAM EXITING BOILER IS DRY SATURATED.
 ISOPENTANE EXITING BOILER IS SUPERHEATED.

HEIGHT OF BRINE IN BOILER (INCHES) = 60.0

 * DIRECT CONTACT BOILER PERFORMANCE ANALYSIS *

	BRINE FLOW IN	BASED ON BRINE FLOW OUT	ISOPENTANE VAPOR
HEAT TRANSFER IN BOILER (MMBTU/HR)	3.03814	2.97961	4.31973
VOLUMETRIC HEAT TRANSFER COEFFICIENT (BTU/HR-FT3-F)	1334.5	1308.8	1897.5

 * TURBINE PERFORMANCE DATA *

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	ENTROPY BTU/LBM-R	SPECIFIC VOLUME FT ³ /LBM
VAPOR MIXTURE IN - TOTAL	18061.800	48.7	157.2	-416.3813	-	-
- ISOPENTANE PART	16500.000	43.8	157.2	-557.8438	1.1596	1.9085
- STEAM PART	1491.362	4.4	157.2	1129.0480	1.8542	82.3058
- NONCONDENSABLES	70.439	0.4	157.2			

NOTE : STEAM ENTERING TURBINE IS DRY SATURATED.
 ISOPENTANE ENTERING TURBINE IS SUPERHEATED.

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	ENTROPY BTU/LBM-R	SPECIFIC VOLUME FT ³ /LBM
VAPOR MIXTURE OUT - TOTAL	18061.800	25.2	129.8	-426.2954	-	-
- ISOPENTANE PART	16500.000	22.8	129.8	-567.6719	1.1601	3.6475
- STEAM PART	1491.362	2.2	129.8	1117.7140	1.9116	158.1251
- NONCONDENSABLES	70.439	0.2	129.8			

NOTE : STEAM EXITING TURBINE IS DRY SATURATED.
 ISOPENTANE EXITING TURBINE IS SUPERHEATED.

EXIT CONDITIONS FOR ISENTROPIC EXPANSION OF VAPOR-
 STEAM IS SATURATED, QUALITY = 96.67 %

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	ENTROPY BTU/LBM-R	SPECIFIC VOLUME FT ³ /LBM
VAPOR MIXTURE OUT - TOTAL	18061.800	25.2	129.0	-429.4546	-	-
- ISOPENTANE PART	16500.000	22.8	129.0	-568.0293	1.1595	3.6339
- STEAM PART-TOT	1491.362	2.2	129.0	1083.4070	1.8557	155.9701
- VAP	-	-	-	1117.3780	1.9134	161.3431
- LIQ	-	-	-	97.3891	0.1798	0.0162
- NONCONDENSABLES	70.439	0.2	129.0			

 * TURBINE PERFORMANCE ANALYSIS *

GROSS GENERATION KWH	AUXILIARY LOAD KWH	NET GENERATION KWH	POWER FACTOR	VAPOR RATE LBM/NET KWH
26.9	57.0	-30.1	0.62	-601.06

PRESSURE DROP FROM BOILER TO TURBINE INLET = 2.00 PSIA.
 TEMPERATURE DROP FROM BOILER TO TURBINE INLET = -0.00 F
 ENTHALPY DROP THROUGH TURBINE - ACTUAL = 9.9141 BTU/LBM
 - ISENTROPIC = 13.0732 BTU/LBM

TURBINE EFFICIENCY = 75.83 %
 68.68 % DUE TO EXPANSION OF ISOPENTANE FRACTION
 7.16 % DUE TO EXPANSION OF STEAM FRACTION

 * DIRECT CONTACT CONDENSER PERFORMANCE DATA *

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LHM	MASS FRACTION %
VAPOR MIXTURE IN - TOTAL	18061.800	23.7	129.8	-426.1177	-
- ISOPENTANE PART	16500.000	21.3	129.8	-567.4773	91.3530
- STEAM PART	1491.362	2.2	129.8	1117.7140	8.2570
- NONCONDENSABLES	70.439	0.2	129.8	-	0.3900
LIQUID ISOPENTANE OUT	16500.000	-	92.8	-728.5928	-
ISOPENTANE MAKEUP IN	216.771	-	78.0	-736.7329	-
CIRC WATER IN	321822.300	39.7	84.4	52.7836	-
CIRC WATER MIXTURE OUT - TOTAL	323530.500	-	95.2	63.0098	-
- ISOPENTANE PART	216.771	-	95.2	-727.2729	0.0670
- CIRC WATER PART	323313.700	-	95.2	63.5397	99.9330

NOTE : STEAM ENTERING CONDENSER IS DRY SATURATED.
 ISOPENTANE ENTERING CONDENSER IS SUPERHEATED.

 * DIRECT CONTACT CONDENSER PERFORMANCE ANALYSIS *

	BASED ON CIRC WATER	BASED ON ISOPENTANE
HEAT TRANSFER IN CONDENSER (MMBTU/HR)	3.55630	4.23056
VOLUMETRIC HEAT TRANSFER COEFFICIENT (BTU/HR-FT ² -F)	3101.9	3690.0

SUBCOOLING OF ISOPENTANE OUT = 1.4 F
 PRESSURE DROP FROM TURBINE EXHAUST TO CONDENSER = 1.5 PSIA

 * COOLING TOWER DATA AND ANALYSIS *

	TEMP IN	TEMP OUT	TEMP DROP	APPROACH
CIRCULATING WATER	95.2	84.4	10.8	7.4

COOLING TOWER HEAT LOAD = 3.47991 MMBTU/HR

 * OVERALL PLANT SUMMARY *

	BRINE FLOW	ISOPENTANE FLOW
OVERALL GROSS CYCLE EFFICIENCY (%)	3.0273	2.1292
OVERALL NET CYCLE EFFICIENCY (%)	-3.3755	-2.3741

THIS TESTING WAS DONE DURING THE EARLY MORNING SO AS TO BENEFIT FROM LOW WET AND DRY BULB AMBIENT TEMPERATURES. THE ELECTRICAL MEASUREMENTS WERE OBTAINED BY THE TIMED DISK CHECK METHOD. SAMPLE ANALYSES USED ARE ACTUAL, NOT ASSUMED. ISOPENTANE FLOW ASSUMED BECAUSE OF OSCILLATIONS IN MANOMETER ACROSS ORIFICE PLATE DUE TO ISOPENTANE PUMP CAVITATION.

APPROXIMATELY 10 INCH ISOPENTANE LOSS FROM STORAGE TANKS OVER 1.25 HR PERIOD.
 POWER FACTOR OF PLANT USAGE FROM GRID SYSTEM = .31 LAGGING.

 * GLOMER *
 * GEOTHERMAL BRINE ENERGY RECOVERY *
 * 100 KWH PILOT PLANT HEAT BALANCE *

 * ARKANSAS POWER & LIGHT COMPANY *
 * PLANT PERFORMANCE EVALUATION SECTION *

 TEST CONDITIONS -

	START	FINISH
DATE	7/22/80	
TIME	4:20 AM	5:00 AM
DRY BULB TEMPERATURE (F)	78.0	78.0
WET BULB TEMPERATURE (F)	77.0	75.0
BAROMETRIC PRESSURE (IN HG)	29.88	29.88

 * DIRECT CONTACT BOILER PERFORMANCE DATA *

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	MASS FRACTION %	SPECIFIC HEAT BTU/LBM-F	DENSITY LBM/FT3
BRINE IN	79413.000	55.0	203.0	-	-	0.7710	70.22
BRINE OUT	77756.500	-	157.8	-	-	-	-
ISOPENTANE IN	17500.000	74.7	96.9	-726.3213	-	-	-
VAPOR MIXTURE OUT - TOTAL	19156.450	53.0	159.0	-415.9812	-	-	-
- ISOPENTANE PART	17500.000	47.9	159.0	-557.4719	91.3530	-	-
- STEAM PART	1581.748	4.6	159.0	1129.7800	8.2570	-	-
- NONCONDENSABLES	74.709	0.4	159.0	-	0.3900	-	-

NOTE : STEAM EXITING BOILER IS DRY SATURATED.
 ISOPENTANE EXITING BOILER IS SUPERHEATED.

HEIGHT OF BRINE IN BOILER (INCHES) = 60.0

 * DIRECT CONTACT BOILER PERFORMANCE ANALYSIS *

	BRINE FLOW IN	BASED ON BRINE FLOW OUT	ISOPENTANE VAPOR
HEAT TRANSFER IN BOILER (MMBTU/HR)	2.76734	2.70961	4.54101
VOLUMETRIC HEAT TRANSFER COEFFICIENT (BTU/HR-FT3-F)	1215.6	1190.2	1994.6

 * TURBINE PERFORMANCE DATA *

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	ENTROPY BTU/LBM-R	SPECIFIC VOLUME FT ³ /LBM
VAPOR MIXTURE IN - TOTAL	19156.450	51.0	159.0	-415.7727	-	-
- ISOPENTANE PART	17500.000	45.9	159.0	-557.2437	1.1594	1.8189
- STEAM PART	1581.748	4.6	159.0	1129.7800	1.8506	79.0356
- NONCONDENSABLES	74.709	0.4	159.0			

NOTE : STEAM ENTERING TURBINE IS DRY SATURATED.
 ISOPENTANE ENTERING TURBINE IS SUPERHEATED.

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	ENTROPY BTU/LBM-R	SPECIFIC VOLUME FT ³ /LBM
VAPOR MIXTURE OUT - TOTAL	19156.450	28.7	139.4	-422.4116	-	-
- ISOPENTANE PART	17500.000	25.6	139.4	-563.7827	1.1635	3.2917
- STEAM PART	1581.748	2.8	139.4	1121.7220	1.8907	124.7949
- NONCONDENSABLES	74.709	0.2	139.4			

NOTE : STEAM EXITING TURBINE IS DRY SATURATED.
 ISOPENTANE EXITING TURBINE IS SUPERHEATED.

EXIT CONDITIONS FOR ISENTROPIC EXPANSION OF VAPOR-
 STEAM IS SATURATED. QUALITY = 97.25 %

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	ENTROPY BTU/LBM-R	SPECIFIC VOLUME FT ³ /LBM
VAPOR MIXTURE OUT - TOTAL	19156.450	28.7	133.9	-427.1885	-	-
- ISOPENTANE PART	17500.000	26.0	133.9	-566.2800	1.1590	3.2059
- STEAM PART-TOT	1581.748	2.5	133.9	1091.4990	1.8555	138.8454
- VAP	-	-	-	1119.4300	1.9026	142.7646
- LIQ	-	-	-	102.1497	0.1880	0.0163
- NONCONDENSABLES	74.709	0.2	133.9			

 * TURBINE PERFORMANCE ANALYSIS *

GROSS GENERATION KWH	AUXILIARY LOAD KWH	NET GENERATION KWH	POWER FACTOR	VAPOR RATE LBM/NET KWH
18.3	55.3	-36.9	0.50	-518.86

PRESSURE DROP FROM BOILER TO TURBINE INLET = 2.00 PSIA.
 TEMPERATURE DROP FROM BOILER TO TURBINE INLET = 0.00 F
 ENTHALPY DROP THROUGH TURBINE - ACTUAL = 6.6389 BTU/LBM
 - ISENTROPIC = 11.4158 BTU/LBM

TURBINE EFFICIENCY = 58.16 %
 52.33 % DUE TO EXPANSION OF ISOPENTANE FRACTION
 5.83 % DUE TO EXPANSION OF STEAM FRACTION

 * DIRECT CONTACT CONDENSER PERFORMANCE DATA *

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	MASS FRACTION %
VAPOR MIXTURE IN - TOTAL	14156.450	27.0	139.4	-422.2212	-
- ISOPENTANE PART	17500.000	23.9	139.4	-563.5742	91.3530
- STEAM PART	1581.748	2.8	139.4	1121.7220	8.6570
- NONCONDENSABLES	74.709	0.2	139.4	-	0.3900
LIQUID ISOPENTANE OUT	17500.000	-	95.3	-727.2014	-
ISOPENTANE MAKEUP IN	234.541	-	78.0	-736.7329	-
CIRC WATER IN	348236.300	39.3	85.1	53.4772	-
CIRC WATER MIXTURE OUT - TOTAL	350052.600	-	95.5	63.2716	-
- ISOPENTANE PART	234.541	-	95.5	-727.0913	0.0670
- CIRC WATER PART	349818.000	-	95.5	63.8015	99.9330

NOTE : STEAM ENTERING CONDENSER IS DRY SATURATED.
 ISOPENTANE ENTERING CONDENSER IS SUPERHEATED.

 * DIRECT CONTACT CONDENSER PERFORMANCE ANALYSIS *

	BASED ON CIRC WATER	BASED ON ISOPENTANE
HEAT TRANSFER IN CONDENSER (MMBTU/HR)	3.64619	4.53684
VOLUMETRIC HEAT TRANSFER COEFFICIENT (BTU/HR-FT ² -F)	2267.0	2782.6

SUBCOOLING OF ISOPENTANE OUT = -0.5 F
 PRESSURE DROP FROM TURBINE EXHAUST TO CONDENSER = 1.7 PSIA

 * COOLING TOWER DATA AND ANALYSIS *

	TEMP IN	TEMP OUT	TEMP DROP	APPROACH
CIRCULATING WATER	95.5	85.1	10.5	8.1

COOLING TOWER HEAT LOAD = 3.61404 MMBTU/HR

 * OVERALL PLANT SUMMARY *

	BASED ON	
	BRINE FLOW	ISOPENTANE FLOW
OVERALL GROSS CYCLE EFFICIENCY (%)	2.2617	1.3783
OVERALL NET CYCLE EFFICIENCY (%)	-4.5531	-2.7747

THIS TESTING WAS DONE DURING THE EARLY MORNING SO AS TO BENEFIT FROM LOW WET AND DRY BULB AMBIENT TEMPERATURES. THE ELECTRICAL MEASUREMENTS WERE OBTAINED BY THE TIMED DISK CHECK METHOD. SAMPLE ANALYSES USED ARE ACTUAL, NOT ASSUMED. ISOPENTANE FLOW ASSUMED BECAUSE OF OSCILLATIONS IN MANOMETER ACROSS ORIFICE PLATE DUE TO ISOPENTANE PUMP CAVITATION.

APPROXIMATELY 10 INCH ISOPENTANE LOSS FROM STORAGE TANKS OVER 1.25 HR PERIOD.
 POWER FACTOR OF PLANT USAGE FROM GRID SYSTEM = .41 LAGGING.

 * GEOTHERMAL BRINE ENERGY RECOVERY *
 * 100 KWH PILOT PLANT HEAT BALANCE *

 * ARKANSAS POWER & LIGHT COMPANY *
 * PLANT PERFORMANCE EVALUATION SECTION *

TEST CONDITIONS -

	START	FINISH
DATE	8/27/80	
TIME	5:00 AM	6:15 AM
DRY BULB TEMPERATURE (F)	72.0	72.0
WET BULB TEMPERATURE (F)	69.0	69.0
BAROMETRIC PRESSURE (IN HG)	29.96	29.96

 * DIRECT CONTACT BOILER PERFORMANCE DATA *

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	MASS FRACTION %	SPECIFIC HEAT BTU/LBM-F	DENSITY LBM/FT3
BRINE IN	101341.600	58.7	204.0	-	-	0.7711	70.19
BRINE OUT	99815.930	-	155.0	-	-	-	-
ISOPENTANE IN	14809.390	84.7	86.8	-731.8928	-	-	-
VAPOR MIXTURE OUT - TOTAL	16335.090	52.7	163.4	-435.9749	-	-	-
- ISOPENTANE PART	14809.390	43.6	163.4	-554.9048	90.6600	-	-
- STEAM PART	968.671	5.1	163.4	1131.5620	5.9300	-	-
- NONCONDENSABLES	557.024	4.0	163.4	-	3.4100	-	-

NOTE : STEAM EXITING BOILER IS DRY SATURATED.
 ISOPENTANE EXITING BOILER IS SUPERHEATED.

HEIGHT OF BRINE IN BOILER (INCHES) = 60.0

 * DIRECT CONTACT BOILER PERFORMANCE ANALYSIS *

	BRINE FLOW IN	BASED ON BRINE FLOW OUT	ISOPENTANE VAPOR
HEAT TRANSFER IN BOILER (MMBTU/HR)	3.82893	3.77128	3.58991
VOLUMETRIC HEAT TRANSFER COEFFICIENT (BTU/HR-FT3-F)	1681.9	1656.5	1576.9

 * TURBINE PERFORMANCE DATA *

		FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	ENTROPY BTU/LBM-R	SPECIFIC VOLUME FT ³ /LBM
VAPOR MIXTURE IN	- TOTAL	16335.090	51.7	163.4	-435.8801	-	-
	- ISOPENTANE PART	14809.390	42.7	163.4	-554.8003	1.1650	1.9912
	- STEAM PART	968.671	5.1	163.4	1131.5620	1.8421	1.6617
	- NONCONDENSABLES	557.024	3.9	163.4			

NOTE : STEAM ENTERING TURBINE IS DRY SATURATED.
 ISOPENTANE ENTERING TURBINE IS SUPERHEATED.

		FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	ENTROPY BTU/LBM-R	SPECIFIC VOLUME FT ³ /LBM
VAPOR MIXTURE OUT	- TOTAL	16335.090	25.7	131.6	-447.4565	-	-
	- ISOPENTANE PART	14809.390	21.5	131.6	-566.7131	1.1633	3.8899
	- STEAM PART	968.671	2.3	131.6	1118.4680	1.9077	151.1568
	- NONCONDENSABLES	557.024	1.9	131.6			

NOTE : STEAM EXITING TURBINE IS DRY SATURATED.
 ISOPENTANE EXITING TURBINE IS SUPERHEATED.

EXIT CONDITIONS FOR ISENTROPIC EXPANSION OF VAPOR-
 STEAM IS SATURATED. QUALITY = 96.73 %

		FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	ENTROPY BTU/LBM-R	SPECIFIC VOLUME FT ³ /LBM
VAPOR MIXTURE OUT	- TOTAL	16335.090	25.7	133.2	-448.7424	-	-
	- ISOPENTANE PART	14809.390	21.4	133.2	-565.9963	1.1647	3.9213
	- STEAM PART-TOT	968.671	2.4	133.2	1085.8280	1.8479	140.5071
	- VAP	-	-	-	1119.1380	1.9041	145.2622
	- LIQ	-	-	-	101.6625	0.1873	0.0163
	- NONCONDENSABLES	557.024	1.9	133.2			

 * TURBINE PERFORMANCE ANALYSIS *

GROSS GENERATION KWH	AUXILIARY LOAD KWH	NET GENERATION KWH	POWER FACTOR	VAPOR RATE LBM/NET KWH
23.4	49.3	-25.9	0.56	-630.92

PRESSURE DROP FROM BOILER TO TURBINE INLET = 1.00 PSIA.
 TEMPERATURE DROP FROM BOILER TO TURBINE INLET = 0.00 F
 ENTHALPY DROP THROUGH TURBINE - ACTUAL = 11.5764 BTU/LBM
 - ISENTROPIC = 12.8623 BTU/LBM

TURBINE EFFICIENCY = 90.00 %
 83.97 % DUE TO EXPANSION OF ISOPENTANE FRACTION
 6.04 % DUE TO EXPANSION OF STEAM FRACTION

 * DIRECT CONTACT CONDENSER PERFORMANCE DATA *

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	MASS FRACTION %
VAPOR MIXTURE IN - TOTAL	16335.090	23.7	131.6	-447.2388	-
- ISOPENTANE PART	14809.390	19.6	131.6	-566.4729	90.6600
- STEAM PART	968.671	2.3	131.6	1118.4680	5.9300
- NONCONDENSABLES	557.029	1.8	131.6		3.4100
LIQUID ISOPENTANE OUT	14809.390	-	89.8	-730.2429	-
ISOPENTANE MAKEUP IN	60.277	-	72.0	-740.0330	-
CIRC WATER IN	272883.800	34.7	79.2	47.6064	-
CIRC WATER MIXTURE OUT - TOTAL	273912.800	-	92.2	60.3601	-
- ISOPENTANE PART	60.277	-	92.2	-728.9229	0.0220
- CIRC WATER PART	273852.500	-	92.2	60.5338	99.9780

NOTE : STEAM ENTERING CONDENSER IS DRY SATURATED.
 ISOPENTANE ENTERING CONDENSER IS SUPERHEATED.

 * DIRECT CONTACT CONDENSER PERFORMANCE ANALYSIS *

	BASED ON CIRC WATER	BASED ON ISOPENTANE
HEAT TRANSFER IN CONDENSER (MMBTU/HR)	3.58633	3.45013
VOLUMETRIC HEAT TRANSFER COEFFICIENT (BTU/HR-FT ³ -F)	2545.5	2448.8

SUBCOOLING OF ISOPENTANE OUT = -0.4 F
 PRESSURE DROP FROM TURBINE EXHAUST TO CONDENSER = 2.0 PSIA

 * COOLING TOWER DATA AND ANALYSIS *

	TEMP IN	TEMP OUT	TEMP DROP	APPROACH
CIRCULATING WATER	92.2	79.2	13.0	10.2

COOLING TOWER HEAT LOAD = 3.54100 MMBTU/HR

 * OVERALL PLANT SUMMARY *

	BASED ON	
	BRINE FLOW	ISOPENTANE FLOW
OVERALL GROSS CYCLE EFFICIENCY (%)	2.0883	2.2274
OVERALL NET CYCLE EFFICIENCY (%)	-2.3077	-2.4613

BRINE SYSTEM ON @ 5:00 AM. UNIT ON LINE @ 6:00 AM.
 ISOPENTANE FLOW CALCULATED FROM U-TUBE DIFFERENTIAL MANOMETER ACROSS ORIFICE.
 ALL SAMPLES ARE ACTUAL.
 ELECTRICAL MEASUREMENTS MADE BY TIMED DISK CHECK.
 BOILER LMTD ASSUMED = 37 F. BRINE HEIGHT ASSUMED = 60 INCHES.
 CONDENSER H.T. VOLUME ASSUMED = 64 FT³.
 POWER FACTOR OF PLANT USAGE FROM GRID = .29 LAGGING.

 • GEOTHER •
 • GEOTHERMAL BRINE ENERGY RECOVERY •
 • 100 KWH PILOT PLANT HEAT BALANCE •

 • ARKANSAS POWER & LIGHT COMPANY •
 • PLANT PERFORMANCE EVALUATION SECTION •

 TEST CONDITIONS -

	START	FINISH
DATE	8/27/80	
TIME	6:15 AM	6:35 AM
DRY BULB TEMPERATURE (F)	72.0	74.5
WET BULB TEMPERATURE (F)	69.0	71.0
BAROMETRIC PRESSURE (IN HG)	29.96	29.96

 • DIRECT CONTACT BOILER PERFORMANCE DATA •

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	MASS FRACTION %	SPECIFIC HEAT BTU/LBM-F	DENSITY LBM/FT3
BRINE IN	104734.800	58.7	203.6	-	-	0.7710	70.20
BRINE OUT	103996.900	-	158.4	-	-	-	-
ISOPENTANE IN	15696.500	86.7	102.0	-723.5330	-	-	-
VAPOR MIXTURE OUT - TOTAL	16434.400	52.7	164.2	-490.1749	-	-	-
- ISOPENTANE PART	15696.500	46.2	164.2	-554.8208	95.5100	-	-
- STEAM PART	576.847	5.2	164.2	1131.8860	3.5100	-	-
- NONCONDENSABLES	161.055	1.2	164.2	-	0.9800	-	-

NOTE : STEAM EXITING BOILER IS DRY SATURATED.
 ISOPENTANE EXITING BOILER IS SUPERHEATED.

HEIGHT OF BRINE IN BOILER (INCHES) = 60.0

 • DIRECT CONTACT BOILER PERFORMANCE ANALYSIS •

	BRINE FLOW IN	BASED ON BRINE FLOW OUT	ISOPENTANE VAPOR
HEAT TRANSFER IN BOILER (MMBTU/HR)	3.65005	3.62433	3.22486
VOLUMETRIC HEAT TRANSFER COEFFICIENT (BTU/HR-FT3-F)	1603.3	1592.0	1416.5

 • TURBINE PERFORMANCE DATA •

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	ENTROPY BTU/LBM-R	SPECIFIC VOLUME FT ³ /LBM
VAPOR MIXTURE IN - TOTAL	16434.400	47.4	164.2	-489.6240	-	-
- ISOPENTANE PART	15696.500	41.1	164.2	-554.2388	1.1669	2.0817
- STEAM PART	576.847	5.2	164.2	1131.8860	1.8405	70.4088
- NONCONDENSABLES	161.055	1.1	164.2			

NOTE : STEAM ENTERING TURBINE IS DRY SATURATED.
 ISOPENTANE ENTERING TURBINE IS SUPERHEATED.

VAPOR MIXTURE OUT - TOTAL	16434.400	25.7	141.0	-497.9768	-	-
- ISOPENTANE PART	15696.500	22.1	141.0	-562.6353	1.1693	3.8361
- STEAM PART	576.847	3.0	141.0	1122.3870	1.8873	120.0699
- NONCONDENSABLES	161.055	0.6	141.0			

NOTE : STEAM EXITING TURBINE IS DRY SATURATED.
 ISOPENTANE EXITING TURBINE IS SUPERHEATED.

EXIT CONDITIONS FOR ISENTROPIC EXPANSION OF VAPOR-
 STEAM IS SATURATED. QUALITY = 97.50 %

VAPOR MIXTURE OUT - TOTAL	16434.400	25.7	137.6	-500.3923	-	-
- ISOPENTANE PART	15696.500	22.4	137.6	-564.1809	1.1664	3.7667
- STEAM PART-TOT	576.847	2.7	137.6	1095.6280	1.8521	127.1157
-VAP	-	-	-	1120.9740	1.8946	130.3710
-LIQ	-	-	-	106.0767	0.1946	0.0163
- NONCONDENSABLES	161.055	0.6	137.6			

 • TURBINE PERFORMANCE ANALYSIS •

GHOSSE GENERATION KWH	AUXILIARY LOAD KWH	NET GENERATION KWH	POWER FACTOR	VAPOR RATE LBM/NET KWH
26.7	47.6	-20.9	0.62	-784.83

PRESSURE DROP FROM BOILER TO TURBINE INLET = 5.30 PSIA.
 TEMPERATURE DROP FROM BOILER TO TURBINE INLET = 0.00 F
 ENTHALPY DROP THROUGH TURBINE - ACTUAL = 8.3528 BTU/LBM
 - ISENTROPIC = 10.7683 BTU/LBM

TURBINE EFFICIENCY = 77.57 %
 74.47 % DUE TO EXPANSION OF ISOPENTANE FRACTION
 3.10 % DUE TO EXPANSION OF STEAM FRACTION

 * DIRECT CONTACT CONDENSER PERFORMANCE DATA *

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	MASS FRACTION %
VAPOR MIXTURE IN - TOTAL	16434.400	24.2	141.0	-497.8018	-
- ISOPENTANE PART	15696.500	20.7	141.0	-562.4519	95.5100
- STEAM PART	576.847	3.0	141.0	1122.3870	3.5100
- NONCONDENSABLES	161.055	0.6	141.0	-	0.9800
LIQUID ISOPENTANE OUT	15696.500	-	100.8	-724.1929	-
ISOPENTANE MAKEUP IN	55.785	-	72.0	-740.0330	-
CIRC WATER IN	252864.600	34.7	86.6	54.9397	-
CIRC WATER MIXTURE OUT - TOTAL	253497.300	-	102.0	70.2122	-
- ISOPENTANE PART	55.785	-	102.0	-723.5330	0.0220
- CIRC WATER PART	253441.500	-	102.0	70.3869	99.9780

NOTE : STEAM ENTERING CONDENSER IS DRY SATURATED.
 ISOPENTANE ENTERING CONDENSER IS SUPERHEATED.

 * DIRECT CONTACT CONDENSER PERFORMANCE ANALYSIS *

	BASED ON CIRC WATER	BASED ON ISOPENTANE
HEAT TRANSFER IN CONDENSER (MMBTU/HR)	3.94666	3.14561
VOLUMETRIC HEAT TRANSFER COEFFICIENT (BTU/HR-FT ² -F)	4442.0	3540.4

SUBCOOLING OF ISOPENTANE OUT = 0.2 F
 PRESSURE DROP FROM TURBINE EXHAUST TO CONDENSER = 1.5 PSIA

 * COOLING TOWER DATA AND ANALYSIS *

	TEMP IN	TEMP OUT	TEMP DROP	APPROACH
CIRCULATING WATER	102.0	86.6	15.4	17.6

COOLING TOWER HEAT LOAD = 3.91583 MMBTU/HR

 * OVERALL PLANT SUMMARY *

	BRINE FLOW	ISOPENTANE FLOW
OVERALL GROSS CYCLE EFFICIENCY (%)	2.4955	2.8245
OVERALL NET CYCLE EFFICIENCY (%)	-1.9579	-2.2160

BRINE SYSTEM ON @ 5:00 AM. UNIT ON LINE @ 6:00 AM.
 ISOPENTANE FLOW CALCULATED FROM U-TUBE DIFFERENTIAL MANOMETER ACROSS ORIFICE.
 ALL SAMPLES ARE ACTUAL. VAPOR SAMPLE @ 7:00 AM. CIRC WATER @ 6:25 AM.
 ELECTRICAL MEASUREMENTS MADE BY TIMED DISK CHECK.
 BOILER LMTD ASSUMED = 37 F. BRINE HEIGHT ASSUMED = 60 INCHES.
 CONDENSER H.T. VOLUME ASSUMED = 64 FT³.
 POWER FACTOR OF PLANT USAGE FROM GRID = .227 LAGGING.
 UNIT TRIPPED @ 6:37 AM. IMMEDIATE RESTART.

 * GEOTHER *
 * GEOTHERMAL BRINE ENERGY RECOVERY *
 * 100 KWH PILOT PLANT HEAT BALANCE *

 * ARKANSAS POWER & LIGHT COMPANY *
 * PLANT PERFORMANCE EVALUATION SECTION *

 TEST CONDITIONS -

	START	FINISH
DATE	8/27/80	
TIME	6:35 AM	7:05 AM
DRY BULB TEMPERATURE (F)	74.5	74.5
WET BULB TEMPERATURE (F)	71.0	71.0
BAROMETRIC PRESSURE (IN HG)	30.00	30.00

 * DIRECT CONTACT BOILER PERFORMANCE DATA *

	FLOW LBM/HK	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	MASS FRACTION %	SPECIFIC HEAT BTU/LBM-F	DENSITY LBM/FT3
BRINE IN	106393.300	58.7	204.4	-	-	0.7711	70.18
BRINE OUT	105533.500	-	158.6	-	-	-	-
ISOPENTANE IN	17226.000	86.7	93.8	-728.0430	-	-	-
VAPOR MIXTURE OUT - TOTAL	18035.800	50.7	170.0	-487.1831	-	-	-
- ISOPENTANE PART	17226.000	43.5	170.0	-551.7688	95.5100	-	-
- STEAM PART	633.057	6.0	170.0	1134.2170	3.5100	-	-
- NONCONDENSABLES	176.748	1.2	170.0	-	0.9800	-	-

NOTE : STEAM EXITING BOILER IS DRY SATURATED.
 ISOPENTANE EXITING BOILER IS SUPERHEATED.

HEIGHT OF BRINE IN BOILER (INCHES) = 60.0

 * DIRECT CONTACT BOILER PERFORMANCE ANALYSIS *

	BRINE FLOW IN	BASED ON BRINE FLOW OUT	ISOPENTANE VAPOR
HEAT TRANSFER IN BOILER (MMBTU/HK)	3.75748	3.72888	3.66716
VOLUMETRIC HEAT TRANSFER COEFFICIENT (BTU/HK-FT3-F)	1650.5	1637.9	1610.8

 * TURBINE PERFORMANCE DATA *

		FLOW LBM/HH	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	ENTROPY BTU/LBM-R	SPECIFIC VOLUME FT ³ /LBM
VAPOR MIXTURE IN	- TOTAL	18035.800	47.7	159.4	-491.9412	-	-
	- ISOPENTANE PART	17226.000	41.9	159.4	-556.5935	1.1626	2.0135
	- STEAM PART	633.057	47.7	159.4	1129.9420	1.8498	78.3302
	- NONCONDENSABLES	176.748	1.1	159.4			

NOTE : STEAM ENTERING TURBINE IS DRY SATURATED.
 ISOPENTANE ENTERING TURBINE IS SUPERHEATED.

VAPOR MIXTURE OUT	- TOTAL	18035.800	25.7	136.4	-500.0410	-	-
	- ISOPENTANE PART	17226.000	22.5	136.4	-564.7263	1.1654	3.7400
	- STEAM PART	633.057	2.6	136.4	1120.4740	1.8972	134.2479
	- NONCONDENSABLES	176.748	0.6	136.4			

NOTE : STEAM EXITING TURBINE IS DRY SATURATED.
 ISOPENTANE EXITING TURBINE IS SUPERHEATED.

EXIT CONDITIONS FOR ISENTHROPIC EXPANSION OF VAPOR-
 STEAM IS SATURATED, QUALITY = 97.14 %

VAPOR MIXTURE OUT	- TOTAL	18035.800	25.7	132.8	-502.6465	-	-
	- ISOPENTANE PART	17226.000	22.7	132.8	-566.3491	1.1624	3.6731
	- STEAM PART-TOT	633.057	2.4	132.8	1090.4060	1.8568	142.8939
	-VAP	-	-	-	1118.9700	1.9050	146.7104
	-LIQ	-	-	-	101.0668	0.1864	0.0163
	- NONCONDENSABLES	176.748	0.6	132.8			

 * TURBINE PERFORMANCE ANALYSIS *

GROSS GENERATION KWH	AUXILIARY LOAD KWH	NET GENERATION KWH	POWER FACTOR	VAPOR RATE LBM/NET KWH
25.9	56.5	-30.6	0.80	-588.64

PRESSURE DROP FROM BOILER TO TURBINE INLET = 3.00 PSIA.
 TEMPERATURE DROP FROM BOILER TO TURBINE INLET = 10.60 F
 ENTHALPY DROP THROUGH TURBINE - ACTUAL = 8.0999 BTU/LBM
 - ISENTHROPIC = 10.7053 BTU/LBM

TURBINE EFFICIENCY = 75.66 %
 72.56 % DUE TO EXPANSION OF ISOPENTANE FRACTION
 3.10 % DUE TO EXPANSION OF STEAM FRACTION

 * DIRECT CONTACT CONDENSER PERFORMANCE DATA *

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	MASS FRACTION %
VAPOR MIXTURE IN - TOTAL	18035.800	24.7	136.4	-499.9221	-
- ISOPENTANE PART	17226.000	21.5	136.4	-564.6016	95.5100
- STEAM PART	633.057	2.6	136.4	1120.4740	3.5100
- NONCONDENSABLES	176.748	0.6	136.4	-	0.9800
LIQUID ISOPENTANE OUT	17226.000	-	91.4	-729.3628	-
ISOPENTANE MAKEUP IN	66.447	-	74.5	-731.6580	-
CIRC WATER IN	288033.800	42.7	82.2	50.5336	-
CIRC WATER MIXTURE OUT - TOTAL	288733.300	-	94.4	62.4871	-
- ISOPENTANE PART	66.447	-	94.4	-727.7129	0.0230
- CIRC WATER PART	288666.800	-	94.4	62.6690	99.9770

NOTE : STEAM ENTERING CONDENSER IS DRY SATURATED.
 ISOPENTANE ENTERING CONDENSER IS SUPERHEATED.

 * DIRECT CONTACT CONDENSER PERFORMANCE ANALYSIS *

	BASED ON CIRC WATER	BASED ON ISOPENTANE
HEAT TRANSFER IN CONDENSER (MMBTU/HR)	3.53506	3.50782
VOLUMETRIC HEAT TRANSFER COEFFICIENT (BTU/HR-FT ³ -F)	2513.7	2494.3

SUBCOOLING OF ISOPENTANE OUT = -1.2 F
 PRESSURE DROP FROM TURBINE EXHAUST TO CONDENSER = 1.0 PSIA

 * COOLING TOWER DATA AND ANALYSIS *

	TEMP IN	TEMP OUT	TEMP DROP	APPROACH
CIRCULATING WATER	94.4	82.2	12.2	11.2

COOLING TOWER HEAT LOAD = 3,50389 MMBTU/HR

 * OVERALL PLANT SUMMARY *

	BASED ON	
	BRINE FLOW	ISOPENTANE FLOW
OVERALL GROSS CYCLE EFFICIENCY (%)	2.3524	2.4103
OVERALL NET CYCLE EFFICIENCY (%)	-2.7829	-2.8514

BRINE SYSTEM ON @ 5:00 AM. UNIT ON LINE @ 6:00 AM.
 ISOPENTANE FLOW CALCULATED FROM U-TUBE DIFFERENTIAL MANOMETER ACROSS ORIFICE.
 ALL SAMPLES ARE ACTUAL.
 ELECTRICAL MEASUREMENTS MADE BY TIMED DISK CHECK.
 BOILER LMTD ASSUMED = 37 F. BRINE HEIGHT ASSUMED = 60 INCHES.
 CONDENSER H.T. VOLUME ASSUMED = 64 FT³.
 POWER FACTOR OF PLANT USAGE FROM GRID = .33% LAGGING.
 UNIT TRIPPED @ 6:37 AM. IMMEDIATE RESTART.

 * GLODER *
 * GEOTHERMAL BRINE ENERGY RECOVERY *
 * 100 KWH PILOT PLANT HEAT BALANCE *

 * ARKANSAS POWER & LIGHT COMPANY *
 * PLANT PERFORMANCE EVALUATION SECTION *

TEST CONDITIONS -

	START	FINISH
DATE	8/27/80	
TIME	7:05 AM	7:30 AM
DRY BULB TEMPERATURE (F)	74.5	75.0
WET BULB TEMPERATURE (F)	71.0	71.0
BAROMETRIC PRESSURE (IN HG)	30.02	30.02

 * DIRECT CONTACT BOILER PERFORMANCE DATA *

	FLOW LHM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LHM	MASS FRACTION %	SPECIFIC HEAT BTU/LHM-F	DENSITY LHM/FT3
BRINE IN	103045.600	57.7	203.6	-	-	0.7710	70.20
BRINE OUT	102335.300	-	159.2	-	-	-	-
ISOPENTANE IN	17500.000	74.7	97.4	-726.0630	-	-	-
VAPOR MIXTURE OUT - TOTAL	10210.190	52.7	161.0	-496.4194	-	-	-
- ISOPENTANE PART	17500.000	47.2	161.0	-556.4482	96.1000	-	-
- STEAM PART	617.325	4.9	161.0	1130.5910	3.3900	-	-
- NONCONDENSABLES	92.870	0.7	161.0	-	0.5100	-	-

NOTE : STEAM EXITING BOILER IS DRY SATURATED.
 ISOPENTANE EXITING BOILER IS SUPERHEATED.

HEIGHT OF BRINE IN BOILER (INCHES) = 60.0

 * DIRECT CONTACT BOILER PERFORMANCE ANALYSIS *

	BRINE FLOW IN	BASED ON BRINE FLOW OUT	ISOPENTANE VAPOR
HEAT TRANSFER IN BOILER (MMBTU/HR)	3.52761	3.50330	3.58657
VOLUMETRIC HEAT TRANSFER COEFFICIENT (BTU/HR-FT3-F)	1549.5	1538.8	1575.4

 * TURBINE PERFORMANCE DATA *

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	ENTROPY BTU/LBM-R	SPECIFIC VOLUME FT ³ /LBM
VAPOR MIXTURE IN - TOTAL	18210.190	47.7	161.8	-495.4954	-	-
- ISOPENTANE PART	17500.000	42.2	161.8	-555.4980	1.1642	2.0097
- STEAM PART	617.325	4.9	161.8	1130.9150	1.8452	74.2464
- NONCONDENSABLES	92.870	0.6	161.8			

NOTE : STEAM ENTERING TURBINE IS DRY SATURATED.
 ISOPENTANE ENTERING TURBINE IS SUPERHEATED.

VAPOR MIXTURE OUT - TOTAL	18210.190	28.0	143.6	-501.7734	-	-
- ISOPENTANE PART	17500.000	24.5	143.6	-561.7681	1.1680	3.4679
- STEAM PART	617.325	3.2	143.6	1123.4640	1.8819	112.8290
- NONCONDENSABLES	92.870	0.3	143.6			

NOTE : STEAM EXITING TURBINE IS DRY SATURATED.
 ISOPENTANE EXITING TURBINE IS SUPERHEATED.

EXIT CONDITIONS FOR ISENTROPIC EXPANSION OF VAPOR-

STEAM IS SATURATED, QUALITY = 97.90 %

VAPOR MIXTURE OUT - TOTAL	18210.190	28.0	138.6	-504.7644	-	-
- ISOPENTANE PART	17500.000	24.9	138.6	-564.0544	1.1638	3.3793
- STEAM PART-TOT	617.325	2.8	138.6	1100.0510	1.8568	124.5621
- VAP	-	-	-	1121.3900	1.8925	127.2385
- LIQ	-	-	-	107.0487	0.1963	0.0163
- NONCONDENSABLES	92.870	0.3	138.6			

 * TURBINE PERFORMANCE ANALYSIS *

GROSS GENERATION KWH	AUXILIARY LOAD KWH	NET GENERATION KWH	POWER FACTOR	VAPOR RATE LBM/NET KWH
24.9	57.1	-32.1	0.54	-566.94

PRESSURE DROP FROM BOILER TO TURBINE INLET = 5.00 PSIA.

TEMPERATURE DROP FROM BOILER TO TURBINE INLET = -0.80 F

ENTHALPY DROP THROUGH TURBINE - ACTUAL = 6.2761 BTU/LBM

- ISENTROPIC = 9.2690 BTU/LBM

TURBINE EFFICIENCY = 67.73 %

65.01 % DUE TO EXPANSION OF ISOPENTANE FRACTION

2.73 % DUE TO EXPANSION OF STEAM FRACTION

 * DIRECT CONTACT CONDENSER PERFORMANCE DATA *

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	MASS FRACTION %
VAPOR MIXTURE IN - TOTAL	18210.190	20.2	143.6	-501.5620	-
- ISOPENTANE PART	17500.000	22.8	143.6	-561.5479	96.1000
- STEAM PART	617.325	3.2	143.6	1123.4640	3.3900
- NONCONDENSABLES	92.870	0.3	143.6	-	0.5100
LIQUID ISOPENTANE OUT	17500.000	-	95.8	-726.9429	-
ISOPENTANE MAKEUP IN	66.416	-	74.5	-738.6580	-
CIRC WATER IN	287914.300	42.7	84.4	52.7836	-
CIRC WATER MIXTURE OUT - TOTAL	288598.100	-	96.8	64.9478	-
- ISOPENTANE PART	66.416	-	96.8	-726.3928	0.0230
- CIRC WATER PART	288531.600	-	96.8	65.1300	99.9770

NOTE : STEAM ENTERING CONDENSER IS DRY SATURATED.
 ISOPENTANE ENTERING CONDENSER IS SUPERHEATED.

 * DIRECT CONTACT CONDENSER PERFORMANCE ANALYSIS *

	BASED ON CIRC WATER	BASED ON ISOPENTANE
HEAT TRANSFER IN CONDENSER (MMBTU/HR)	3.59488	3.54775
VOLUMETRIC HEAT TRANSFER COEFFICIENT (BTU/HR-FT ² -F)	2416.7	2385.0

SUBCOOLING OF ISOPENTANE OUT = -1.6 F
 PRESSURE DROP FROM TURBINE EXHAUST TO CONDENSER = 1.8 PSIA

 * COOLING TOWER DATA AND ANALYSIS *

	TEMP IN	TEMP OUT	TEMP DROP	APPROACH
CIRCULATING WATER	96.8	84.4	12.4	13.4

COOLING TOWER HEAT LOAD = 3.56312 MMBTU/HR

 * OVERALL PLANT SUMMARY *

	BASED ON	
	BRINE FLOW	ISOPENTANE FLOW
OVERALL GROSS CYCLE EFFICIENCY (%)	2.4118	2.3722
OVERALL NET CYCLE EFFICIENCY (%)	-3.1074	-3.0563

BRINE SYSTEM ON @ 5:00 AM. UNIT ON LINE @ 6:00 AM.
 ISOPENTANE FLOW CALCULATED FROM U-TUBE DIFFERENTIAL MANOMETER ACROSS ORIFICE.
 ALL SAMPLES ARE ACTUAL.
 ELECTRICAL MEASUREMENTS MADE BY TIMEU DISK CHECK.
 BOILER LMTD ASSUMED = 37 F. BRINE HEIGHT ASSUMED = 60 INCHES.
 CONDENSER H.T. VOLUME ASSUMED = 6% FT³.
 POWER FACTOR OF PLANT USAGE FROM GRID = .312 LAGGING.
 UNIT TRIPPED AFTER 7:05 AM READINGS. IMMEDIATE RESTART.

 * GEOTHERMAL BRINE ENERGY RECOVERY *
 * 100 KWH PILOT PLANT HEAT BALANCE *

 * ARKANSAS POWER & LIGHT COMPANY *
 * PLANT PERFORMANCE EVALUATION SECTION *

 TEST CONDITIONS -

	START	FINISH
DATE	8/27/80	
TIME	8:40 PM	9:30 PM
DRY BULB TEMPERATURE (F)	79.0	79.0
WET BULB TEMPERATURE (F)	71.0	71.0
BAROMETRIC PRESSURE (IN HG)	29.98	29.98

 * DIRECT CONTACT BOILER PERFORMANCE DATA *

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	MASS FRACTION %	SPECIFIC HEAT BTU/LBM-F	DENSITY LBM/FT3
BRINE IN	94633.370	56.7	202.6	-	-	0.7709	70.23
BRINE OUT	92963.880	-	153.6	-	-	-	-
ISOPENTANE IN	17500.000	84.7	92.4	-728.8130	-	-	-
VAPOR MIXTURE OUT - TOTAL	19169.070	49.7	156.6	-441.6279	-	-	-
- ISOPENTANE PART	17500.000	42.4	156.6	-557.9541	91.2900	-	-
- STEAM PART	1150.180	4.4	156.6	1128.8030	6.0000	-	-
- NONCONDENSABLES	519.495	3.0	156.6	-	2.7100	-	-

NOTE : STEAM EXITING BOILER IS DRY SATURATED.
 ISOPENTANE EXITING BOILER IS SUPERHEATED.

HEIGHT OF BRINE IN BOILER (INCHES) = 60.0

 * DIRECT CONTACT BOILER PERFORMANCE ANALYSIS *

	BRINE FLOW IN	BASED ON BRINE FLOW OUT	ISOPENTANE VAPOR
HEAT TRANSFER IN BOILER (MMBTU/HR)	3.57477	3.51170	4.14504
VOLUMETRIC HEAT TRANSFER COEFFICIENT (BTU/HR-FT3-F)	1570.2	1542.5	1820.7

 * TURBINE PERFORMANCE DATA *

	FLOW LBM/HR	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	ENTROPY BTU/LBM-R	SPECIFIC VOLUME FT ³ /LBM
VAPOR MIXTURE IN - TOTAL	19169.670	45.7	156.6	-441.2278	-	-
- ISOPENTANE PART	17500.000	38.6	156.6	-557.5159	1.1632	2.1906
- STEAM PART	1150.190	4.4	156.6	1128.8030	1.8554	83.4308
- NONCONDENSABLES	519.495	7.7	156.6			

NOTE : STEAM ENTERING TURBINE IS DRY SATURATED.
 ISOPENTANE ENTERING TURBINE IS SUPERHEATED.

VAPOR MIXTURE OUT - TOTAL	19169.670	20.7	128.0	-451.2832	-	-
- ISOPENTANE PART	17500.000	17.4	128.0	-567.7522	1.1673	4.8204
- STEAM PART	1150.180	2.1	128.0	1116.9590	1.9157	165.4666
- NONCONDENSABLES	519.495	1.2	128.0			

NOTE : STEAM EXITING TURBINE IS DRY SATURATED.
 ISOPENTANE EXITING TURBINE IS SUPERHEATED.

EXIT CONDITIONS FOR ISENTROPIC EXPANSION OF VAPOR-
 STEAM IS SATURATED. QUALITY = 95.83 %

VAPOR MIXTURE OUT - TOTAL	19169.670	20.7	123.3	-455.8562	-	-
- ISOPENTANE PART	17500.000	17.6	123.3	-569.8240	1.1634	4.7048
- STEAM PART-TOT	1150.180	1.9	123.3	1072.2630	1.8530	178.7929
- VAP	-	-	-	1114.9790	1.9263	186.5812
- LIQ	-	-	-	91.7372	0.1703	0.0162
- NONCONDENSABLES	519.495	1.2	123.3			

 * TURBINE PERFORMANCE ANALYSIS *

GROSS GENERATION KWH	AUXILIARY LOAD KWH	NET GENERATION KWH	POWER FACTOR	VAPOR RATE LBM/NET KWH
36.7	58.0	-21.3	0.74	-902.10

PRESSURE DROP FROM BOILER TO TURBINE INLET = 4.00 PSIA.
 TEMPERATURE DROP FROM BOILER TO TURBINE INLET = -0.00 F
 ENTHALPY DROP THROUGH TURBINE - ACTUAL = 10.0554 BTU/LBM
 - ISENTROPIC = 14.6284 BTU/LBM

TURBINE EFFICIENCY = 68.74 %
 63.88 % DUE TO EXPANSION OF ISOPENTANE FRACTION
 4.86 % DUE TO EXPANSION OF STEAM FRACTION

 * DIRECT CONTACT CONDENSER PERFORMANCE DATA *

	FLOW LBM/MH	PRESSURE PSIA	TEMPERATURE DEG. F	ENTHALPY BTU/LBM	MASS FRACTION %
VAPOR MIXTURE IN - TOTAL	19169.670	19.7	128.0	-451.1702	-
- ISOPENTANE PART	17500.000	16.4	128.0	-567.6282	91.2900
- STEAM PART	1150.180	2.1	128.0	1116.9590	6.0000
- NONCONDENSABLES	519.495	1.2	128.0		2.7100
LIQUID ISOPENTANE OUT	17500.000	-	92.2	-728.9229	-
ISOPENTANE MAKEUP IN	95.656	-	79.0	-736.1829	-
CIRC WATER IN	317429.200	39.7	81.4	49.7920	-
CIRC WATER MIXTURE OUT - TOTAL	318675.100	-	93.2	61.2307	-
- ISOPENTANE PART	95.656	-	93.2	-728.3728	0.0300
- CIRC WATER PART	318579.400	-	93.2	61.4678	99.9700

NOTE : STEAM ENTERING CONDENSER IS DRY SATURATED.
 ISOPENTANE ENTERING CONDENSER IS SUPERHEATED.

 * DIRECT CONTACT CONDENSER PERFORMANCE ANALYSIS *

	BASED ON CIRC WATER	BASED ON ISOPENTANE
HEAT TRANSFER IN CONDENSER (MMBTU/MH)	3.77694	4.03666
VOLUMETRIC HEAT TRANSFER COEFFICIENT (BTU/MH-FT ³ -F)	6321.6	6756.3

SUBCOOLING OF ISOPENTANE OUT = -0.4 F
 PRESSURE DROP FROM TURBINE EXHAUST TO CONDENSER = 1.0 PSIA

 * COOLING TOWER DATA AND ANALYSIS *

	TEMP IN	TEMP OUT	TEMP DROP	APPROACH
CIRCULATING WATER	93.2	81.4	11.8	10.4

COOLING TOWER HEAT LOAD = 3.72079 MMBTU/MH

 * OVERALL PLANT SUMMARY *

	BRINE FLOW	ISOPENTANE FLOW
OVERALL GROSS CYCLE EFFICIENCY (%)	3.5056	3.0233
OVERALL NET CYCLE EFFICIENCY (%)	-2.0287	-1.7496

BRINE SYSTEM STARTED @ 8:40 PM UNIT ON LINE @ 9:15 PM.
 ISOPENTANE FLOW ASSUMED DUE TO FLUCTUATION IN READINGS AT METER.
 VAPOR SAMPLE USED IS FROM 10:00 PM. CIRC WATER IS FROM 9:30 PM.

APPENDIX 5 - FLUID SAMPLE ANALYSES

FLUID SAMPLE ANALYSES IN MASS PERCENTS

GEOBER PROJECT

DATE & TIME

7/22/80	7/22/80	8/27/80	8/27/80	8/27/80	8/27/80	8/27/80	8/27/80
3:45 am	5:00 am	6:25 am	7:00 am	7:30 am	9:30 pm	10:00 pm	10:30 pm

Vapor To Turbine

Components

N ₂	55.895%	.288%	2.96%	.7718%	.2539%	4.66	2.005%	.4809%
O ₂	9.234	.0938	.252	.1295	.0737	1.56	.665	.035
CO ₂	.013	.0081	.2003	.0822	.1825	.0498	.0369	.0618
H ₂ O	3.080	8.257	5.93	3.51	3.39	17.95	5.995	3.89
C ₅ H ₁₂	31.778	91.353	90.66	95.5	96.1	75.78	91.298	95.54
Unknowns	-	.0001	-	-	-	-	-	-
Comments	Probable	Good	Good	Good	Good	Probable	Good	Good
	air leak					air leak		
	in bomb.					in bomb.		

FLUID SAMPLE ANALYSES IN MASS PERCENTS

GEOBER PROJECT

DATE & TIME

7/22/80	7/22/80	8/27/80	8/27/80	8/27/80	8/27/80	8/27/80	8/27/80
3:45 am	5:00 am	6:25 am	7:00 am	7:30 am	9:30 pm	10:00 pm	10:30 pm

Condenser Vapor

Components

N ₂	24.335%	38.130%	53.78%	73.51%	67.22%	73.63%	58.94%	44.58%
O ₂	9.571	15.001	18.37	24.13	22.24	24.46	19.58	15.75
CO ₂	.820	.456	.1819	.0618	.0441	.0614	.0549	.3757
H ₂ O	3.616	3.022	1.74	2.29	2.37	1.698	2.56	2.74
C ₅ H ₁₂	61.658	43.388	25.93	0	8.13	.1511	18.87	36.55
Unknowns	-	.003	-	-	-	-	-	-
Comments	Good	Good	Good	Probable	Good	Probable	Good	Good
				air leak		air leak		
				in bag.		in bag.		

FLUID SAMPLE ANALYSES IN MASS PERCENTS

GEOBER PROJECT

DATE & TIME

7/22/80	7/22/80	8/27/80	8/27/80	8/27/80	8/27/80	8/27/80	8/27/80	8/27/80
3:45 am	5:00 am	6:25 am	7:00 am	7:30 am	9:30 pm	10:00 pm	10:30 pm	

Brine Out Boiler

Components

C_5H_{12}	.0043%	.0140%	.000772%	.00206%	.00101%	.001%	.000537%	.00117%
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Comments	Good	Good	Good	Good	Good	Good	Good	Good
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FLUID SAMPLE ANALYSES IN MASS PERCENTS

GEOBER PROJECT

DATE & TIME

7/22/80	7/22/80	8/27/80	8/27/80	8/27/80	8/27/80	8/27/80	8/27/80
3:45 am	5:00 am	6:25 am	7:00 am	7:30 am	9:30 pm	10:00 pm	10:30 pm

Circ Water to C.T.

Components

C ₅ H ₁₂	.0615%	.0726%	.0222%	-	.0228%	.0266%	.0208%	.0211%
Chlorides	-	-	.00396%	-	.00396%	.0198%	.0222%	.0198%
Comments	Good	Good	Good	Bad	Good	Good	Good	Good

Valve

On

Sample

Bomb

APPENDIX 6 - PROJECT PHOTOGRAPHS

NO SMOKING

GEOHERMAL BRINE ENERGY RECOVERY PROJECT

SPONSORED BY:

- ★ **ARKANSAS POWER & LIGHT COMPANY**
- ★ **GREAT LAKES CHEMICAL COMPANY**
- ★ **UNITED STATES DEPARTMENT OF ENERGY**

DESIGNED AND BUILT BY:

**DAEDALEAN ASSOCIATES INC.
WOODBINE, MARYLAND**

BALTIMORE AIRCOIL
EJECTOR COOLING TOWER

GREAT LAKES CHEMICAL CORP.
BROMINE EXTRACTION PLANT OFFICE BLD

SAFETY FLARE

ROTOFLOW SINGLE STAGE
RADIAL-INFLOW TURBINE

100 KW AIR-COOLED
INDUCTION GENERATOR

DIRECT CONTACT BOILER

100 KW GEOBER PILOT PLANT

A black and white photograph showing a large, dark, cylindrical storage tank for an isopentane makeup system. The tank is situated in an industrial setting, with various pipes, valves, and structural elements visible. A large, light-colored, curved structure, possibly a pipe or a part of a larger tank, is visible in the foreground on the left. The background shows a complex network of pipes and structural supports. The overall scene is industrial and technical.

ISOPENTANE MAKEUP SYSTEM STORAGE TANKS

LIQUID NITROGEN STORAGE TANK

APPENDIX 7 - ORIGINAL DATA SHEETS

R

D. WALL

DATE: 6-9-80 3:51 AM SHUT-DOWN 7:31:15 PM

TIME	ARKANSAS	12:10	12:20	12:40	12:55	1:20	2:05	2:25	2:45	3:00	
T DRY BULB.	75	76	76	77	78	80	80	81	79	79	
E WET BULB	64	66	66	66	67	68	69	69	68	67	
M IP TO BLR	81	84	73	96	7	93	99	94	90	90	
P BRINE IN	201	200	199	199	199	201	201	200	201	202	
E BRINE OUT	161	154	156	152	157	152	148	154	151	154	
R BOILER OUTLET	181	173	172	170	173	168	167	168	167	172	
A TURBINE INLET	167	156	156	155	160	154	153	155	155	157	
T TURBINE EXHAUST	156	134	135	131	141	131	129	134	135	135	
U CIRC WATER IN	75	76	82	83	84	83	82	82	79	79	
R CIRC WATER OUT	84	85	93	95	76	95	94	92	89	89	
E IP FROM COND	81	83	92	95	95	93	93	92	87	89	
/ COND VAPOR	87	85	91	76	95	97	93	92	89	88	
F LUBE OIL	92	99	112	120	110	109	107	112	113	114	
P BOILER	7	34	31	34	36	36	36	36	27	36	
R BRINE IN	16	35	36	36	27	37	36	38	38	38	
E IP TO BOILER	60	42	56	45	35	38	60	55	40	40	
S TURBINE INLET	14	32	33	32	33	33	34	35	35	34	
S TURBINE EXHAUST	8	10	12	10	12	11	10	12	12	12	
U CONDENSER SHELL	7	9	10	7	12	10	9	11	12	11	
R CIRC WATER IN	27	27	26	26	28	28	27	29	24	24	
E CIRC WATER OUT	64	66	67	63	66	67	64	61	62	63	
P BACKWHEEL	9	14	14	13	15	15	14	15	15	14	
S SEAL GAS	21	16	18	17	19	19	19	20	20	19	
G LUBE OIL	146	110	138	136	132	137	137	137	136	136	
F ISOPENTANE	16/HR	3500	2400	1750	1750	1900	20500	*	*	*	
L BRINE	GPM	165	129	132	138	168	172	171	178	178	
O CIRC WATER	GPM	620	610	600	620	570	635	610	590	690	
W SEAL GAS	SCFM	20	20	20	20	20	20	20	20	20	
E GROSS GEN.	KW	6.4	20.8	18.3	10.6	19.2	12.8	35.5	24.0	24.0	20.2
L AUX. USAGE	KW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E APPARENT FWR	KVA	053	051	054	054	054	051	055	055	055	055
C POWER FACTOR		1.64	1.58	1.54	1.61	1.50	1.55	1.66	1.61	1.54	1.60
T GEN. VOLTAGE	VOLTS	475	480	477	477	477	478	475	470	480	480
C STEAM IN VAPOR	W/O										
O IP IN BRINE OUT	W/O										
N IP IN CW OUT	W/O										
C IP IN COND VAPOR	W/O										
BAROMETER	MMHG	763	763	763	763	763	762	762	762	762	

7:15 PM 7 KIP 12:00/RESTART-12:00
 2 INCREASED IP FLOW TO 90%
 2:12 INCREASED CIRC WATER FLOW
 TO 600 GPM
 2:13 INCREASED IP FLOW TO 100%
 MULTIPLY AUX. USAGE X 160
 * INDICATOR PEGGED HIGH 20000 TB/HR
 Net kW output has been zero on all reading sets (according to control room meter)

2:00 10" GANE FROM
 IP STORAGE
 PUT IN 2 DRAUMS
 3:00 5" GANE FROM
 STORAGE
 Subtract 18°F from all boiler out temp readings on this sheet
 Subtract app. 2°F from all brine out temps on this sheet
 An hour = (Am2 - Am1) x 60 = kW out in multiple
 Same for kW

TIME	12:10	12:30	01:50	1:15	1:30	1:50	2:15
DRY BULB	81	90	88	87	91	91	91
WET BULB	67	68	72	70	72	71	73
IP TO BLR	83	89	92	91	91	96	95
BRINE IN	201	204	204	204	204	204	204
BRINE OUT	178	171	172	172	152	157	157
BOILER OUTLET	183	181	173	198	159	163	163
TURBINE INLET	182	179	172	176	157	160	161
TURBINE EXHAUST	179	167	172	172	132	140	146
CIRC WATER IN	76	77	77	77	80	82	83
CIRC WATER OUT	83	85	85	85	90	94	94
IP FROM COND	82	86	86	78	90	94	94
COND VAPOR	104	93	92	7	93	95	97
LUBE OIL	101	115	130	121	121	120	122
BOILER	31	26	32	32	31	40	40
BRINE IN	31	29	33	37	40	40	42
IP TO BOILER	78	39	35	40	40	50	40
TURBINE INLET	29	25	27	33	36	39	39
TURBINE EXHAUST	17	12	12	9	12	15	17
CONDENSER SHELL	16	11	12	12	10	12	16
CIRC WATER IN	28	24	25	25	24	25	26
CIRC WATER OUT	74	63	62	57	62	66	73
BACKWHEEL	19	16	16	13	16	18	20
SEAL GAS	21	21	19	21	21	21	22
LUBE OIL	140	136	134	137	137	137	136
ISOPENTANE	15/4	7.5	9.5	(ND)	*	*	*
BRINE	GPM	214	220	210	170	180	192
CIRC WATER	GPM	700	700	700	720	700	600
SEAL GAS	SCFH	20	20	20	20	20	20
GROSS GEN.	KW	3.2	5.1	3.2	4.8	20.8	32.0
ANX. USAGE	KW	0.61	0.61	0.61	0.61	0.61	0.61
APPARENT PWR	KVA	3.2	5.1	3.2	4.8	20.8	32.0
POWER FACTOR		.57	.50	.50	.80	.73	.50
GEN. VOLTAGE	VOLTS	480	470	470	477	475	470
STEAM IN VAPOR	W/O						
IP IN BRINE OUT	W/O						
IP IN CW OUT	W/O						
IP IN COND VAPOR	W/O						
BAROMETER	MMHG	761	761	761	760	761	760

2 SAMPLES

DATE A-1785 1960 200 JP from JP

JP
ARKANSAS
General
JUN 13

DATE: 7/21/80

TIME		5:01 PM	5:36 AM
T	DRY BULB	76	75
E	WET BULB	72	72
M	IP TO BLR	100	106.4
P	BRINE IN	202.2	202.2
E	BRINE OUT	151.8	154.
R	BOILER OUTLET	154.5	153.1
A	TURBINE INLET	154.6	155.8
T	TURBINE EXHAUST	133	137.8
U	CIRC WATER IN	86.4	90.2
R	CIRC WATER OUT	100.6	105
E	IP FROM COND	99.4	104.6
/	COND VAPOR	99.0	104.4
F	LUBE OIL	100	110
P	BOILER	34	36
R	BRINE IN	37	37
E	IP TO BOILER	45	40
S	TURBINE INLET	32	34
S	TURBINE EXHAUST	11	12.5
U	CONDENSER SHELL	9.5	10
R	CIRC WATER IN	28	28
E	CIRC WATER OUT	64	67
P	BACKWHEEL	14	16
S	SEAL GAS	24.5	24.4
G	LUBE OIL	150	146
F	ISO PENTANE	16/HR	X
L	BRINE	GPM	186
O	CIRC WATER	GPM	540
W	SEAL GAS	SCFH	
E	GROSS GEN.	KWH	18.56
L	AUX. USAGE	KWH	CARE
E	APPARENT PWR	KVA	
C	POWER FACTOR		.56
T	GEN. VOLTAGE	VOLTS	480
C	STEAM IN VAPOR	W/O	
O	IP IN BRINE OUT	W/O	
N	IP IN CW OUT	W/O	
C	IP IN COND VAPOR	W/O	
BAROMETER		mmHg	759

* 12 good high.

Start 5 AM
End 5 $\frac{12}{AM}$

2.3
3.6
6.9

DATE: 7/22/80

TIME		3 $\frac{30}{AM}$	3 $\frac{45}{AM}$	4 $\frac{20}{AM}$	4 $\frac{40}{AM}$	5 $\frac{00}{AM}$														
T E M P E R A T U R E / °	DRY BULB	79	78	78	78	78														
	WET BULB	77	77	77	75	75														
	IP TO BLR	92.2	91.8	99.0	96.9	95.4														
	BRINE IN	204	204	202.8	203	203.2														
	BRINE OUT	165.8	155.4	157.2	159.2	157.														
	BOILER OUTLET	164.0	157	157	159.2	159														
	TURBINE INLET	162.4	157.2	158.6	159.2	159.2														
	TURBINE EXHAUST	143.2	129.8	138.8	139.6	139.8														
	CIRC WATER IN	83.8	84.4	86.2	84.6	84.4														
	CIRC WATER OUT	93.8	95.2	97.6	94.8	94.2														
	IP FROM COND	92.0	92.8	97.2	95	93.8														
	COND VAPOR	91.2	94.2	96.2	97.8	93.6														
	LUBE OIL		112	122	116	118														
	BOILER		RESTART	36	38	39														
	BRINE IN		40	42	40	39														
	IP TO BOILER		65	60	60	60														
	TURBINE INLET		34	37	36	36														
	TURBINE EXHAUST		10.5	15	14	13														
	CONDENSER SHELL		9	13	12	12														
	CIRC WATER IN		25	26	24	24														
	CIRC WATER OUT		62	67	64	62														
P S I G	BACKWHEEL	13	12.5	17.5	17	15														
	SEAL GAS		25	25	25	25														
	LUBE OIL		142	142	140	140														
	ISO PENTANE	16/HR	Q	4"hr	6.2"hr	6.0"hr														
F L O W	BRINE	GPM	F	144	141	141														
	CIRC WATER	GPM		650	620	740														
	SEAL GAS	SCFH																		
	GROSS GEN.	KWH	F	4.83	2.50	3.51														
E L E C	KW INTO PLANT	KWH		3 REV	3.51	3.64														
	Q		3	10	5.110	5.58														
	POWER FACTOR	Factor Reading		.62	.48	.6														
	GEN. VOLTAGE	VOLTS		480	480	480														
C O N D	STEAM IN VAPOR	W/O		*	—	—														
	IP IN BRINE OUT	W/O		*	—	—														
	IP IN CW OUT	W/O		*	—	—														
	IP IN COND VAPOR	W/O		*	—	—														
BAROMETER		mmHg		759	759	759														

* Samples taken

2 10 inch loss of isopentane
from storage tanks

DATE: 8/27/80

	1.1"hg	1.2"hg	1.5"hg	1.55"hg
Started with 1P storage tanks full to mark (4 drums used to top off)				
Net GROSS KWH	0002.5			
KVA	0002.5			
To KWH	0064.7			
Q	0062.0			
From KWH	0000.6			
Q	0000.1			

END GROSS KWH 0002.8
KVA 0002.7 X 160
TO KWH 0065.0
CO 0063.1
PRG KWH 0000.6
Q 0000.1

150 STORAGE TANKS
DRY
Take 8 drums to fill
at end.

Add 2 drums
isopentane @ $7 \frac{00}{\text{An}}$
Total
@ $7 \frac{00}{\text{An}}$

DATE: 8/27/80

TIME		9:30 PM	10:00 PM	10:30 PM																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														</
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ON LINE 9 ¹⁵/_{PM}

2 TRIPS OVERSPEED
BACK ON IMMEDIATELY

From Plant
to Grid
O Q
O KWH

9⁴⁵ 3 drums 1A into Storage tanks

They were completely dry. If Had gone over into latter section.