PROJECT DEVELOPMENT DESERT PEAK

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ABSTRACT

In late 1982 Phillips Petroleum Company began preliminary design of a power plant for Desert Peak in Churchill County, Nevada. Because each geothermal resource is unique, careful consideration of existing process schemes and design technologies was required. This paper will review process studies, examine some of the detail design and discuss the construction program. No attempt will be made to discuss geological aspects of the resource.

INTRODUCTION

Phillips Petroleum Company has obtained approximately 24,000 acres of Federal and Southern Pacific Railroad leases in the Brady-Hazen Known Geothermal Resource Area (KGRA), an area commonly referred to as Desert Peak. This medium temperature hot water dominated resource is located in arid rolling desert of the Hot Springs Mountains, 65 miles northeast of Reno, Nevada. After preliminary evaluations of the resource, Phillips began in late 1982 a comprehensive study of alternatives which ultimately resulted in the current 9 MW facility design.

Process Parameters

Table 1 shows process parameters utilized for Desert Peak.

Table 1

Production Well Characteristics

Average flowrate per well	500,000 lbm/hr.
Average wellhead temp	326°F
Average wellhead pressure	97 PSIA
Average resource temp	400°F
Average resource enthalpy	384 BTU/lb
Steam flash by mass	9.9%

Studies

The process specification for Desert Peak evolved from criteria established by Phillips Geothermal Branch and process studies. Each study was based upon existing conditions at Desert Peak and an objective to generate the most power at the lowest capital cost.

Cooling Towers vs Air Fin Exchangers

Table 2 summarizes electrical power produced by a system cooled by either air fin exchangers or cooling tower.

Table 2

Air Fin/Cooling Tower Electrical Power Production Comparison

Electrical Power	Air Fin	Cooling Tower
Gross Power Output KWH	7279	10022
Parasitic KWH	1509	756
Net Power for Sale KWH	5770	9266
Difference	(3496)	
Effectiveness	62%	

Also, the capital cost of the cooling tower was one third of the cost of the air fin exchangers.

Two Phase Flow vs Wellhead Separation

Wellhead separator systems and two phase flow systems were studied to determine which could provide the lowest pressure drop at the lowest investment and operating costs. Two phase flow was selected because operating and investment costs were reduced by eliminating wellhead separators. By locating the plant downhill of the production wells and insuring there were no pockets in the line; damage due to slug flow was eliminated. Large diameter pipes also assisted in separating fluids.

Floating Power

Floating power means that equipment is sized to take advantage of temperature ranges. As the cooling system responds to lower temperatures more horsepower can be developed by the turbine and more power can be generated. When floating power is considered, the production rate remains constant; however, temperature fluctuations are reflected by annualized mean termperatures. Table 3 summarizes design conditions and power output.

Table 3
Constant Power/Floating Power Comparison

Conditions	Constant Power	Floating Power
Production rate lbm/hr	1,086,000	1,086,000
Cooling Water to Process	67°F(1)	53°F(2)
Cooling Water from Process	107°F(1)	93°F(2)
Electrical Power		
Net Power KWH	10,000	11,050
Percent increase		10.5%

(1) Summer conditions
(2) Mean annual

Binary vs Full Flow Unit

Phillips compared an internally designed binary system with a rotary separator turbine (RST) system. RST power skid operating parameters were provided by Transamerica Delaval Biphase Energy Systems and Phillips developed the process flowsheet for the system. The RST process was selected primarily because it produced more net power at a lower capital cost. Table 4 summarizes both processes.

Table 4
Binary/RST Comparison

	Binary	RST
System Characteristics		
Well flow lbm/hr	1,500,000	1,500,000
Isobutane flow lbm/hr	2,026,000	
Cooling water circulation rate lbm/hr	12,865,000	6,488,620
Electrical Power		
Gross MW	15.08	13.46
Parastic MW	4.10	1.40
Net for sale MW	10.98	12.06
Conversion Efficiency		
Net	7.09%	7.32%
Estimate Cost Differential (1982 costs)	$7,200,000	Base

NOTE: Geothermal fluid was cooled to approximately 167°F in the binary system to accomodate minimum injection temperature.

Current Design

The current design is the result of implementing the conclusions of previously discussed studies. Figure 1 shows the 24 in. and 30 in. two phase gathering system with the plant located at the lowest elevation. As shown by Figure 2 geothermal fluids are separated into high pressure steam and brine in the high pressure separator. High pressure steam flows through a knock out vessel to the steam turbine inlet. Brine from the high pressure separator is divided between the RST and the low pressure separator. Because of low system pressure, the RST cannot process all brine produced in the high pressure separator. Excess brine is flashed in the low pressure separator. Low pressure steam from the RST and low pressure separator enters the steam turbine after any excess moisture is removed by a knock out vessel. Steam at less than atmospheric pressure is discharged from the steam turbine into a direct contact spray condenser where vacuum is provided by steam ejectors. Heat is rejected through a cooling tower and make up for the system is condensate. Brine from the RST flows to the low pressure separator. The injection system includes the discharge from the second stage separator, cooling tower blow down, injection pumps and an injection well. Figure 3 shows the plant layout.

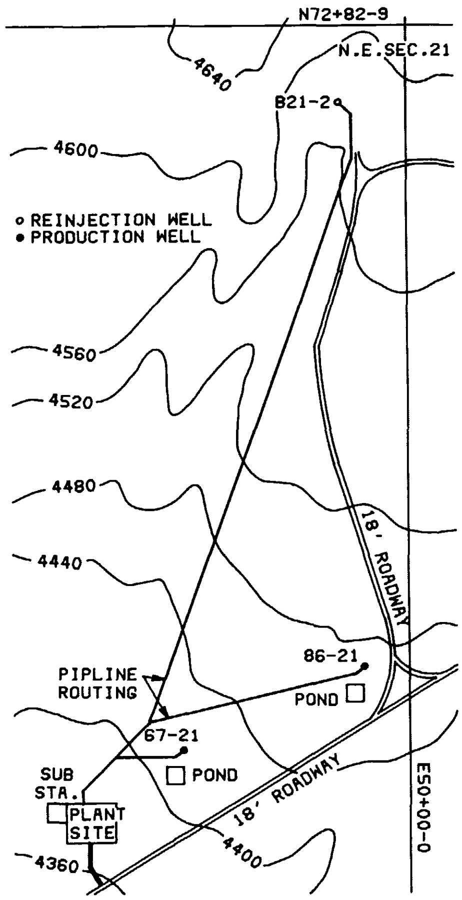
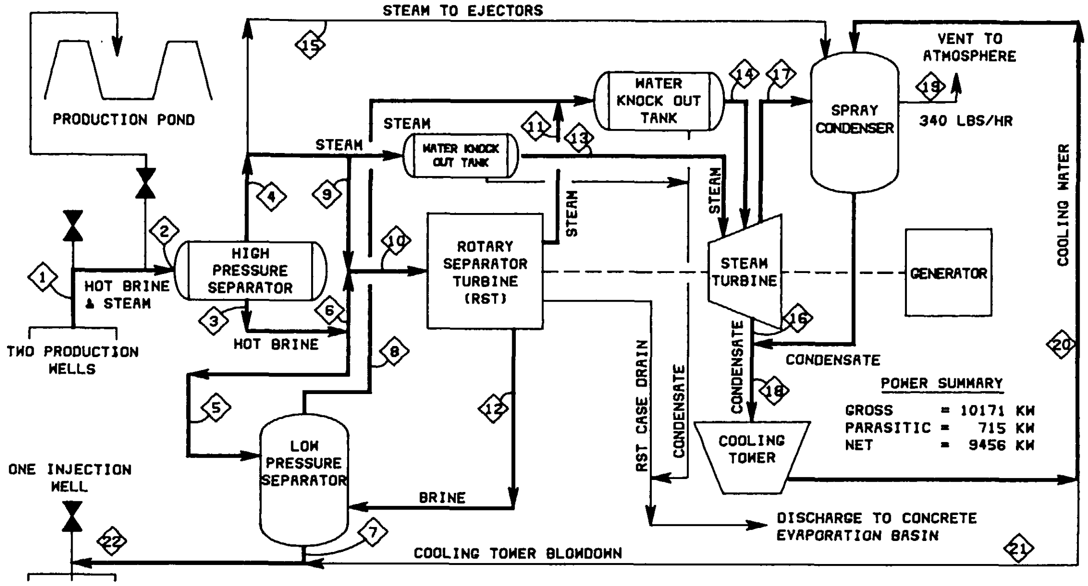


FIGURE 1
DESERT PEAK PLOT PLAN



DESCRIPTION	GEOTHERMAL RESOURCE	FEED	H.P. SEPARATOR LIQUID	H.P. SEPARATOR STEAM	FEED TO L.P. SEPARATOR	LIQUID TO RST	L.P. SEPARATOR LIQUID	L.P. SEPARATOR VAPOR	H.P. RST CONTROL STEAM	TOTAL FEED TO RST	RST OUTLET STEAM	RST OUTLET LIQUID	H.P. STEAM TO TURBINE	L.P. STEAM TO TURBINE	H.P. STEAM TO EJECTORS	LIQUID FROM STEAM TURBINE	VAPOR FROM STEAM TURBINE	LIQUID TO COOLING TOWER	COOLING WATER TO SPRAY COND.	COOLING TOWER BLOWDOWN	RE-INJECTION LIQUID
STREAM NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	21	22
LIQUID LBS/HR ($X10^3$)	901	894.4	894.4		84.1	810.3	809.2			807.2		733.3				21.5		3548	3357	24.1	833.3
STEAM LBS/HR ($X10^3$)	99	105.6		105.6				8.2	13.4	16.5	90.4		87.2	98.6	5.0		164.3				
PRESSURE (PSIA)	97	89	89	89	89	89	20	20	89	85	20	41	89	20	89	1.1	1.1				
TEMPERATURE (°F)	326	319.5	319.5	319.5	319.5	319.5	228	228	319.5	316	228	228	319.5	228	319.5	105	105	105	53	53	224

FIGURE 2
9 MW PROCESS FLOW AND MATERIAL BALANCE

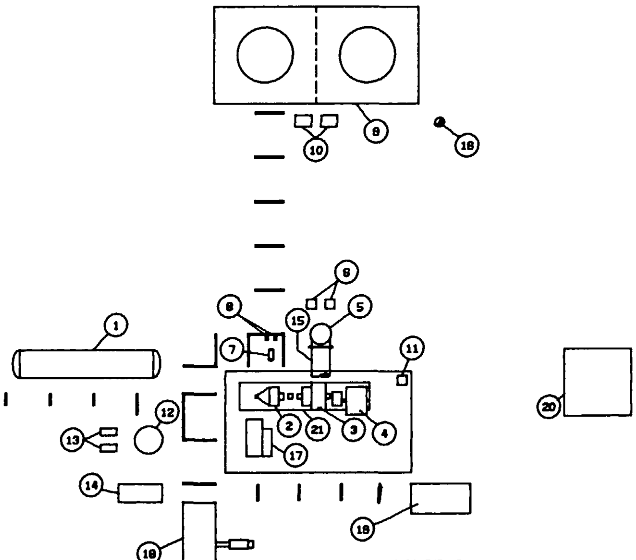


FIGURE 3
DESERT PEAK EQUIPMENT LAYOUT

1. HIGH PRESSURE SEPARATOR
2. ROTARY SEPARATOR TURBINE
3. DUAL STAGE STEAM TURBINE
4. ELECTRICAL GENERATOR
5. DIRECT CONTACT SPRAY COND.
6. CONDENSATE C.W.PUMPS
7. TURBINE DRAIN TANK
8. DRAIN TANK PUMPS
9. COOLING TOWER
10. COOLING TOWER WATER PUMPS
11. NEUTRAL GROUNDING RESISTORS
12. LOW PRESSURE SEPARATOR
13. REINJECTION PUMPS
14. PACKAGED INST. & TOOL AIR SKID
15. TURBINE EXHAUST DUCT
16. VENT STACK
17. LUBE OIL SKID
18. POWER HOUSE & SWITCHGEAR BLDG.
19. CONTROL ROOM & OFFICE
20. RST DRAIN POND
21. PACKAGE POWER GENERATION SKID

Desert Peak Simulator

Process studies, process design and detail design could not have been accomplished in the short time allocated in the project schedule if the Desert Peak Simulator (DPSIMF) had not been developed. The simulator developed by C. P. Diddle, Phillips Petroleum Company models single flash, dual flash and RST systems from production wellhead(s) to the injection wellhead including all auxiliary systems. Its program is written in BASICA for use on the IBM PC. Table 5 shows the variables which can be changed by the engineer with input from the keyboard. The temperature, pressure, flow, and percent vapor at the top of the wellhead are given conditions which can be changed for different reservoirs. The remainder of the variables are selected by the process engineer.

The program provides for change of variables which are listed by letter codes. An input will result in a question to be answered for all codes except: (1) XT = GET OUT OF THE SIMULATOR, (2) RUNS = Causes the program to run after changes of variables are complete and a

Table 5
Engineers Input Screen

```
ENTER VARIABLE CODE LETTERS?
  THIS PROGRAM IS A RST/STEAM TURBINE POWER PLANT SIMULATOR + DPSIMFD ******
***************************************************************************
   Designer of Simulator: Courtney Diddle; Phillips Petroleum Co.          *
     SIMULATOR INPUT VARIABLES -- SYMBOLS (use CAPITAL LETTERS)            *
       TO INITIALIZE = INT then ENTER = Base Case VALUES                   *
   Wellhead Temperature      = WT     HI. Press. Sep. Temp.     =  FA1     *
   Wellhead Flash            = VO     Low Press. Sep. Temp.     =  F1      *
   Wellhead Flow             = FW
   RST INLET Temperature     = FA     RST Feed Rate, LBS/HR     =  RSTF    *
   RST Enhance Stm, LBS.     = VST6   RST Feed Liquid Factor    =  FS      *
   RST Efficiency Factor     = N1     Steam Ejector, LBS/HR     =  SJ      *
   H.P. Steam Vent LBS/HR    = VH     L.P. Steam Vent LBS/HR    =  VL      *
   Stm Turb. Oulet Temp.     = F6     Steam Turb. Efficienty    =  N2&N3   *
   Cooling Two. H20 Temp.    = F7     Pump Efficiency           =  PEFF    *
   Spray Cond Pump del P     = DP1    Cooling Twr Pump delta P  =  DP2     *
   Blowdown Pump delta P     = DP3    Re-Injection Pump delta P =  DP4     *
   RETURN TO STARTING MENU   = MU     GET OUT OF THE PROGRAM    =  XT      *
   RUN NUMBER                = RUNA   RUN SIMULATOR             =  RUNS    *
   ENTER - Your NAME         = N$     ENTER - Plant Site NAME   =  S$      *
***************************************************************************
ENTER VARIABLE CODE LETTERS?
```

run is desired. (3) RUNA = Allows for an override of the Run Number, since the program will automatically increment the run number by one (1) each RUNS.

The simulator contains a steam table with saturated data between 32-705 degrees F. The program will interpolate as a function of temperature. Output is in the form of a single page summary (Table 6) which includes gross, net and parasitic power or a six page detailed printout. Details include process parameters of all major components, pump horsepower, and power developed by RST and steam turbine.

Table 6
Single Page Power Summary Sequence

```
*************************************************
ENTER VARIABLE CODE LETTERS ? RUNS
  The DPSIMF SIMULATOR is now calculating the
  problem.
*************************************************
THIS PROGRAM IS A RST-STEAM TURB POWER PLANT
SIMULATOR = DPSIMFD
Designer of Simulator: Courtney Diddle
                        Phillips Petroleum Co.
DATE OF RUN = 02-22-1985
TIME OF RUN = 08:28:00     RUN NO. = 1
ENG'R:  J. Q. ENGINEER
  SUMMARY OF POWER OUTPUT IN KILOWATT HOURS
  SITE = ANYWHERE, WORLD
  RST POWER AT N1 EFF.                =    657.7
  HI.PR. TURB AT N2 EFF.              =   5457.0
  L.P. TURN AT N3 EFF.                =   4046.4
  GROSS POWER-TOTAL POWER             =  10161.2
  TOTAL PARASITIC POWER               -    714.8
  NET POWER FOR SALE                  =   9446.3
Number of Variable CHANGES            =      0.0
  (Maximum = 5 different)
*************************************************
IS A HARDCOPY REQUIRED? Y OR N?
```

Deserk Peak Graphic Simulator

Phillips is currently developing an interactive graphic simulator of the Desert Peak process. It will also be able to simulate single flash and dual flash systems. The advantage of the graphic simulator is that variables can be increased or decreased by holding one's finger on the appropriate key. As the variable changes the engineer can observe corresponding changes in power production and other system parameters.

Detail Design

Several changes to project premises were made to accomodate solutions to problems which were solved during detail design. The impact on other equipment specifications were determined by DPSIMF which provided for maximizing net power at all times.

Liquid at saturation temperature and pressure leaving the first stage separator is flashed due to normal pressure drop in piping enroute to the RST. This could cause unequal distribution of liquid to RST nozzles. After study, a cooler condensate injection system was designed to be used if required. The DPSIMF calculated quantities of liquid flashed and quantities of condensate required to lower the temperature to match the expected pressure at the RST inlet.

The vent-relief system is essential for the management of steam during the start-up of the RST and dual stage steam turbine. Low pressure steam will be vented while the turbine is started utilizing high pressure steam. Optimization of the size of the vent control valves was accomplished by calculating the expected flow rates as a function of changing back pressure. The calculation was made by the DPSIMF simulator.

In order to meet excepted operating conditions the brine disposal ponds which were premised to be installed if required have been constructed. Diverting production to the ponds will assist in limiting the rate of the increase in the systems temperature during start-up. Also solids loosenedby well cleaning can be prevented from entering production pipelines and equipment.

As the operating and startup procedures developed, it was determined that a distributed control and permissive interlock systems would be required. A programable controller with 8K memory and 128 I/O points was selected to implement shut-down logic and permissive start sequencing. The process will be controlled by 4 eight loop programable controllers. A CRT station will be used to monitor and make process adjustment. Because the system floats on the wet bulb temperature and production characteristics change as the result of well scaling all systems must be kept in balance and have a reasonable operation range. It would be impossible to manually control this dynamic system.

Construction

The overall project schedule was developed to take advantage of all tax incentives and be operational by December 31, 1985. In order to meet this objective the construction philosophy provide for separate site preparation, plant erection, insulation and painting contracts. Site preparation was completed in mid March 1985 and the main contract was awarded in early April. The RST power skid is scheduled to be shipped by mid-July and plant start-up is scheduled for December.

References

Phillips Petroleum Company Computer Programs
a) DPSIMF RST-Steam Turbine Power Plant Simulator
b) DPGSIM RST-Steam Turbine Power Plant Graphic Simulator

Cerini, D. J., Diddle, C. P. and Gonser, W. C. Project Development Desert Peak 9MW Power Plant Proceedings Eight Annual Geothermal Resources Council pgs. 33-39, 1984.