DESIGN AND CONSTRUCTION OF A MOBILE TEST CAPABILITY FOR DETERMINING THE CHARACTERISTICS OF GEOTHERMAL FLUIDS AND RESERVOIRS

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Introduction

The parameters determining the usefulness of geothermal reservoirs are temperature, producibility and chemistry of the brine (or steam). Accurate measurement of these parameters is necessary to make the decisions for development, production, utilization and marketing of geothermal resources. We have designed and constructed two mobile test facilities for determining the characteristics of geothermal fluids and reservoirs, i.e. temperature, pressure, flow rate, enthalpy, and chemistry.

Our initial efforts were directed towards identification of the phases of geothermal development and the quantification of requirements for testing and measurement during these phases. It was during this period that we identified the need that the mobile test capability be split into two units. The first unit is the Mobile Chemical Analysis Trailer, CAT, which has the capability of measuring the chemical composition of geothermal brines and other waters, e.g. hot springs. One of its major functions will be to accurately prepare samples for shipment for more detailed chemical analysis. The second unit is the Geothermal Energy Evaluation Prototype, GEEP, which is used for determination of flow rate, enthalpy, temperature, pressure of the geothermal reservoir and recovery of samples for chemical analysis.

Figure 1 shows the phases of geothermal development and how the CAT and GEEP interact to obtain the required information. This figure shows that as field development progresses additional larger size process test units will be required to provide final design information for the power plants and field development. The information required to design these larger size test units will come from CAT and GEEP. The operations of these larger sized units will in part be evaluated by use of CAT and GEEP.

The use of CAT and GEEP is thus very valuable to our overall geothermal development. The units have been designed to provide rapid, accurate information, be highly mobile and thus minimize the costs and time.

Description of GEEP

The GEEP consists of three major parts (Figure 2),

1) the orifice run which determines the flow rate and enthalpy by the Russell James method and provides ports for chemical sampling and temperature and pressure measurements,

2) the calorimeter which makes a direct measurement of the enthalpy and

3) the condenser which provides large sized samples of brine and non-condensible gases.

GEEP Field Test Results

The GEEP was transported to DOE East Mesa Geothermal Test Facility for flow testing using well EM 6-2. Results of flow test data analysis are shown in Tables 1 and 2. Table 1 summarizes those runs with liquid phase flow across the orifice plate; Table 2 those runs with two phase flow across orifice plate.

In Table 1, the number under "flow rate calculated" is obtained from Russell James' correlation:

$$W = \frac{205{,}185\ P_c^{0.96}(d_c)^2}{h^{1.102}y^{0.063}} \qquad (1)$$

where

W = Flow Rate, lb/hr

P_c = Critical pressure, psia

d_c = Diameter of discharge pipe, in.

h = Specific stagnation enthalpy, Btu/lb.

y = Distance from the pipe discharge face to the center of the pressure hole, in.

The number under "flow rate measured" is computed from the orifice meter formula:

$$Q = \frac{F_b\ F_{gt}\ F_r\ F_a}{60}\sqrt{h_w} \qquad (2)$$

where

Q = liquid flow rate across orifice, gpm.

h_w = differential pressure, in. of water.

F_b = orifice factor

F_{gt} = specific gravity - temperature factor

F_r = Reynolds' number factor

F_a = Orifice thermal expansion factor

The orifice meter constants, F_b, F_{gt}, F_r, F_a, can be found from Handbook E-2 published by American Meter Company.

Comparing calculated and measured flow rate in Table 1, it can be seen that the agreement is within $\pm 10\%$ except the run EM-5.

In Table 2, the calculated flow rate and enthalpy are obtained from ~~Russell~~ James' correlation:

$$h^{1.102} = 1450 \frac{P_c^{0.96}}{Y_{TP}} \left(\frac{dc}{dm}\right)^2 \sqrt{1-B^4} \sqrt{\frac{X^{1.5}(V_g - V_f) + V_f}{(\emptyset_{TP})(55.8)}} \qquad (3)$$

and Equation (1)

where

d_c = Diameter of discharge pipe, in.

d_m = Diameter of orifice, in.

B = Ratio of orifice diameter to inside diameter of main pipe.

Y_{TP} = Expansion factor for two-phase steam - water mixture.

V_g = Specific volume of saturated vapor, ft^3/lb.

V_f = Specific volume of saturated liquid, ft^3/lb.

X = Steam quality (homogeneous dryness fraction).

$\emptyset_{TP}$ = Differential pressure, psi

P_c = Critical pressure, psia

The solution of Equation 3 for enthalpy needs trial and error, a portable computer program was written for this calculation. In Run EM-6, flow across wellhead orifice was in the liquid phase and the flow rate measured with the orifice plate was compared to value calculated from James' Method and excellent agreement was observed. In Run EM-7, the calorimeter experiment was conducted. Enthalpy measured by the calorimeter was compared with that calculated from James' method and a 6% difference was noticed.

It should be noted that the readings on both the gauge and Barton Recorder oscillate within a significantly large range when flow through the orifice is two-phase or when the well flow surges. For example, in Run EM-7, the reading for critical pressure ranged from 19.7 psia to 34.7 psia; the reading for differential pressure ranged from 20 inches of water to 60 inches of water. The mean values were used for flow rate calculation. Readings were fairly constant with liquid phase flow in the GEEP pipe meter run and well flow was stable.

CAT Description

Figure 3 shows the layout of CAT which provides laboratory space and storage for support of brine sampling activities. Minimum living accommodations are also included.

Parameters to be evaluated onsite (in CAT) include:

1) pH
2) Conductivity
3) Chloride
4) Carbon dioxide
5) Ammonia
6) Silica
7) Hydrogen sulfide
8) Boron
9) Sulfate
10) Mercury
11) Suspended solids
12) Calcium
13) Turbidity
14) Dissolved oxygen, NH_3, H_2S (field test kits)
15) Space and utilities provided for other tests as needed
16) Preserve samples for transport and reconstitution.

The construction of the CAT is underway.

REFERENCES

1. American Meter, "Orifice Meter Constants, Handbook E-2," 1973.

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3. Russell James,"Measurement of Steam - Water Mixtures Discharging at the Speed of Sound to the Atmosphere," New Zealand Engineering, 21 (10): 437-41 (October, 1966).

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TABLE 1

RESULTS FOR LIQUID FLOW ACROSS ORIFICE

Run No.	Flow Rate Calculated by James' Method, GPM	Flow Rate Measured by Orifice Plate, GPM	% Difference
EM-2	116.3 (58,300)*	107.4	+8%
EM-3	180.0 (90,600)	177.0	+2%
EM-4	196.6 (98,500)	192.6	+2%
EM-5	79.6 (39,900)	93.0	-14%
EM-8	68.9 (34,500)	76.0	-9%

* The numbers in the parenthesis are in the unit of lb/hr.

TABLE 2

RESULTS FOR TWO PHASE FLOW ACROSS ORIFICE

Run No.	Flow Rate Calculated by James' Method, GPM	Enthalpy , Calculated by James' Method', BTU/lb	Flow Rate Measured by Orifice Plate, GPM	Enthalpy Measured, BTU/lb	% of Difference
EM-6	282 (141,300)*	309	283	---	-.35%
EM-7	293 (146,800)	325	---	306	+6%

* The numbers in the parenthesis are in the unit of lb/hr.

FIGURE 1

Stages of Geothermal Development

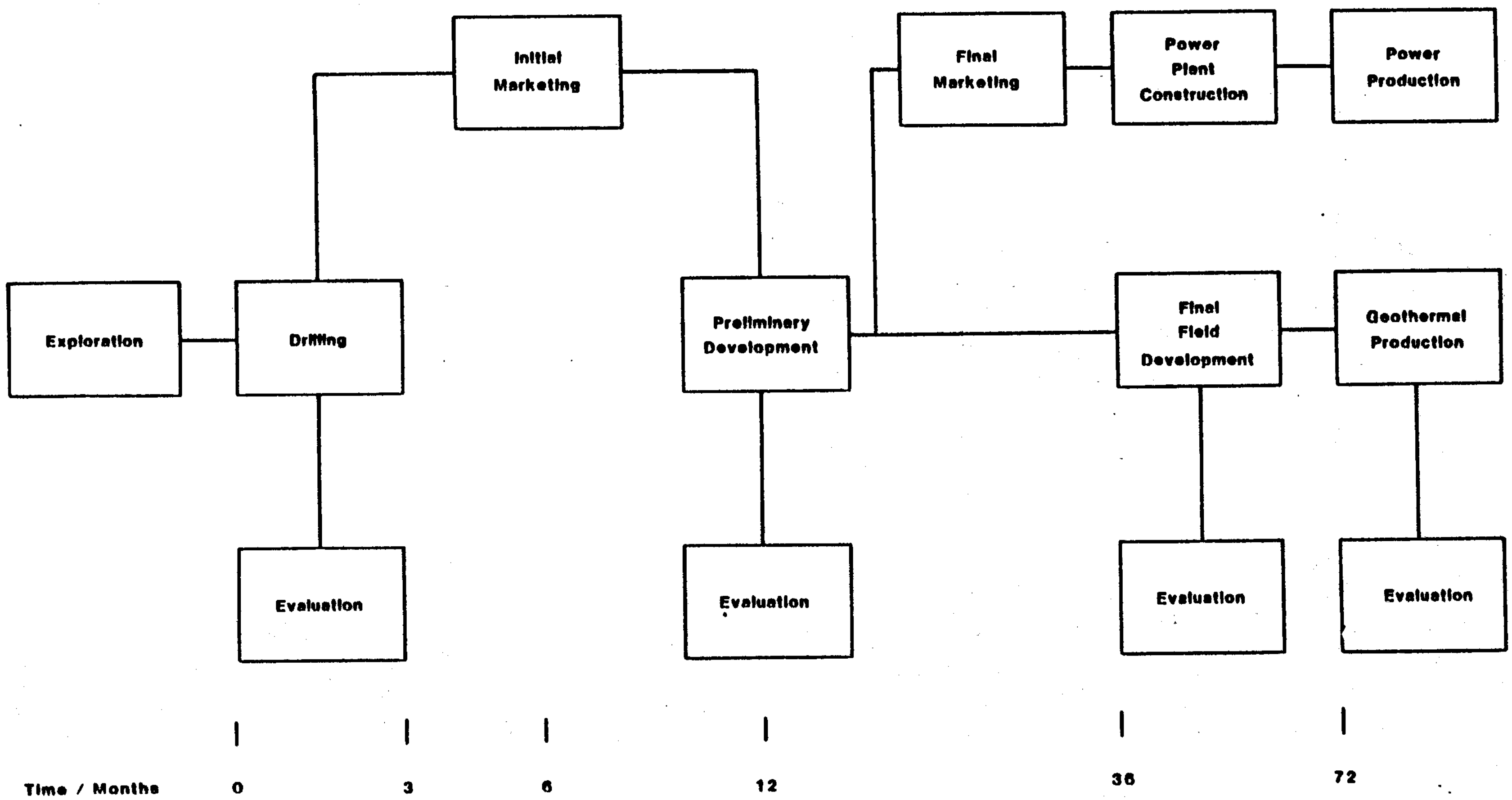

FIGURE 2

GEEP EQUIPMENT LOCATION PLAN
AND SOUND LEVEL WITH FLOW AT 262,000 LB/HR

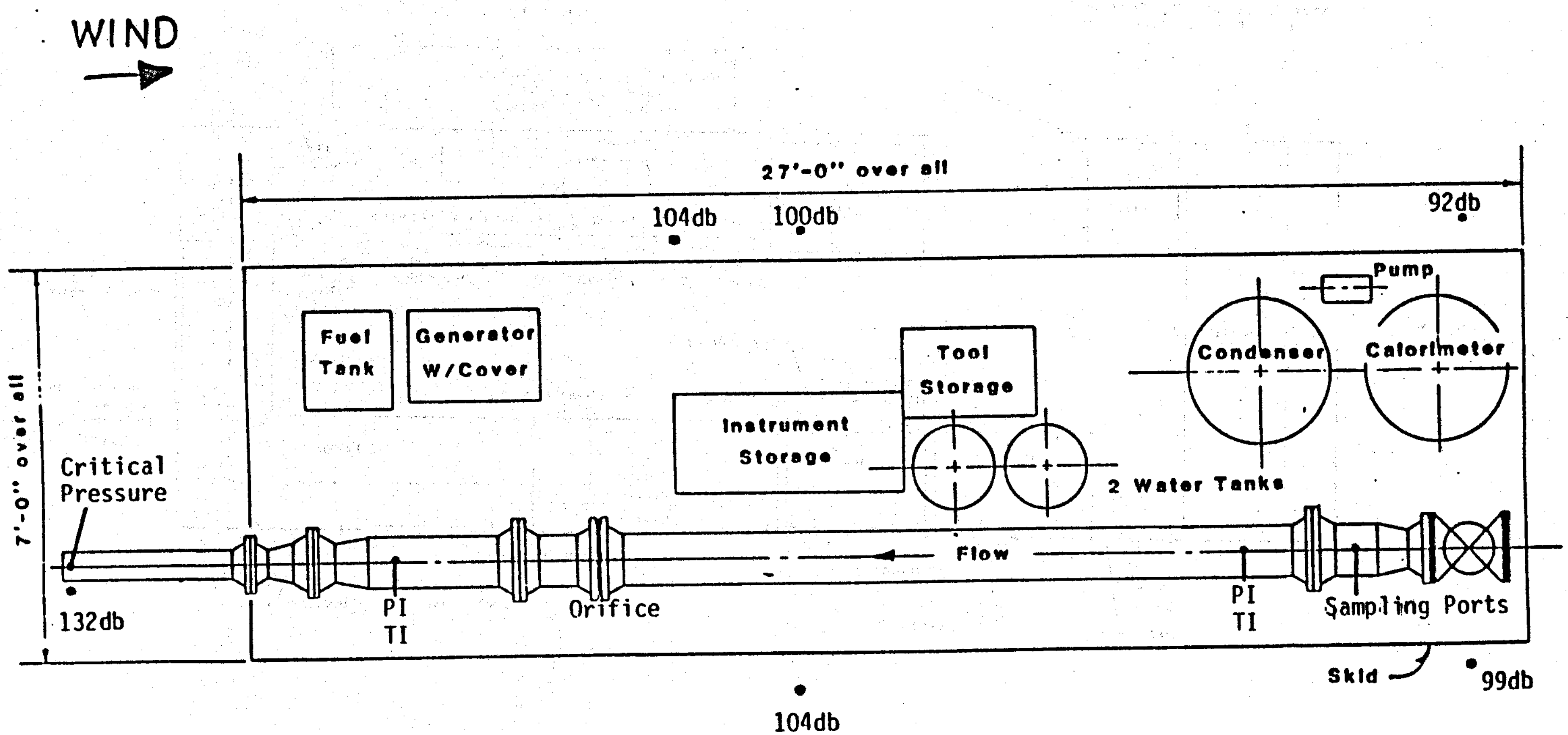

FIGURE 3

CHEMICAL ANALYSIS TRAILER LAYOUT