EAST MESA RESERVOIR

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INTERCOMP Resource Development and Engineering is currently working on contract to TRW Systems and the Bureau of Reclamation to provide petrophysical and reservoir engineering analysis of the East Mesa geothermal field. The twelve-month project was divided into three phases which consist of:

1. Analysis of current data and reservoir evaluation.
2. Design and execution of a long term flow test program.
3. Analysis of results and design of full scale reservoir development.

The first phase of the project is underway and portions of the work have been completed.

There are currently five wells drilled in the portion of the KGRA operated by the Bureau of Reclamation: 5-1, 6-1, 6-2, 8-1, 31-1. Each of these wells has a complete set of geophysical logs run and a SARABAND analysis by Schlumberger is available on a 1 ft. increment. In addition, core analysis was obtained from the 5-1 well in sufficient quantity to develop preliminary petrophysical transforms. Using the transforms developed in 5-1, INTERCOMP has performed a petrophysical analysis of the other wells to determine average reservoir properties over 250 ft. intervals. In particular, we determined ϕ, h, k_v and k_h averages for each interval. To date there has been no geologic correlation established between any of the wells, so that property averaging by individual sand groups would not be meaningful.

This data will be used by TRW Systems to develop a geologic interpretation of areally distributed reservoir properties. These properties will then be used to compute the heat and mass in place within a selected areal contour for each interval. This will only give a refined estimate of the magnitude of the resource within the KGRA since actual data control is limited *to* the region near the wells. A substantial portion of the KGRA has not had deep wells drilled to date.

All of the flow test data taken to date is also being analyzed. INTERCOMP's 3-D Geothermal Wellbore-Reservoir model is being used *to* establish the effective flow properties of the system surrounding each well. Drawdown and/or buildup data is available on each well and shows that the reservoir exhbits complex flow behavior. We are investigating the possibilities that the flow can be represented as a dual porosity, fractured, or damaged system.

A 2-D model of the reservoir has also been developed using a 1000 ft. grid within the current drilled area. Using estimated properties, a sensitivity analysis is being performed in order to design an effective interference test for the reservoir. We plan to develop a testing program that can be feasibly executed by the Bureau of Reclamation and that will yield sufficient data to determine effective reservoir performance characteristics between wells.

Fig. 1 shows a schematic of the KGRA with the heat flux contours and test grid. Fig. 2 shows a sample pressure map after 45 days of production from 6-1 at 600,000 lb/hr and reinjecting at the same rate in 5-1. The plot scale runs from 2400 to 2800 psia over the plot symbol range 0 through 10. In this case an aquifer of infinite extent has been attached to all edges of the grid. By varying rates, locations, and reservoir properties the sensitivity of reservoir to different testing plans can be determined.

The reservoir model will be calibrated to match the interference test data obtained from the field and an engineering design will be performed in the last phase of this project. In particular we will develop estimates for 1) resource lifetime, 2) well design and spacing, and 3) injection pumping requirements in accordance with operating characteristics and demands of surface facilities. TRW and INTERCOMP will be working with the Bureau of Reclamation to develop the operating plans on which each of these estimates will be based.

Reservoir Lifetime Estimate

The definition of "reservoir lifetime" is open to interpretation. However, the basic criteria used in this study will be a minimum allowable flowing wellhead temperature of 300°F. We will consider two basic cases in which the wells are produced by:

1. Submersible pumps which maintain single-phase flow in the wells.
2. Free flow in which the fluid will flash at some point in the wellbore. Two-phase flow in the wellbore will be accounted for above the flash point.

The calibrated reservoir-wellbore model will be used to predict the lifetime under the following delivery schedules:

1. Total flow of 10,000 lbm/min
2. Total flow of 100,000 lbm/min
3. Total flow of 1,000,000 lbm/min

There will be different lifetime estimates for each of these cases depending upon the spacing of production wells and location of reinjection wells.

Well Design and Spacing

From a reservoir engineering standpoint with water reinjection at the edge of the thermal area, this process is characterized as a "unit mobility waterflood." Under ideal conditions, the first cool water breakthrough will occur after roughly 708 of the original water is produced. After this Point, surface temperatures will gradually decline until the 300°F limit is reached. The total energy recovery depends upon the location of reinjection wells and therefore the total volume swept.

Maximizing energy recovery would at first appear to dictate reinjection as far from the thermal area as possible in order to sweep maximum water volume. However, the history match permeability distribution will dictate the allowable distance from the producing area in order to maintain pressure. Without adequate water recharge, the reservoir lifetime will be very short and dictated solely by reservoir pressure.

Similarly, drilling wells directionally from a single location for production would appear to minimize heat losses in the system. However, this usually results in a reduced well spacing. Under these conditions, the inner wells could interfere severely with the outer producing wells and therefore would be "starved." Again, the history match will determine the minimum allowable spacing for each of the proposed production schedules considering the environmental desirability drilling. The numerical model will be used in a trial and error fashion to establish this spacing.

Injection Well Pumping Requirements

For large scale developments the produced water must be reinjected into the producing zones in order to maintain reservoir pressure. This process, if designed properly, will also minimize any possible subsidence. The production-injection operation will set up a pressure gradient through the reservoir which will cause some subsidence within the producing area. If all of the produced water is recharged by reinjection the subsidence will be localized and small in magnitude.

The injection pumping requirements are strictly a function of the operating plans under consideration. For each plan there are three parameters which must be considered in order to evaluate the pumping requirements:

1. Location of reinjection wells,
2. Volumes reinjected per well,
3. Productivity index (PI) of each well.

The volume that must be reinjected is dependent upon the operating plan. The location of reinjection wells will be based upon the history match as discussed above. The productivity index can be estimated based on permeability, porosity and thickness at each particular reinjection location.

In addition to the above work at East Mesa, we are working with Republic Geothermal on their wells in the north end of the KGRA. We are assisting them in the evaluation of test results and the design of a testing program for the northern end. The results of this work are confidential and cannot be presented at this time.

GEOPRESSURED SYSTEMS

INTERCOMP is actively engaged in feasibility and geologic studies of geopressured geothermal systems. These systems contain substantial amounts of dissolved natural gas in addition to thermal energy. Fig. 3 shows that as much as 60 scf/Bbl of natural gas may be dissolved in these aquifers. The resource is generally located along the Texas-Louisiana Gulf Coast at depths of 12,000 to 15,000 feet.

The development of this resource is dependent on many factors, but the three most important are:

1. Is the fluid economically accessible?
2. Are the aquifers prolific enough?
3. Is the fluid technologically accessible?

We are currently conducting prospect evaluation and site selection studies in order to develop pilot projects that will help answer these questions. However, details of this work are confidential at this time.

NUMERICAL MODELING

INTERCOMP has developed numerical models that are used in the engineering evaluation of geothermal systems. One model is a two-phase wellbore calculation. A second model consists of a 3-D reservoir model for single and two-phase flow in porous media with the wellbore model coupled in at the sand face.

Details on the first model have been published by Gould, "Vertical Two-Phase Steam-Water Flow in Geothermal Wells," JPT (Aug. 1974). Details on the second model were presented by Coats et al., "Three-Dimensional Simulation of Steamflooding," SPE 4500 (October, 1973). We are currently engaged in upgrading the flexibilities and engineering features of these models in order to meet current design requirements.

Figure 1

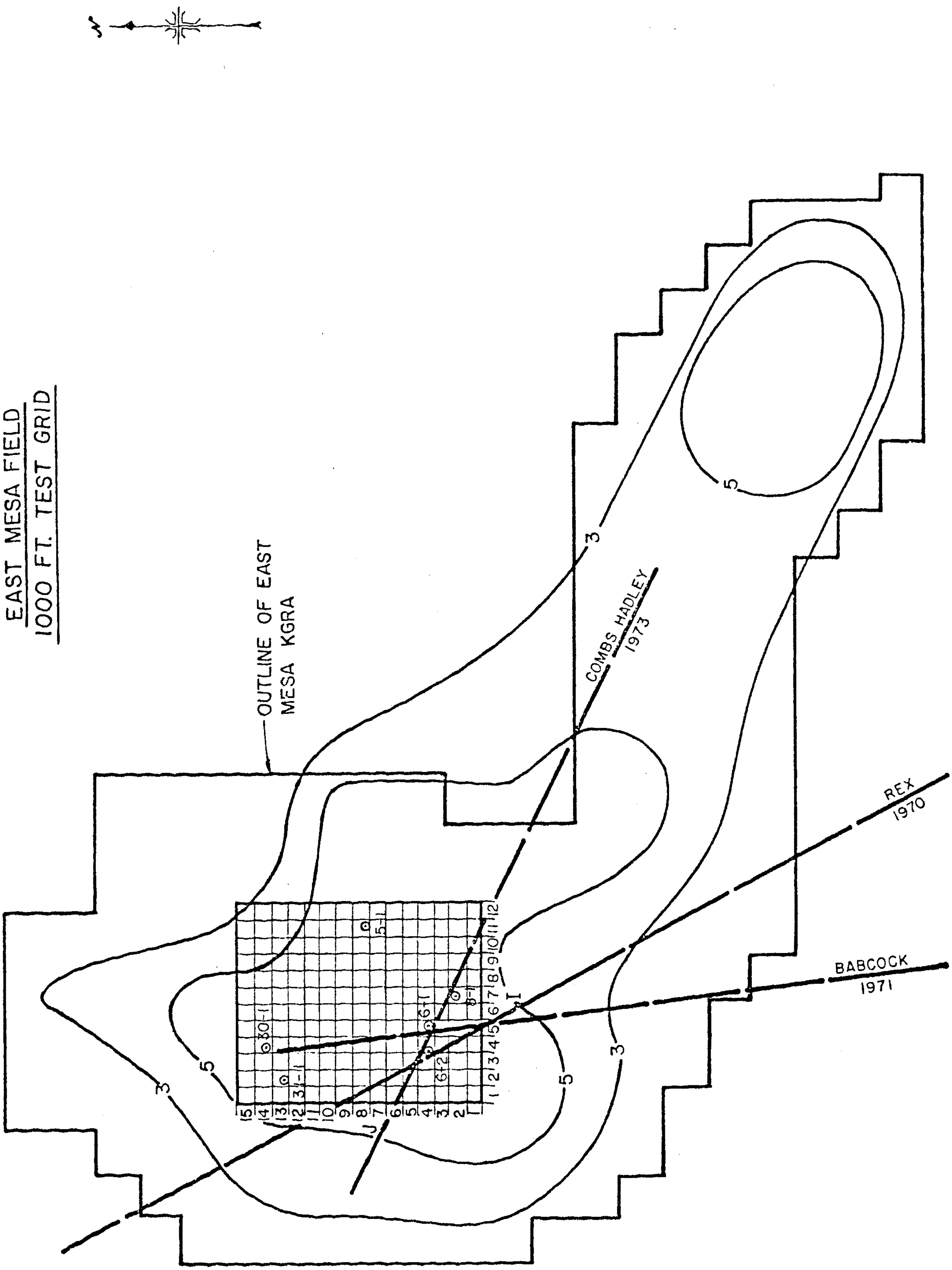
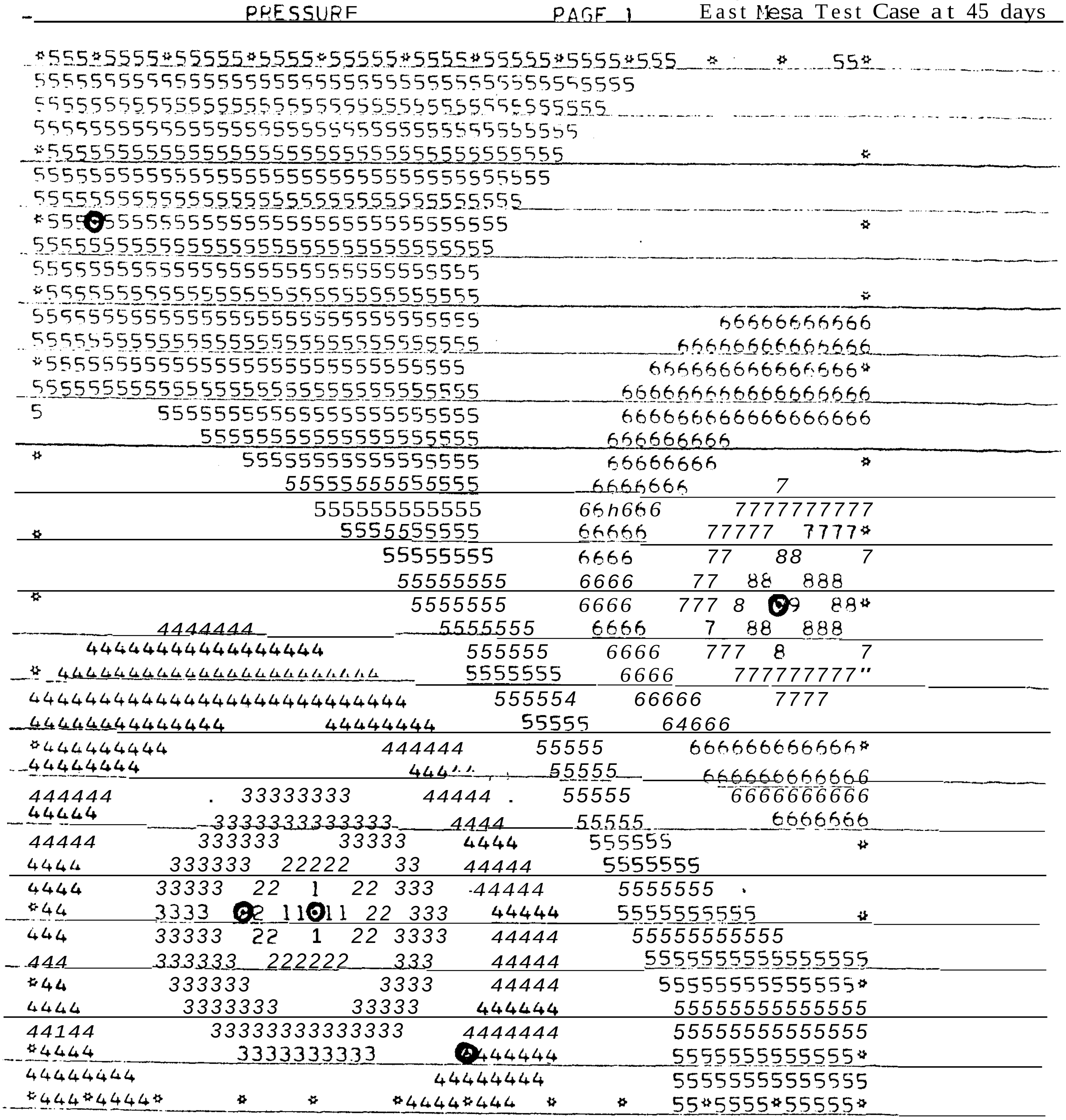

EAST MESA FIELD
1000 FT. TEST GRID
OUTLINE OF EAST MESA KGRA
COMBS HADLEY
1973
REX
1970
BABCOCK
1971
I
J
3
5
5-1
30-1
31-1
6-1
6-2
8-1

Figure 2

East Mesa Test Case at 45 days



LABORATORY MEASUREMENT OF 98.7% METHANE GAS SOLUTION IN DISTILLED WATER

(Culberson and McKetta, 1951)

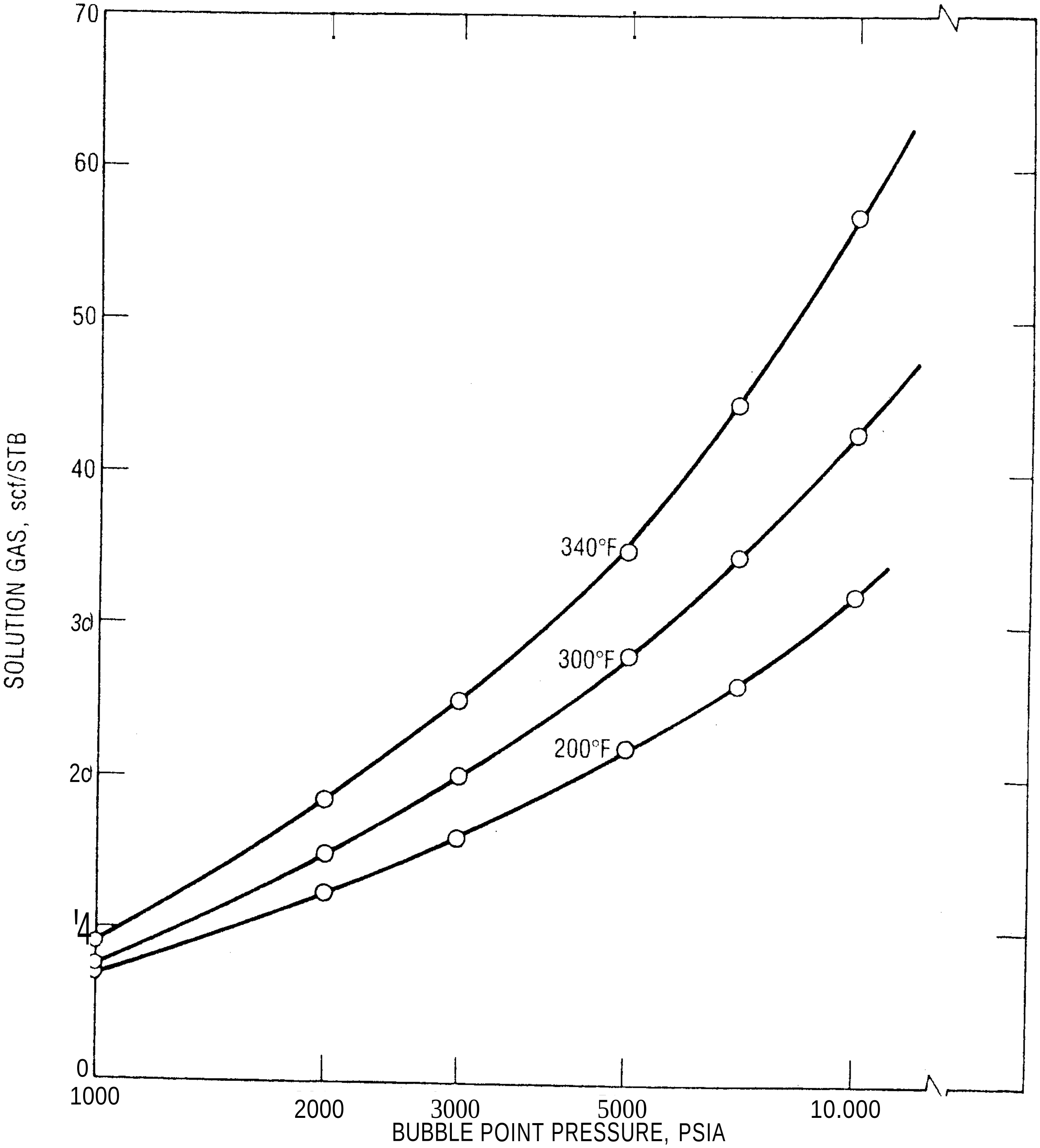


Figure 3.