WRIGHT

2.2.5 FLUIDS TRANSPORT

2.2.5 A Introduction

The objective of 2.2.5 is to present a qualitative description of the functional elements of the fluids transport system which extends from the production wells to the powerhouse intake, and from the powerhouse discharge to the injection wells. This description is intended to provide supporting background information for the discussion of Overall System Design in 3.0. The description identifies the distinguishing physical features of the supply and return components, as well as those parameters and relationships which most strongly affect the technical and economic performance of the fluids transport system.

2.2.5 B Wells Discharge

The discharge from geothermal well-bores can be in the form of either all vapor (single phase), or all liquid (single phase), or a vapor/liquid mixture (two phase).

Free-flow: All economically attractive free-flow wells discharge either dry-steam or a vapor/liquid mixture as a result of reservoir pressure only.

Pumped-flow: Under certain circumstances, it is technically and economically necessary to mechanically pump the fluid from the wells. For this purpose the pump is installed down in the well casing. The total pressure provided by the reservoir plus the pump is sufficient to prevent boiling (flashing), release of non-condensible gases, and consequent deposition of solids. An auxiliary pump, which is located above ground near the well-head, is required to maintain single-phase flow and prevent release of disolved gases thru the entire transport/conversion system.

Single-phase liquid flow thru the entire transport/conversion system is a necessary condition for the effective operation of the simple binary energy conversion process, because it prevents blocking the binary heat-exchanger with water vapor and released non-condensible gas. The power required to drive the deep-well pumps is substantial and it must be subtracted from the gross power output of the system. Commercially available deep-well pumps currently have a maximum continuous operating temperature of approximately 180° C (356°F), and a limited flow capacity. These temperature and flow limitations make them marginally useful for medium temperature geothermal applications, and not at all applicable for high temperature cases. At present, there are at least four concepts of deep-well high temperature pumps which are in various stages of development in the United States. Certain of these concepts have been advanced to the hardware stage, but none of them are commercially available at the present time.

2.2.5 C Phase Separation

In free-flowing, liquid-dominated wells, the boiling (flashing) begins down in the bore-hole (or in the geological formation) and it must be completed in the flash/separator vessels above ground.

Fluid pressure is reduced at the flash/separator to cause final boiling; the resulting liquid and vapor phases are then separated. The percentage of steam (mass basis) that is released is determined by the heat content (enthalpy) of the saturated 100%-liquid in the bore, and by the selected levels of pressure in the flash/separator. One or more sequential levels of flash pressure can be used to achieve the system thermodynamic performance which gives the most favorable economic performance.

The flash/separation process can be completed in multiple flash/separator stations located near the well-heads, or in one flash/separator station located at the powerhouse after two-phase flashing-flow transmission. Substantial savings in capital cost may be achieved by using a single flash/separator station at the powerhouse, with a single two-phase transmission pipe instead of separate parallel transmission pipes for each pressure level.

Economic comparisons of the available options will identify the most favorable choice.

2.2.5 D Piping Systems

Characteristics of the flow stream which must be known in order to perform the transport system design include: static and dynamic pressures, temperature, vapor/liquid ratio (thermodynamic quality), identification of entrained solids (if any), and chemical constituents of the flow stream. Designing economically competitive two-phase, flashing-flow piping systems is more complex than designing single-phase piping systems, however such a design employs the same technical and economic parameters. The two-phase flashing-flow piping system is economically advantageous when used with the double flash process, especially with high-pressure, high production wells. Limited experimentation has been conducted for the purpose of verifying the theoretical analysis of two-phase flashing-flow in horizontal pipes (See Ref. 1 and 2).

In the design of pipelines for carrying single phase fluids, there are no unsolved tecnological problems. Nevertheless, there are a number of significant differences between geothermal plants and the usual industrial plants, for the following reasons:

a) the physical and chemical characteristics of geothermal fluids

b) the requirements for repeatedly heating and cooling the piping system; the pipe must be worked at relatively low stress levels to maintain elasticity

c) relatively long runs of piping which are often located on very steep terrain

The design objective is to reduce pressure loss, reduce heat loss, and minimize system capital & operating cost. Often, the engineering values actually chosen are different from the theoretical values, because of manufacturing standarization of the dimensions of the pipe and the insulation. A topographic survey of the proposed pipe routes is essential to carrying out the preliminary design. The design engineer must consider the most extreme range of temperature expected because the pipeline, which is anchored in multiple sections, must be free to move laterally and longitudinally between the anchors. The use of bellows-type expansion joints should be used as seldon as possible, because of high initial cost and severe maintenance problems. For economic reasons, it is preferable to rely on the geometry of the pipeline to provide flexibility required to accommodate the thermal expansion. The pipeline layout pattern can have a triangular or rectangular base. The omega-type expansion loop is expensive, and often does not conform to the topography of the pipe-route terrain.

Pipelines for transmission of steam (including superheated) must have drain valves located at their low-points for removal of condensate. The use of automatic steam-traps should be limited to only special cases, because solid deposits can cause trap failure, resulting in unacceptable stresses to be imposed on the pipeline. It is preferable to maintain a continuous small discharge of steam to remove the condensate as small droplets.

2.2.6 ENERGY CONVERSION

2.2.6 A Introduction

The objective of 2.2.6 is to present a qualitative description of the presently available energy conversion processes, as supporting background information for the discussion of Overall System Design in 3.0. The description identifies the distinguishing physical features and relative technical merits of the conversion processes. It also identifies those parameters and relationships which most strongly affect the economic competitiveness of the various candidate energy conversion processes.

2.2.6 B Available Conversion Processes

1) Generalities

At present, there are essentially three basic energy conversion processes which are either well established or are strong future contenders. Each of these basic conversion processes has a number of variations which are intended to make the process more widely applicable. Certain of the conversion processes (and their variations) can be combined with each other in order to achieve technical advantages which facilitate greater economic competitiveness. All of these energy conversion processes employ the classical Rankine thermodynamic cycle.

2) Dry-steam Process

The Dry-steam Process is the simplest available process and therefore it is the least costly to build and to operate. Dry-steam, which discharges as a single-phase from the production wells, is fed directly into the turbine after relatively simple pre-treatment. The turbine exhaust vapor is condensed, and this liquid can then be supplied to an evaporative cooling system (i.e. towers, spray ponds, etc.), or put to other uses. Any condensate which is not consumed during cooling (or other use) can be disposed of by the methods discussed in 2.2.4.

The major advantages of the Dry-steam process are:

a) lowest initial capital cost
b) provides its own cooling-water supply
c) relatively small volume of waste liquid
d) it is based on well established, proven technology

There are some disadvantages associated with this process, such as:

a) dry, fine solid material (rock dust), which is entrained in the high velocity steam from the well, causes erosion of the turbine blades and embedment in the turbine blades surface
b) corrosion rates are accelerated in the presence of chlorine gas in superheated steam
c) the energy penalty for removal of relatively large volumes of non-condensible gases

3) Flashed-steam Process

In this context, the term "flashing" is synonimous with "boiling". The flashing process, which starts down in the well-casing, is continued and completed in the flash/ separator vessel by means of a sudden pressure reduction at the point where the two-phase stream from the wells enters the flash/separator vessel. Immediately after flashing, the two phases are separated from each other and are continuously withdrawn from the vessel thru two separate pipelines. The steam-phase is fed directly into a high pressure turbine. The liquid-phase may be discarded immediately, or if it still has a sufficiently high energy content, it may be flashed again thru another flash/separator to a second lower pressure level. Again the two-phases are continuously separated, and the resulting low-pressure steam is fed into a low pressure turbine (or to low-pressure stages of the high-pressure turbine). By this procedure, approximately 10 to 25 percent of the total mass flow from the reservoir can be converted to usable steam. Under certain special circumstances it may be economically advantageous to incorporate a third stage of flash. However, each case must be examined individually in the light of all prevailing technical and economic factors in order to determine the most favorable combination, and to provide sufficient pressure for reinjection.

The percentage of energy obtained depends on the total initial energy content (enthalpy) of the reservoir fluid and the selected flash-pressure levels. The residual liquid from the last stage flash is continuously withdrawn from the flash/separator and is discarded by one of the methods discussed in 2.2.4. A number of variations and refinements can be introduced into the above basic process in order to achieve greater economic competitiveness. For economic reasons, the Flash-steam process is best suited to high temperature fluids.

The advantages of the flash-process are:

a) relatively clean steam is supplied to the turbine
b) the condensed exhaust vapor from the turbine can be used as the water supply to an evaporative cooling system

The disadvantage of this process is:

As with the dry-steam process, it can release large volumes of non-condensable gases (if originally present in the reservoir). The presence of these gases degrades the turbine performance and requires expenditure of additional energy for their removal from the conversion system. The discharge of large volumes of waste-liquid will be disposed of by the methods discussed in 2.2.4.

4) Binary Process

The most significant aspect of the binary process is the transfer of thermal energy from the geothermal fluid to a designer-selected "working-fluid", within a heat exchange vessel. During this heat transfer step, the working-fluid is vaporized; it is then fed directly into the turbine to produce the required mechanical work. The binary energy conversion process for geothermal applications is in the experimental/developmental stage at the present time. The most common type of heat exchanger provides a mechanical barrier between the geothermal-fluid, and the working-fluid, which prevents physical contact between them. However, a serious operational problem arises if solid materials become deposited from the geothermal fluid onto the heat transfer surfaces. Relatively thin layers of solid deposits on the heat transfer surfaces will greatly impair the performance of the Binary Process. As a means of overcoming this difficulty, experimental investigations are currently being conducted in which the hot geothermal-fluid is intimately mixed with an immicible working-fluid in order to achieve the required heat-transfer effect without the use of heat-transfer surfaces (See Ref. 3 and 4). This technique is commonly referred to as "direct-contact" heat transfer. Elimination of the heat-transfer surfaces eliminates the deposition problem within the heat exchanger. Although this heat-transfer method has long been used successfully in other industrial applications, it must be understood that much developmental work remains to be completed before it is proven for use in geothermal applications.

Several hundred chemical substances exist, whose physical properties make them suitable as thermodynamic working-fluids. Unfortunately, many of these fluids have undesirable chemical and physical characteristics, or high cost, that may disqualify them for most applications. An *ideal* working-fluid that possesses all of the desirable physical properties but none of the unfavorable properties, does not exist. Therefore, selection of a working-fluid involves a series of compromises. The problem of discriminating among the candidate fluids, and finally selecting the *one* fluid that best satisfies the requirement of a given application is a rather involved task. The systematic selection of the most favorable working-fluid first requires development of a set of selection *criteria* that reflects the requirements of the application at hand. Such a procedure as described above, is outlined in Ref. (5), and an illustrative example is presented. The physical and thermodynamic properties of approximately 35 different working-fluids are tabularized and charted in Ref. (6).

Existing physical property data (thermodynamic and transport) for many of the most promising single-component working-fluids is often not reliable. This is particularly true in the vicinity of the fluids´ critical point. This deficiency of reliable physical data is even more severe with the hydrocarbon mixtures (blends). Theoretical and experimental investigations are currently being conducted for the purpose of obtaining and verifying the required physical property data.

The materials, and technology that are presently available to turbine manufacturers are more than adequate to meet the performance requirements of hydrocarbon turbines that are intended for electric power generation in the geothermal industry. However, the turbine units that have been constructed to-date are of relatively small power capacities, the largest one of which is of the order of 25,000 hp (18.64 MWm). Increasing the power capacity from existing designs, and making other necessary modifications, are not considered to be major technical problems. It must be recognized however, that although designs of 65 MWe already exist for hydrocarbon turbines intended for geothermal binary applications, the equipment itself does not yet exist. Building such large capacity hydrocarbon turbines, and testing them successfully still remains to be accomplished.

The "sink temperature" is the temperature of the atmosphere or natural water bodies to which heat is rejected from electric power plant conversion cycles (and other thermodynamic cycles).

In conjunction with the application of the binary energy conversion process, it is possible to achieve substantial reductions in the average annual cost of electrical energy at the busbar by taking advantage of daily and seasonal variations in atmospheric temperature ("sink temperature").

This mode of operation requires that the power plant cooling system closely follow the sink temperature as it declines and rises during daily and seasonal changes. This concept is commonly referred to as the "floating-cooling mode". The single most critical physical parameter controlling the feasibility of floating cooling is the molecular weight of the working-fluid. Power cycles, having working-fluids of relatively high molecular weight (such as Isobutane, M=54), can achieve substantial increases in thermodynamic efficiency by following a declining sink temperature. However, cycles using water as the working fluid (M= 18), such as in dry-steam and flash-steam processes, cannot achieve an economic advantage by this method. Detailed discussions of this technique and its merits are presented in Ref. 7, 8, 9, & 10.

The advantages of the binary process can be summarized as follows:

1. eliminates contamination of the turbine case and rotor by the geothermal fluid, resulting in no corrosion or erosion

2. Through the use of low boiling-point working fluids, it is possible to economically extract energy from low thermal-quality geothermal fluids.

3. The higher molecular weight working-fluids make possible a reduction in the turbine annular discharge area, and therefore a reduction in turbine size and cost.

4. Operating the binary process in the floating-cooling mode (when possible) can yield a substantial reduction in the busbar cost of energy.

5. The binary process can preclude release of nuisance gases to the atmosphere, or solid and liquid wastes to the land surface.

6. The costs of fluid-production and fluid-disposal are the dominant components of the cost of electric energy for low temperature resources because of low net resource utilization efficiencies. Because the net utilization efficiency of binary cycles is inherently higher than flashed steam cycles at low temperatures, the electric energy cost for binary process can be the lowest.

The <u>disadvantages</u> of the binary process can be summarized as follows:

1. The leading candidate working-fluids, which are preferred because of their thermodynamic and economic advantages, are highly flammable.

2. Deep-well pumps, suitable for continuous high volume, <u>high</u> temperature service in the severe environment of a geothermal well, are not yet commercially available; however, they are under development at this time.

3. The problem of excessive deposition from the geothermal fluid onto the heat-transfer surfaces is only partially solved.

4. The necessary developmental work, associated with constructing and perfecting large-capacity hydrocarbon turbines for electric power generation remains to be performed.

Although full commercial application of the binary conversion process will require development of long-life deep-well pumps, and construction and testing of high power capacity hydrocarbon turbines, there is a substantial portion of the lower temperature resources on which the binary process is clearly the superior choice.

REFERENCES

Fluids Transport System and Energy Conversion System

1) Masahiro Soda, Kentaro Aikawa, Yasuro Takahashi Katsuto Kubota, Yasuhiko Ejima "Experimental Study on Transient Phenomena of Steam-Water Mixtures Flowing Through a Large Pipeline for Geothermal Power Stations". U.N. Symposium on the Development and Utilization of Geothermal Resources, San Francisco May, 1975.

2) Kentaro Aikawa, Masahiro Soda "Advanced Design in Hatchobaru Geothermal Power Station". U. N. Symposium on the Development and Utilization of Geothermal Resources, San Francisco May 1975.

3) Urbanek, M.W., "Development of Direct Heat Exchangers for Geothermal Brines, Final Report", DSS Engineering, Inc., Serial #LBL-8558, UC-66d, October 4, 1977 - June 30, 1978.

4) Pessina, S., Rumi, O., Silvestri, M., and Sotigia, G., "Gravimetric Loop for the Generation of Electrical Power from Low Temperature Water", U. N. Symposium on the Development and Utilization of Geothermal Resources, Pisa 1970, Vol. 2, Part I.

5) Horn, G. and Norris, T. D., "The Selection of Working Fluids Other Than Steam for Future Power Generation Cycles", The Chemical Engineer, November 1966, p. CE 298 thru CE 305.

6) ASHRAE, "Thermodynamic Properties of Refrigerants, 1969", American Society of Heating, Refrigerating, and Air-Conditioning Engineering, Inc., 345 East 47th St., New York, New York, 10017.

7) C. J. Shaffer, "Floating Power Optimization Studies for the Cooling System of a Geothermal Power Plant", TREE-1164 EG&G Idaho, Inc., Idaho National Engineering Laboratory, Idaho Falls, August 1977.

8) H. E. Khalifa, "Effect of Seasonal Variations of Ambient Temperature on the Performance of Low Temperature Power Cycles", Division of Engineering Report Brown University COO/4051-10, Providence, R. I., June 1978.

9) H. H. Pines, W. L. Pope, M. A. Green, P. A. Doyle, L. F. Silvester, and R. L. Fulton, "The Thermodynamic and Cost Benefits of a Floating Cooling Geothermal Binary Cycle Power Plant at Heber, California", presented at the Geothermal Resources Council 1978, Lawrence Berkeley Laboratory, Berkeley, California.

10) H. S. Pines, M. A. Green, W. L. Pope, and P. A. Doyle, "Floating Dry Cooling, a Competitive Alternative to Evaporative Cooling in a Binary Cycle Geothermal Power Plant", presented at the 1978 Annual Winter Meeting of the ASME, San Francisco, California, December 10-15, 1978, LBL-7087, July 1978, Lawrence Berkeley Laboratory, Berkeley, California.

Final English Draft
4/28/76

3.0 Overall System Design

3.1 Introduction

A general methodology for the conceptual design of a geothermal energy conversion system is presented in this section. When the geothermal reservoir characteristics and field potential have been established in the feasibility stage, a conceptual design of the geothermal power plant can be performed. The conceptual design stage can be sub-divided into the following steps:

1) information gathering,
2) identification of candidate conversion alternatives,
3) selection of the best geothermal alternative,
4) evaluating its commercial feasibility.

A simplified sequence of events and decision points will be outlined for the conceptual design period which can be used by the management team to control this phase of the project.

For liquid-dominated resources in the temperature range between say 150 C and approximately 220 C, it will often be necessary to consider other energy conversion plant types besides the conventional flashed steam process. System level simulation and optimization of competing alternatives using digital computers will facilitate selections. Features of currently used computer programs will be highlighted along with techniques for: 1) selecting, screening, and eliminating candidate power plant alternatives, 2) optimizing the serious candidates, and 3) making the final geothermal power plant type selection. At that point the feasibility test for commercial operation will be discussed followed by a very brief outline of the subsequent preliminary design phase. The ultimate objective of this phase is to provide a complete specification of the technical and economic aspects of the system design which would be used to obtain the necessary capital for 1) final design, 2) production drilling and testing and 3) plant construction.

Geothermal energy conversion systems are capital intensive. Economic risks are involved in the exploration phase and the subsequent development phase. The financing for resource development and plant construction pre-supposes a very well defined plan to insure that the investment is recoverable. The new geothermal system developer must become familiar with the technical language to deal effectively with specialized outside organizations.

3.2 Definitions of Terms and Concepts

System

The geothermal power plant system as defined in this section consists of 1) the geothermal resource, 2) the geofluid production and disposal sub-systems (wells), 3) the fluids transport sub-systems (supply and disposal piping) and 4) The energy conversion sub-system—commonly referred to as the power house. This system concept is necessary to insure that important sub-system interdependencies are properly characterized in both a technical and economic sense. Only with a system level of characterization will it be possible to perform a general system design optimization with the objective of minimum cost electric energy.

Synthesis

The term synthesis used herein is that process of 1) selecting technically feasible candidate energy conversion systems, 2) reducing those candidates to a limited, or managable, number for subsequent detailed analysis, 3) defining the system boundaries and input assumptions and 4) selecting the degree of detail to be adopted in the analysis.

Analysis

The term analysis used herein is that quantitative process which transforms the input information through the system simulator (or thermodynamic system model) into a specific design. This specific design has technical and economic characteristics which are direct functions of a specific set of independent system variables.

Optimization

The term optimization, on the other hand, refers to that iterative quantitative analysis process of modification of the independent system variables with the goal, or objective of achieving the optimum design.

Optimization is an important part of geothermal power plant design because of inherently low process thermodynamic efficiencies.

Optimization is particularly useful when comparing various competing geothermal energy conversion alternatives for that intermediate temperature range where, for example, the choice between the binary Rankine cycle process and the conventional flashed steam plant thermodynamic efficiency, maximum resource utilization efficiency, or maximum specific net energy, depending on design constraints and other considerations. For the purpose of this discussion the system design objective is minimum cost of electrical energy. This is the only logical, or consistent, overall system design objective with feasibility defined as above (Ref 1).

3.3 Binary Rankine Cycle Complexity and Applicability

The simple binary Rankine cycle process is inherently more complicated than the two-stage flashed steam process. Determining the overall optimum binary cycle for a given resource is difficult because:

1) Thermodynamic and economic performance is influenced by working fluid choice.
2) Six independent plant thermodynamic state parameters are required to characterize thermodynamic and economic performance.
3) If the production well flow must be pumped to maintain single phase liquid in the

process is not obvious. Optimization is especially important in the lower resource temperature range, where binary processes are obviously best, but where economic feasibility is questionable.

Feasibility

A geothermal power plant system is considered feasible when electric energy can be produced at a cost comparable with other available commercial alternatives -for example; 1) hydroelectric plants, 2) fossil fired plants, and 3) nuclear power plants.

Design Objective

The term design objective can, and often does mean many different things to many people. Depending upon whether one is designing the entire system or simply a sub-system, design constraints differ and, therefore, design objectives may logically differ. Design objectives for the power plant sub-system, for example, might be; minimum plant capital cost, maximum primary heat exchanger, the production well mass flow rate is also optimizable.

4) The variability of the system ambient sink temperature can be exploited for additional performance improvements.

Sophisticated computer simulation and optimization routines are obviously required for optimum design. However, the binary Rankine cycle process should not be overlooked by those Latin American countries not posessing high temperature hydrothermal resources. Resource utilization and net thermodynamic cycle efficiencies are higher than flashed steam in the economically applicable temperature range. Depending upon the resource temperature and the cost of electric energy from non-geothermal alternatives, binary cycles will not only be economically feasible, but also the best overall system choice.

3.4 Software State-of-the-art

Some of the more sophisticated and generally useful geothermal system design codes (Ref. 1) incorporate the following features:

1) Modular structure
2) Separate, extensive fluid properties routines
3) Formal economic and thermodynamic process routines
4) Multiparameter optimization capabilities
5) Detailed process design routines
6) Efficient coding
7) User oriented, interactive input with data sufficiency/consistency pre-processing

In addition, previous optimization difficulties attributed to too slack or inconsistent convergence criteria have been overcome. A general economic optimization algorithm has been developed and applied successfully on complex geothermal systems with both continuous and discontinuous objective functions. Binary cycles with six independent process parameters can be optimized in one step at a computation cost of about $30.00 or less.

3.5 Energy Conversion sub-system Synthesis

None of the existing powerful geothermal system simulation/optimization codes can perform the time saving and very important synthesis function which preceeds design objective definition and optimization. Skill and good judgement with respect to system characterization to capture the essential elements of the conversion process are enhanced through extensive understanding of applicable theory. Because of the many potentially controversial technical and economic factors, it is clearly beyond the scope of this document to discuss the synthesis function in detail.

3.6 Overall System Optimization Methodology

After candidate plant types have been selected through some earlier synthesis process, the thermodynamic system is defined to the degree desired for submittal to the computer. The designer specifies some overall system design Objective Function (i.e. minimum busbar cost, minimum capital cost, etc.) and selects some or all of the system independent thermodynamic state parameters as Optimizable Parameters.

Multiparameter optimization calculations generally proceed as depicted in Figure ~~4~~3.1. With the first few passes through the optimizer, the objective function and its numerical derivatives with respect to each of the optimizable parameters are computed. Using this information, the optimizer makes new choices for the optimizable parameters to converge finally on the optimum design. Very important geothermal system optimization considerations are discussed at length in reference 1.

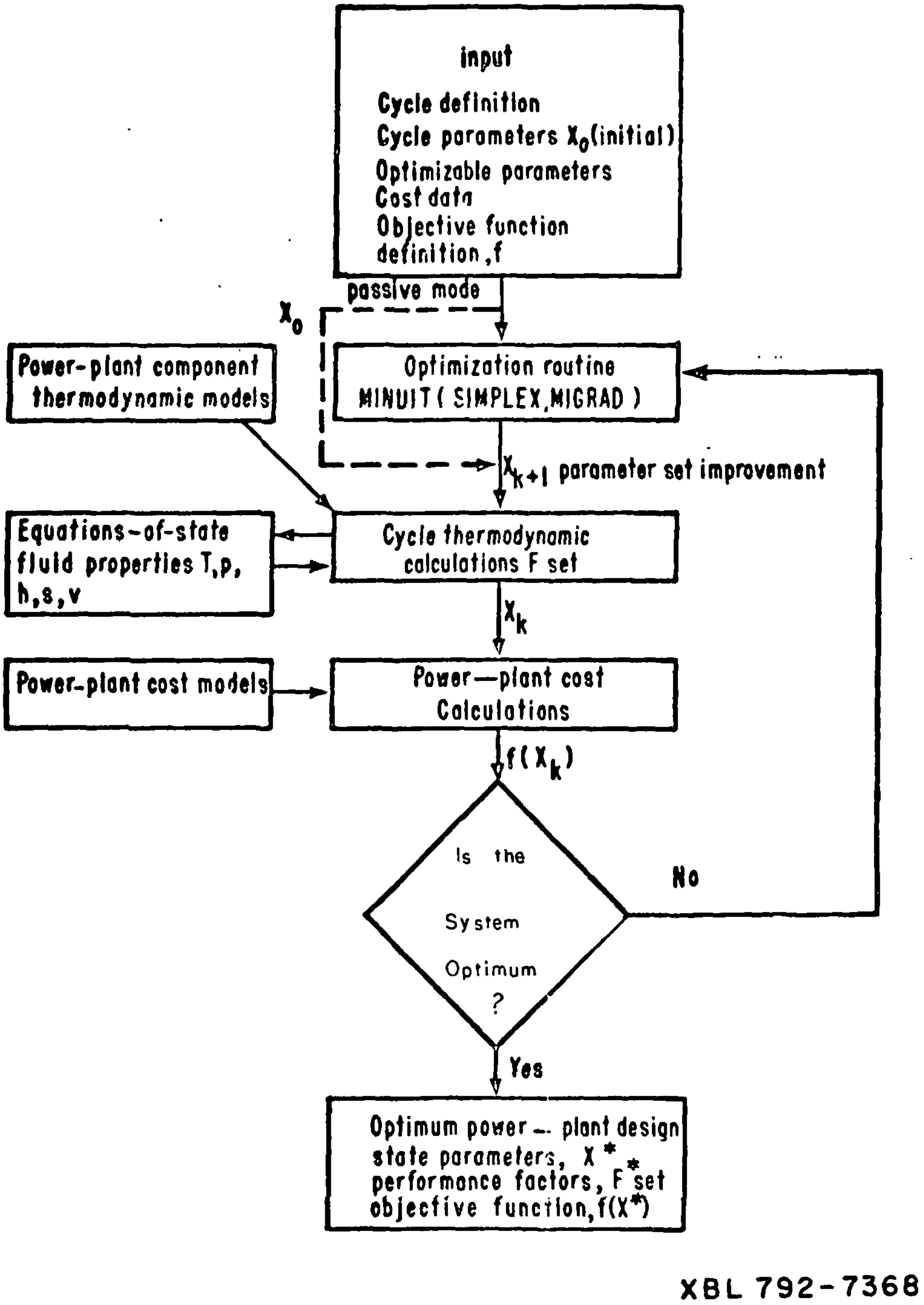

Fig. 3.1

Simplified logic block diagram illustrating calculations in the Design Optimization Mode of the LBL developed process simulator, GEOTHM. (Ref. 2)

3.7 Feasibility Test

After the obvious candidate geothermal energy conversion systems have been optimized for minimum energy cost, the best system is compared with the known energy cost from other non-geothermal alternatives available to the grid. If the feasibility test fails, but by only a few percent the obvious thing to check is the specified system net power output, P_N. The optimization process is repeated with new guesses of P_N until the best candidate plants have been optimized in all relevant variables.

If the feasibility check continues to fail it may be necessary to return to the synthesis stage and examine additional conversion systems. If the best alternatives are flashed steam cycles, the specified number of flash stages can be re-examined. If binary processes are best, other working fluids, multiple stages, or, perhaps, floating cooling could be beneficial. If the feasibility test continues to fail by large margins, the geothermal project should probably be abandoned. — expand! — Local econ, don't [illegible]

3.7.1 Risk Acessment

If the selected design is feasible, but design uncertainties, or risks, are known to be high, it would be wise to re-examine those factors which contribute before going on to the next design phase. Uncertainties might be reduced with improved characterization of:

1) The resource. Get more or better quality technical data if practicable (See 2.2)
2) The overall system. Is the degree of system characterization adequate? Have all important system interdependencies been examined?
3) Costs. Has the best available data been used?

If the geothermal power system is economically competitive, all requirements of the grid have been met, and risks are acceptable to the project management, the preliminary design phase begins.

3.7.2 Funding Agency Requirements Check

By this point the management team should have investigated the formal financial documentation requirements which will be imposed by the funding agency(s). It should be recognized that the level of risk deemed acceptable and adopted by the program management team during the conceptual design phase may not be compatible with funding agency standards.

In addition, the financial assumptions and acceptance criteria used in the system conceptual design phase may have to be modified temporarily so that commercial feasibility can be verified by the lender(s) methods.

3.8 System Design Summary

Because of a) the lack of an existing technology base, b) little reliable cost information, and c) increased system thermodynamic complexity, design uncertainties will probably be greater for the binary process than for the flash steam process, for the forseeable future.

On the other hand, system development risks do not necessarily correlate with these plant design uncertainties (Ref. 3,4,5). Commercial operation of a 10 MWe geothermal binary plant on a 180 C resource in East Mesa, California will very probably begin in 1979 (Ref. 6). The development of moderate temperature resources by binary cycles in Latin American countries should not be overlooked. Multiparameter optimization techniques have reached a level of maturity, such that they can be applied to hydrothermal systems on a commercial scale to perform complex system economic trade-offs with a minimum of bias. These overall system models could reduce design undertainties and the level of risk portrayed to the investor.

3.9 References

1) Pope. W. L.. et al, "Conceptual Design Optimization" - Section 8.2. of

<u>A Sourcebook on the Production of Electricity from Geothermal Energy,</u> J. Kestin, Editor, (in press) Brown University, Providence, R. I, 1979.

2) M. A. Green, R. N. Healey, H. S. Pines, W. L. Pope, L. F. Silvester, and J. D. Williams, "GEOTHM-Part 1, A Users Manual for GEOTHM. (Computer Design and Simulation of Geothermal Energy Cycles.)," LBL publication-202, July 1977.

3) B. Holt, "Geothermal Power Plant Design Risks", Proceedings of the Second Geothermal Conference and Workshop held at Taos, New Mexico, June 20-23, 1978, prepared for EPRI Fossil Fuel and Advanced Systems Division, Vasel Roberts , Project Manager, EPRI WS-78-97, October 1978.

4) T. R. Fick, et al, "Some Technical Risks in Geothermal Power Plants," Proceedings of the Second Geothermal Conference and

Workshop held at Taos, New Mexico, June 20-23, 1978, prepared for EPRI Fossil Fuel and Advance Systems Division, Vasel Roberts, Project Manager, EPRI WS-78-97, October 1978.

5) N. A. Samurin, "Preliminary Design of Axial Flow Hydrocarbon Turbine Generator Set for Geothermal Applications", Proceedings of the Second Geothermal Conference and Workshop held at Taos, New Mexico, June 20-23, 1978, prepared for EPRI Fossil Fuel and Advanced Systems Division, Vasel Roberts, Project Manager, EPRI WS-78-97, October 1978.

6) Hinrichs, T. C., Status Report of the Magma Power Company 10 MWe Binary Cycle Power Plant at East Mesa, Ca. oral presentation at the Geothermal Resources Council 1978 annual meeting, Hilo, Hawaii, July 25-28, 1978.