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Solar Total Energy Modularity Study

McDonnell Douglas Astronautics Company

Prepared for Sandia National Laboratories under Contract No. 07-7164

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SOLAR TOTAL ENERGY MODULARITY STUDY

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ABSTRACT

This is the final report of the McDonnell Douglas Astronautics Company's work on the Solar Total Energy Modularity Study. It presents the results of a 26-month study which included the survey of industrial sites to obtain site-specific energy demand data and other information pertinent to designing solar total energy systems for the sites. Solar systems, using single-axis tracking parabolic-trough solar collectors, were designed for each of the sites to the depth necessary to verify feasibility and identify major system components. Cost and performance estimates for each of the systems were estimated and used to predict internal rate of return over a range of collector cost and performance. Parametric system and component performance data are presented along with solar insolation data for all the Sol-Met data stations which allows the rapid assessment of solar system feasibility for future potential industrial users.

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Section 1.0

INTRODUCTION AND SUMMARY

The objectives of this program were to establish a credible industrial demand data base to determine if a modular approach to solar total energy systems is feasible, establish module sizes, investigate the attendant economics, and recommend areas for further development. The primary emphasis in the industrial survey was to determine the land available for use in the installation of a solar total energy system.

All sizings were limited to parabolic troughes in an east-west orientation. Analyses were conducted to determine the effect on field sizing due to improvements in collector characteristics and turbine efficiency. The results indicate that the greatest reduction in field size was due to improvements in the reflectivity and absorbtivity of the parabolic trough (31%). Improving the turbine efficiency to 0.85 yielded a 6 percent reduction in field size.

Integration of data obtained in this study with existing information indicates that the majority of the industrial processes occur at approximately 350°F. The electrical loads varied considerably as did the process flow rate. To accommodate the latter, field requirements were determined for all Sol-Met locations as a function of process temperature, flow rate, and electrical generation capability. (Depending on the independent variable selected, i.e., flow rate or electrical demand, use of these data may result in only partial load supply.)

The results of the industrial survey yielded process information and electrical requirements, but in the main, the question of land availability as a limiting factor in satisfying full load requirements remains unanswered.

The majority of the industries surveyed expressed a genuine interest in solar and in the total energy concept in particular. Several were in the process of investigating fossil fired total energy systems, but had not considered solar because of their misconception of the temperature capabilities of the various options.

2.0 INDUSTRIAL SURVEY

One of the major objectives of the study was to establish a credible industrial demand data base that would be of use in this study as well as future efforts to determine the commercial viability of solar total energy systems (STES). The types of demand information sought included both process heating and cooling and electrical demands and their associated duty cycle information as well as geographical data pertaining to land availability and climate. Included in the survey was a solicitation of pertinent economic data such as, current cost of energy and company capital investment criteria.

2.1 CONTACT PHILOSOPHY

The basic philosophy was one of personal contact as opposed to blanket mailings or telephone only contacts. This was necessitated by a desire to obtain first hand site specific data as well as affording an opportunity to enlighten and educate the industrial energy user as to the capabilities of solar energy systems.

The survey was limited, by information gained in previous studies, to industrial groups who by nature of their processes were large users of energy and were known to use a variety of energy types (i.e., both electricity and process heat) which would allow the analyses of solar total energy systems. An example of such an industrial group is SIC 20, food and kindred industries. Other high energy using industries were not considered for the survey because of the high temperature at which their processes operate. An example of such an industrial group is SIC 33, primary metal industries.

Several information sources were used in attempting to identify potential interviewees. These included national listings of corporate personnel such as Standard and Poors; National, regional, and local trade association registers;

state and local business directories such as those available from local Chamber of Commerces; and local telephone "yellow pàges." As can be surmised this led to contacts with all levels of management personnel from corporate and division management to local plant maintenance supervision. There were advantages and disadvantages to both ends of the spectrum. In several cases local management had the information available but did not have authority to release or discuss it. Upper management personnel were often hard to reach for unsolicited contact and many calls were unsuccessful or unreturned. The most successful contacts were those made to middle management as follow ups to personal contacts established while attending industrial conferences relating to energy. In these cases the people contacted were associated with, or were responsible for corporate energy policy pertaining to energy management and conservation. Two such contacts led to four of the actual site visits.

Once positive contact had been established, meetings were held, usually at company or corporate headquarters, and briefings pertaining to the study were given to appropriate people. These briefings were repeated on a less formal basis to local plant or site management. Data for use in the study was obtained at both meetings with the level of detail generally increasing at the local level. In one case company management was located at the plant site. The entire process proved to be quite lengthly in terms of the elapsed time between initial visits and site visits due to personnel availability and a desire to schedule at least two visits per out of town trip for economic reasons. This required in some cases coordination of scheduling with two different companies as well as study personnel. Unfortunately, no easy solution to this problem was found and this among other things limited the number of site visits to well below the anticipated number. However, this philosophy worked well in terms of the data obtained. In all but one of the site visits more than ample data to perform the system performance and economic studies was obtained. This was due largely to the generous cooperation of the people contacted, who by nature of their position in their respective companies had a keen interest in energy conservation.

The collection of the data was generally one of iteration. As the system design was undertaken certain additional data was sometimes required to clarify some detail of the energy use. In most cases follow up phone calls were sufficient to verify assumptions made during the system design or to obtain further information. In order to close the loop,results of the system studies have been or are being given to the industrial contacts at their request.

2.2 BRIEFING MATERIALS

As mentioned in the previous section a briefing to industrial personnel was a basic part of the solicitation process. Part of the basic philosophy was to provide for an exchange of information between the industrial user and a representative of solar technology. The format of the briefing was such that it presented to the industrial user not only the objectives and data requirements of this study but an overview of solar technology in terms of candidate components and system options available.

This was done by briefly highlighting the objectives of this study, emphasizing the requirement and necessity of obtaining industrial energy demand along with a discussion of the study approach and an explanation of how, and in what form, the data would be used.

Solar component candidates were presented in the form of collector types. The advantages and limitations of two axis, single axis and non-tracking collector systems were discussed along with their potential applications. Solar energy system options utilizing single axis parabolic troughs were presented using schematic examples of process heat, electrical generation and total energy systems. Potential applications of each were discussed with emphasis given to the solar total energy system.

A specific example of a solar total energy system design consistent with the level of design for this study was presented. The energy demand data used in the design was presented and discussed in terms of both content and format. This helped establish the amount and types of data that were being solicited from the particular industry. An example of the type of useful parametric data that can be derived using the demand data long with a system design was presented. A detailed schematic was shown as an example of the depth to which the study would reach, with a discussion of how the system was influenced by both the demand and component performance.

An example of an economic analyses of an industrial solar total energy system based on the previously discussed system design followed. This included a list of the pertinent system design and performance characteristics along with the pertinent economic/cost data used in the example study. The data was shown for a range of collector costs ranging from optimistic to pessimistic. The pertinent results of the analyses were highlighted in terms of internal rate of return, payback period, and maximum negative cash flow. This data was presented in terms of cumulative cash flow estimates for each collector cost scenario.

Having established by this point in the briefing the general data requirements, and what their intended use would be through the previously discussed examples, the actual survey questionnaire was presented and discussed. At this time the actual data being solicitated was discussed in terms of format and availability.

Following the briefing, meetings were held with appropriate people to obtain as much of the data as was available. The availability depended on the location of the briefing (i.e., either at the site or at company offices). In some cases the forms were left to be filled out and sent later. It was determined to be advantageous, time allowing, to obtain as much of the data as possible while in personal contact.

The actual briefing material used, is contained in Appendix A of this report along with the survey questionnaires filled out to the extent of the data obtained from each of the sites.

2.3 DEMAND DATA SUMMARY

The demand information obtained from the survey questionnaires is recompiled into summary form along with other pertinent demand information obtained from the user for use in the system designs. The type of information used in the designs is given in Table 1 by type of energy use. Details of energy use not necessarily given in the survey questionnaire must be obtained particularly in the area of process cooling or refrigeration requirements. This information is used in determining proper splits of vapor compression and absorption refrigeration in the system designs required to provide a balanced total energy system. The importance of this splitting of cooling loads is discussed in Section 3 of this report.

Table 2 contains the demand data obtained from each user for each of the

TABLE 1
ENERGY DEMAND INFORMATION

ELECTRICITY	Purchased or Generated (Split): Peak and Average Demand (KW): Annual Use (KW HRs): Duty Cycle Information (Hours per day, Start Time, Time of Day of Peak, Number of Days per Week, Operating Weeks per Year): Seasonal Variation of Above: Annual Cost (Demand and Energy)
PROCESS HEAT	Purchased or Generated (Split and Source) : Energy Source (Gas, Oil, Electricity, Other, Generation Efficiency): Transport Fluid (Steam or Other); Generation and End Use; Temperatures, Pressures, Flow Rate (Peak, Average); Condensate Return (Amount, Temperature, Pressure): Duty Cycle Information (Same as Electrical): Seasonal Variation of Above: Annual Cost
PROCESS COOLING (REFRIGERATION AND DIRECT COOLING)	Total Amount (Tons): Source; Vapor Compression or Absorption; Drive-Electrical, Mechanical (Type of Engine), Heat Source (Steam or Other); Fuels (Gas, Diesel, Other); Amount of Each Type: Amount of Energy Derived from above Electrical and Process Heat Demand: Duty Cycle Information (as above)
ENVIRONMENTAL HEATING, COOLING, AND LIGHTING	Amounts (if not included in above) Duty Cycle (if substantially different than above)

TABLE 2

INDUSTRIAL ENERGY REQUIREMENTS

PROCESS STEAM			PEAK ELEC (KW)	LAND AVAILABILITY (ACRES)	LOCATION	DUTY CYCLE	COMMENTS
$\dot{\omega}$ (LB/HR)	PRESS (PSI)	TEMP (°F)					
37,000	150	358	2,300	400 (ALMOST SQ)	TEXAS	2 SHIFTS + 1 CLEAN UP, 24-HR REFRIG 1000 TONS	MEAT PACKING – BEEF SLAUGHTER *
40,000	100	328	3,700	12 (BOXED IN) IRREG	KENTUCKY	1 SHIFT + 1 CLEAN UP, 24-HR REFRIG 130 TONS	MEAT PACKING – SLAUGHTER AND PROCESSING *
5,000	100	328	550 (INCLUDES REFRIG)	50 (IRREG)	CALIF	1 SHIFT + 1 CLEAN UP, 24-HR REFRIG	MEAT PACKING – LAMB SLAUGHTER *
70,000	140	400	4,000	NONE AVAIL, BOXED IN (TC)	CALIF	UNK	CALIF PAPER-BOARD CORP
0	0	0	15,800	12,000 IRREG (TC)	CALIF	UNK	CALIF PORTLAND CEMENT CO
150,000	600	750	35,000	NONE – IN IND PARK (TC)	CALIF	CONT	EXXON CO., USA
833,000	1,300	750	600	UNK	CALIF	CONT	HUSKY OIL CO.
950,000	175	370	104,000	NONE – BOXED IN (TC)	CALIF	UNK	KAISER STEEL CORP
150,000	100	328	6,000	20 ALONG WATERFRONT	CALIF	UNK	KELCO CO.
112,000	600	750	17,000	60 RECT (TC)	CALIF	UNK	SIMPSON PAPER CO
7,500	15	213	4,400	LAND USED TO GROW TIMBER	CALIF	UNK	SIMPSON TIMBER CO

*SITE VISITS

TABLE 2 (continued)

INDUSTRIAL ENERGY REQUIREMENTS (CONT)

PROCESS STEAM			PEAK ELEC (KW)	LAND AVAILABILITY (ACRES)	LOCATION	DUTY CYCLE	COMMENTS
ω (LB/HR)	PRESS (PSI)	TEMP (^{o}F)					
18,000	150	358	4,000	60 (IRREG)	TEXAS	CONTINUOUS	COTTONSEED OIL * EXTRACTION
11,350 94,660	260 150	525 358	4,500 (INCLUDES REFRIG)	MINIMAL (BOXED IN)	CALIFORNIA	12 HR/DAY 6 DAY/WK 1500 TONS REFRIG	* SEAFOOD PROCESSING
3,000 9,000	220 150	390 358	1,400 (INCLUDES REFRIG)	20 (RECTANGULAR)	CALIFORNIA	CONTINUOUS 500 TON REFRIG	VEGATABLE OIL * PROCESSING
51,200 TO 116,900 (SEASONAL)	150	358	6,000 (MINE PUMPS) + MINE AIR COND.	1,000 PLUS	NEW MEXICO	CONTINUOUS	GULF MINERAL * RESOURCES CO. URANIUM MINE & MILL (1982 START)
1500,000	150	358	21,000	2,000	CALIFORNIA	CONTINUOUS	U.S. BORAX AND * CHEMICAL CORP.
3,400	100	328	UNK	13 (BOXED IN)	CALIFORNIA	UNK	SNACK FOOD * PRODUCTION
5,000	125	344	303 (INCLUDES REFRIG)	1.6 (BOXED IN)	TEXAS	16 HR/DAY 5 DAY/WK 24 HR REFRIG (100 TONS)	MEAT (LAMB) PACKING
36,000	150	358	1,500 (INCLUDES REFRIG)	2.0 (BOXED IN)	COLORADO	16 HR/DAY 5 DAY/WK 24 HR REFRIG (750 TONS)	MEAT (CATTLE) PACKING
3,000	25	240	960 (INCLUDES REFRIG)	2.0 (BOXED IN)	NEW MEXICO	8 HR/DAY 5 DAY/WK (REFRIG - 420 TONS)	FLUID MILK

*SITE VISITS

TABLE 2 (continued)

INDUSTRIAL ENERGY REQUIREMENTS (CONT)

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PROCESS STEAM			PEAK ELEC (KW)	LAND AVAILABILITY (ACRES)	LOCATION	DUTY CYCLE	COMMENTS
ω (LB/HR)	PRESS (PSI)	TEMP (^oF)					
5,000	25	240	987 (INCLUDES REFRIG)	15	CALIFORNIA	18 HR/DAY 6 DAY/WK (400 TON REFRIG AT ABOVE 90 TON 24 HR/DAY, 7 DAY/WK)	FLUID MILK AND ICE CREAM
250,000	160	370	6,240 (INCLUDES REFRIG)	31	CALIFORNIA	24 HR/DAY, 7 DAY/WK 4 MONTHS/YR. (1150 TONS REFRIG)	TOMATO PROCESSING
308,000	100	328	1,800 (INCLUDES REFRIG)	6	CALIFORNIA	24 HR/DAY, 6 DAY/WK 2.5 MONTHS/YR. 20 TON REFRIG 10 HR/DAY 6 DAY/WK	TOMATO PROCESSING
108,000	110	335	1,460 (INCLUDES REFRIG)	4	CALIFORNIA	24 HR/DAY, 7 DAY/WK 20 TON REFRIG A.C. 3 MONTHS/YR	PEACH AND PEAR CANNING
17,156 198,730	110 60	335 293	1,450	UNK	COLORADO	24 HR/DAY 7 DAY/WK 3.5 MONTHS/YR.	SUGAR BEET PROC. 225 X 10^6 BTU/HR DRYING HEAT
4,510 120,388	150 31	360 250	2,060	UNK	COLORADO	24 HR/DAY, 7 DAY/WK 7-1/3 MONTHS/YR.	SUGAR BEET PROC. 57 X 10^6 BTU/HR DRYING HEAT
127,000	140	353	7,163	UNK	CALIFORNIA	16 HR/DAY, 5DAY/WK 1,150 TON REFRIG AT ABOVE 620 TONS 24 HR/DAY, 7 DAY/WK	TUNA FISH PLANT
495,410 140,550	235 58	544 377	57,300	UNK	ARIZONA	24 HR/DAY 7 DAY/WK	PAPER PULP MILL 50 X 10^6 BTU/HR DIRECT FIRED HEAT

TABLE 2 (continued)

INDUSTRIAL ENERGY REQUIREMENTS (CONT)

PROCESS STEAM			PEAK ELEC (KW)	LAND AVAILABILITY (ACRES)	LOCATION	DUTY CYCLE	COMMENTS
ω (LB/HR)	PRESS (PSI)	TEMP (°F)					
NONE	NA	NA	1900 (INCLUDES REFRIG)	UNK	OKLAHOMA	24 HR/DAY, 7 DAY/WK 1400 TONS OF REFRIG	SODIUM SULFATE PRODUCTION 4.25×10^6 BTU/HR DIRECT FIRED HEAT
160,000	260	404	5,860	82	NEW MEXICO	CONTINUOUS	POTASH PRODUCTION 21.3×10^6 BTU/HR DRYING HEAT 350°F
89,651	25	240	9,450	UNK	NEW MEXICO	CONTINUOUS	POTASH PRODUCTION 58.7×10^6 BTU/HR DRYING HEAT 350°F
45,000	150	358	4,170	35	COLORADO	CONTINUOUS 50 WEEK/YR	PETROLEUM REFINERY 159×10^6 BTU/HR PROCESS HEAT 900°F
317,444 10,487 13,351 74,684	450 150 70 25	456 358 303 240	10,320	100	TEXAS	CONTINUOUS 51 WEEKS/YR	PETROLEUM REFINERY 720×10^6 BTU/HR 600°F OR LOWER 860×10^6 BTU/HR 700°F OR HIGHER PROCESS HEAT DIRECT FIRED
NONE	NA	NA	1,220	2	CALIFORNIA	6 HR/DAY, 5 DAY/WK	ASPHALT PAVING MATERIAL PRODUCTION 57×10^6 BTU/HR 360° PROCESS HEAT
6,777	25	240	101	16	TEXAS	ELEC: 8 HR/DAY, 5 DAY/WK DAYTIME STEAM: 9 HR/DAY, 5 DAY/WK NIGHTTIME	CONCRETE BLOCK MANUFACTURE

TABLE 2 (continued)

INDUSTRIAL ENERGY REQUIREMENTS (CONT)

PROCESS STEAM			PEAK ELEC (KW)	LAND AVAILABILITY (ACRES)	LOCATION	DUTY CYCLE	COMMENTS
ω (LF/HR)	PRESS (PSI)	TEMP (^{o}F)					
6,700	25	240	340	42	TEXAS	ELEC: 10 HR/DAY, 5 DAY/WK DAYTIME STEAM: 12 HR/DAY, 5 DAY/WK NIGHTTIME	CONCRETE BLOCK MANUFACTURE
7,333	25	240	490	4.6	ARIZONA	ELEC: 8 HR/DAY, 5 DAY/WK DAYTIME STEAM: 12 HR/DAY, 5 DAY/WK NIGHTTIME	CONCRETE BLOCK MANUFACTURE
5,000	25	240	42	UNK	CALIFORNIA	ELEC: 6 HR/DAY, 6 DAY/WK DAYTIME STEAM: 6 HR/DAY, 6 DAY/WK NIGHTTIME	PRESTRESSED CONCRETE PRODUCTS
6,500	25	240	2,000 (INCLUDES REFRIG)	UNK	CALIFORNIA	24 HR/DAY, 5 DAY/WK 150 TONS REFRIG A.C.	PLATING AND ANODIZING PLANT

sites visited along with data obtained from other sources.

Section 3

SYSTEM DESIGN

This section describes the methodology used in analyzing solar total energy systems both from a technical improvement standpoint and for actual system designs. The results of the parametric analyses, as well as specific system designs, are also presented.

3.1 METHODOLOGY

3.1.1 Insolation Methodology

To determine annual insolation characteristics of various locations, the typical week per season method developed in the Industrial Applications of Solar Total Energy (Reference 1) was used. As reported in the study, the method for selection of the typical week (Figure 1) is based on satisfying the long-term monthly average daily total horizontal insolation (as they were originally observed corrected for all known scale, instrument, and calibration problems) and frequency distribution. Instead of the Aerospace data base tapes, the new SOLMET tapes were used. 1962 data was used exclusively in the selection of the typical weeks.

The SOLMET tapes incorporate a new empirical formula which relates hourly direct normal values to total horizontal insolation. Using the improved correlation in the SOLMET data base results in generally lower direct normal values, especially for nonclear conditions. For example, the typical week for June in Fort Worth, Texas based on the Aerospace tapes has an average daily direct normal value of 6.57 KW-hr/m^2 compared to 5.27 KW-hr/m^2, as predicted by the SOLMET tapes for the same seven days selected in the earlier study. The new correlation for direct normal does not depend solely on the total horizontal value. Selection of a different synthesized week for June in Fort Worth that still meets the criteria shown in Figure 1 produces an average daily direct normal value which is over ten percent greater than the value based on the

SELECTION OF TYPICAL WEEK/MONTH

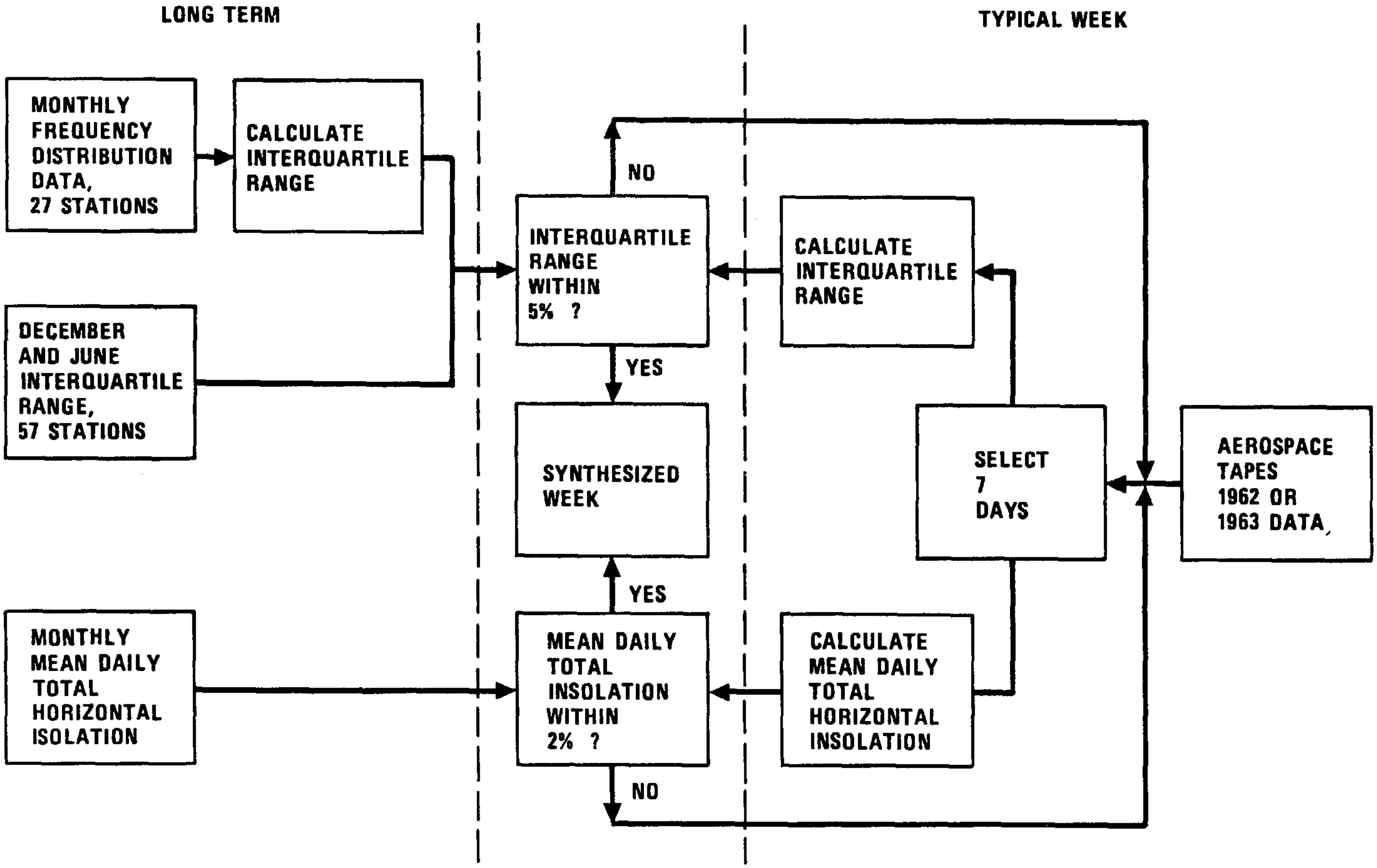

FIGURE 1

old week. Thus, additional test(s) on the synthesized typical week selection process should be made. The additional criteria consists of comparing the annual, standard year corrected, mean daily values of direct normal and total horizontal insolation for the typical week per season values with the values as compiled from the complete SOLMET data base (Reference 2) (approximately 23 years of data). If the discrepancy between the annual typical week per season values and the long term values is greater than five percent, new random weeks are selected until all tests are satisfied. Comparison of the long term versus week per season annual mean daily values (standard year corrected) of direct normal and total horizontal is shown in Figures 2 and 3, respectively.

Typical week selections for three locations are presented in Table 3 and Appendix B contains the selections for all 26 SOLMET stations.

3.1.2 Solar Collector Performance

The parabolic trough configurations are the most developed of all concentrator concepts and were emphasized in the study. In a previous study (Reference 3), performance data were compiled for the parabolic troughs from the open literature or directly from the component designer. Figure 4 presents the results of the survey. Actual experimental data was limited to a few data points for the Sandia and University of Minnesota/Honeywell (M/H) parabolic troughs. Recently, a test series (Reference 4) was completed to characterize the performance of a parabolic trough manufactured by the Hexcel Corporation. The Hexcel collector is fabricated from treated aluminum honeycomb with aluminum skins. The reflecting surface was an aluminized second-surface acrylic film, FEK 163. Reflectivity was estimated to be 0.86. The outer surface of the steel absorber was plated with a selective black chrome to enhance solar radiation absorption and reduce thermal radiation losses. Measurements were made prior to thermal testing of the Hexcel collector to determine the solar spectrum absorptance and emittance of the black chrome absorber tube. The average value of the absorptance was 0.88 which was less than the normal as plated absorptance of ≤ 0.95. After thermal testing, the absorptance had deragded to an average value of 0.86. To further reduce thermal losses from the absorber tube, a half-cylinder of pyrex glass was fitted over the tube on the radiation absorbing side. The back half of the absorber tube was covered with a double layer metal shield. Glazing transmissivity was estimated

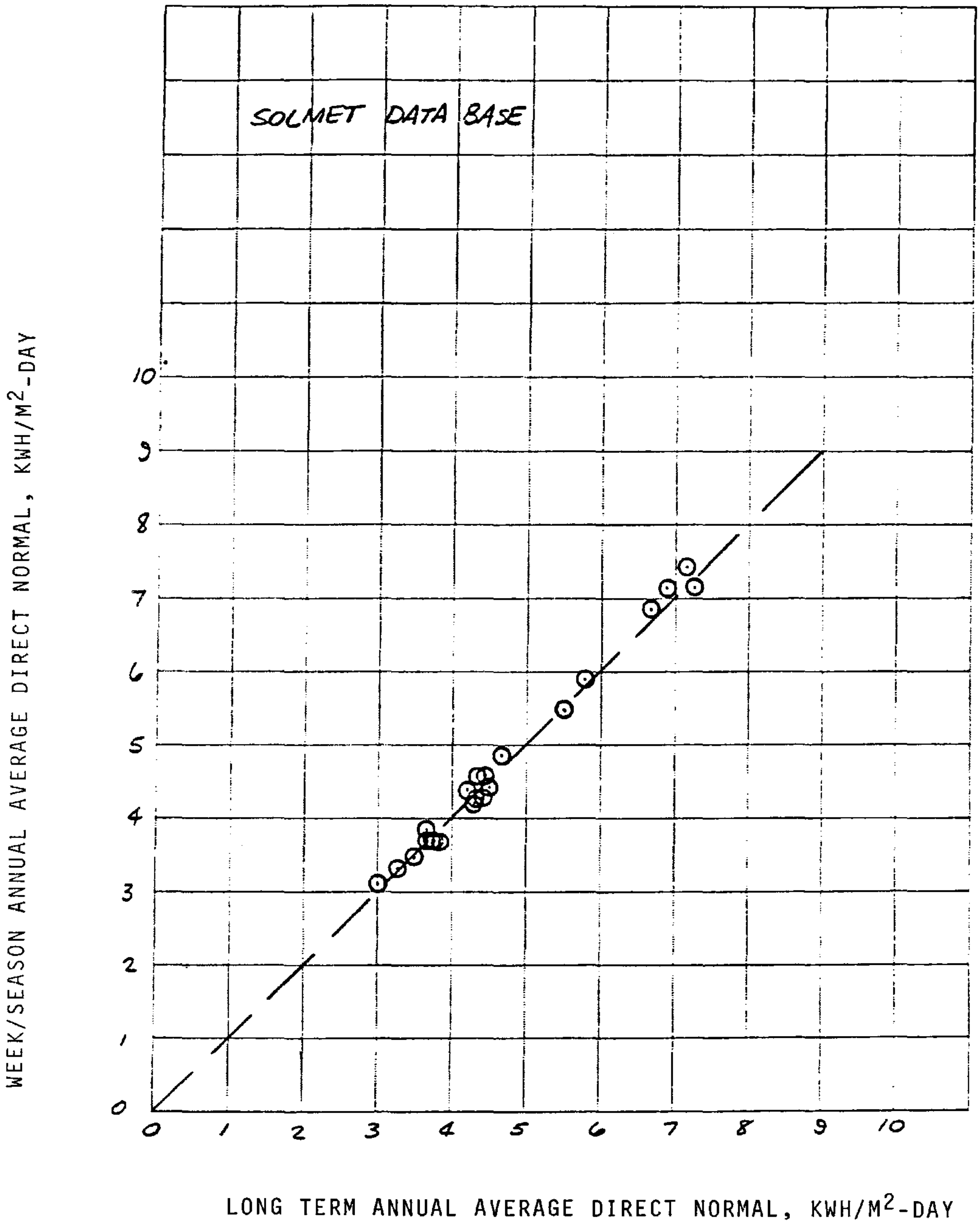

FIGURE 2 COMPARISON OF LONG TERM DATA WITH WEEK/SEASON METHOD--DIRECT NORMAL

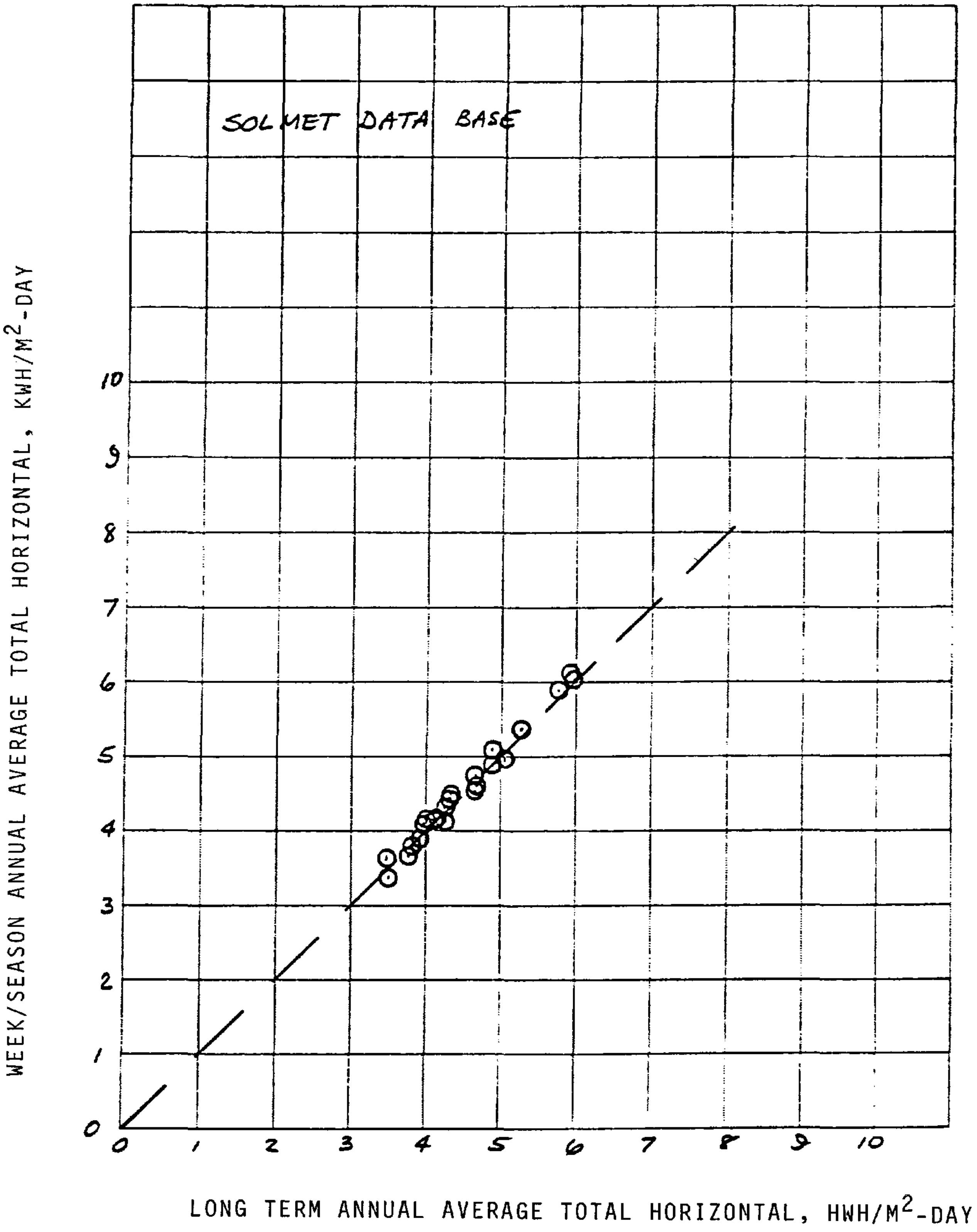

FIGURE 3 COMPARISON OF LONG TERM DATA WITH WEEK/SEASON METHOD--TOTAL HORIZONTAL

LOCATION -- ALBUQUERQUE

MONTH	DAYS	TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	2 3 7 11 19 21 24	5,54	6,99
JUNE	2 6 8 16 24 27 30	8,74	9,56
SEPTEMBER	1 2 5 7 13 17 29	6,40	7,13
DECEMBER	1 2 4 6 9 17 30	2,98	5,97

LOCATION -- APALACHICOLA

MONTH	DAYS	TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	4 9 10 16 21 26 30	4,65	4,06
JUNE	7 8 10 17 23 27 28	6,35	5,19
SEPTEMBER	9 12 13 14 15 27 29	4,70	4,37
DECEMBER	9 14 15 16 20 22 26	2,64	3,48

LOCATION -- BISMARK

MONTH	DAYS	TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	3 5 8 15 16 23 30	3,68	4,38
JUNE	4 8 14 16 19 24 26	6,42	5,90
SEPTEMBER	9 14 16 18 21 25 28	4,38	5,88
DECEMBER	5 6 7 21 23 25 28	1,16	2,15

TABLE 3

TYPICAL WEEK-PER-SEASON SELECTIONS

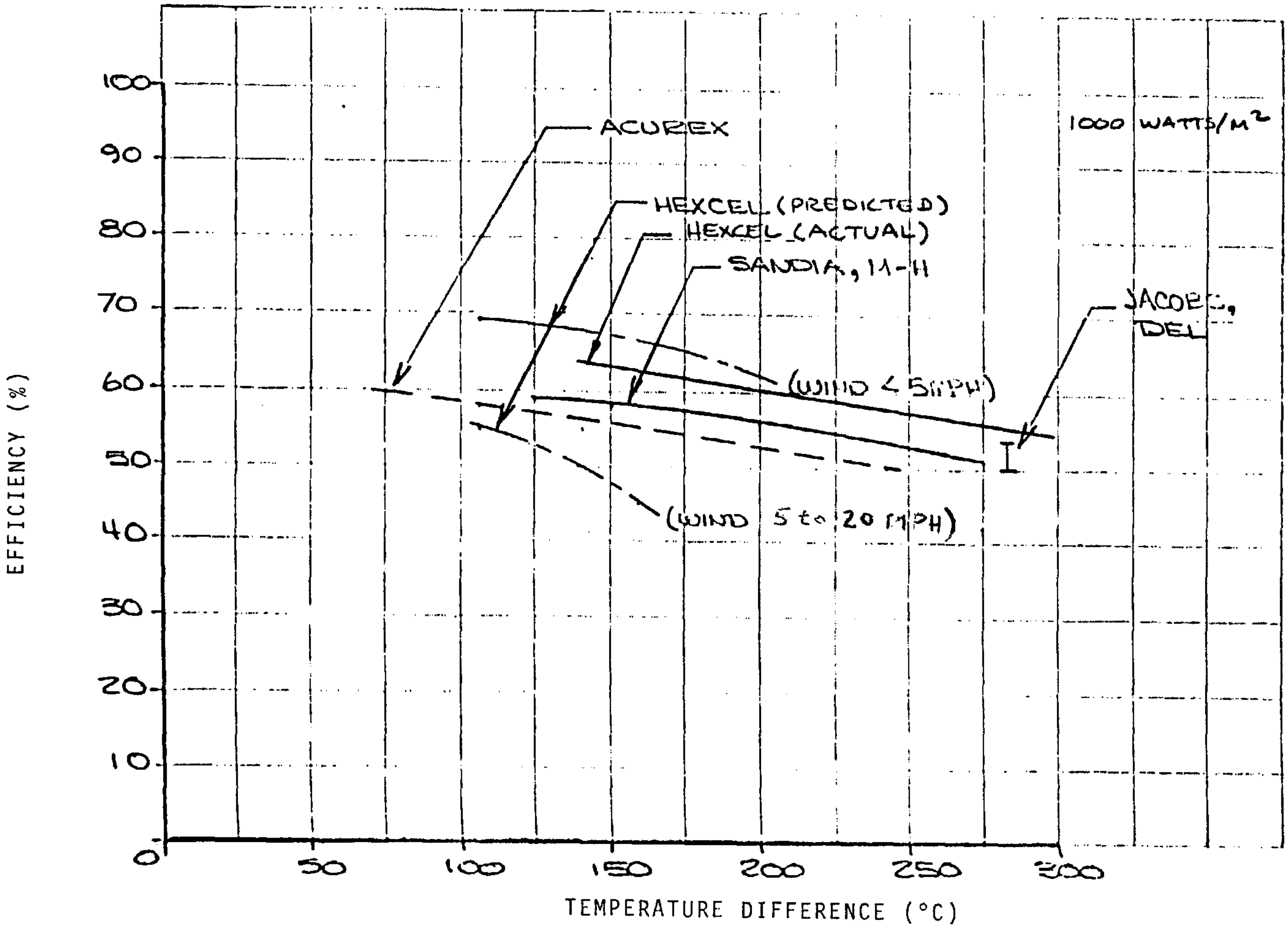

FIGURE 4 COMPARISON OF PARABOLIC TROUGH EFFICIENCIES

to be 0.90. Thus, the optical factor for the Hexcel test collector was 0.86 x 0.86 x 0.90 = 0.666. The collector was tested in the Sandia Laboratories Collector Module Test Facility at receiver output temperatures in excess of 300°C. The peak noon efficiency (adjusted to an insolation of 1,000 watts/m^2) obtained in the tests is shown in Figure 4.

An important test of a one-axis tracking collector's efficiency is not only the instantaneous efficiency at solar noon, but also the all day efficiency curve. In addition to the conventional incidence (cosine) loss, a further reduction in efficiency of the one-axis tracking parabolic trough occurs during the day as a result of shadowing obstructions due to structural elements and end losses due to reflected light rays that either impact the trough end or miss the absorber tube. Figure 5 illustrates the measured Hexcel collector performance throughout the day. Based on experimental data for the M/H test unit, the reduction in optical factor during the day was accounted for by the correction factor

$$F(\alpha) = (1-0.23 \tan \alpha) \cos \alpha$$

where α is the sun-trough angle. This correlation was used in previous solar total energy studies (References 1 and 3) and provides a good fit to the Hexcel data except in the late afternoon when the actual efficiencies decrease at a faster rate. Less end loss would occur when similar collector modules are placed in long East-West rows in a typical collector field, so the all day correlation previously used seems adequate to describe the daily efficiency. Hexcel performance characteristics were used as nominal throughout the study.

Experimental data on parabolic troughs have been primarily obtained with an East-West orientation. Thus, this orientation was assumed, although it is well known that a North-South orientation will collect more energy on an annual basis. Collector spacing was determined by the arbitrary criteria of no shading at 10am solar time during the winter solstice. As will be shown, this criteria generally results in maximizing the energy collected/aperture area.

Using the insolation data selected by the week-per-season method and the assumed collector characteristics, steady-state hour-by-hour performance for seven days in each of the four seasons was calculated. Thermal losses from the interconnecting plumbing and shading losses are included in the performance

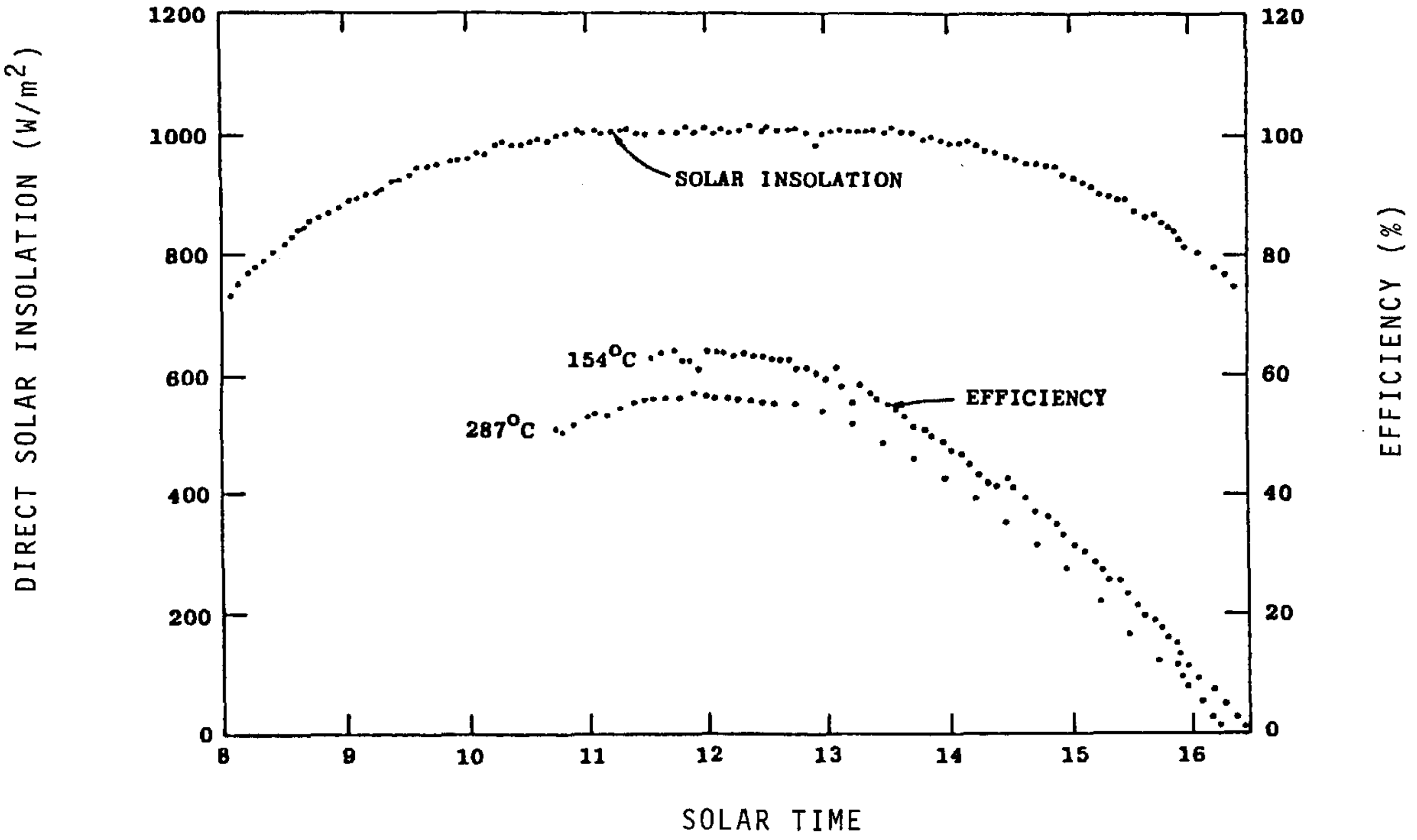

FIGURE 5 HEXCEL ALL DAY EFFICIENCY

calculations. Annual average daily energy collection as a function of average fluid temperature is shown in Figure 6 for the three locations. Maximum and minimum temperatures correspond to total energy and process heat system requirements respectively. Annual collector efficiencies of 40-45 percent are obtained for the process heat system and decreases to 25-30 percent for the total energy system (Figure 7).

Performance sensitivities to variations in $\rho\alpha$ are shown in Figures 8 and 9. Current state-of-the-art reflectivity and absorptivity ($\rho\alpha$ = 0.86 x 0.86 - 0.74) was used to obtain the results in Figures 6 and 7 . Materials improvements have the potential of increasing the reflectivity to 0.91 and absorptivity to 0.95 ($\rho\alpha$ = 0.865). The lower value of $\rho\alpha$ corresponds to the utilization of a Coilzak reflector (clad aluminum alloy, ρ = 0.79) in place of the aluminized second-surface acrylic film, FEK163.

The sensitivity of the parabolic trough energy collection capability to ground cover ratio is shown in Figures 10 to 12 . Nominal ground cover ratios were determined with the criteria of no shading by 10 am solar time on the winter solstice. At lower packing densities, the energy/aperture area decreases slightly because the thermal losses from the longer interconnecting plumbing is greater than the additional energy collected from less shading. At larger packing densities from the nominal, shading losses dominate. Although the efficiency of the collector decreases at the higher packing densities, the total output from a fixed field area continues to increase.

3.1.3 Generalized Total Energy Performance

Over the past few years as energy costs have escalated, the need for energy conservation has become increasingly important.

One obvious way of reducing the energy input for a given output is to go to a total energy system for electrical and process heat demands. At present, electricity is purchased from a utility with a conversion efficiency of approximately 30% at the delivery point and process heat is generated on site with a boiler. The total energy system simply generates the electricity on site and generates the process heat by condensing the turbine discharge

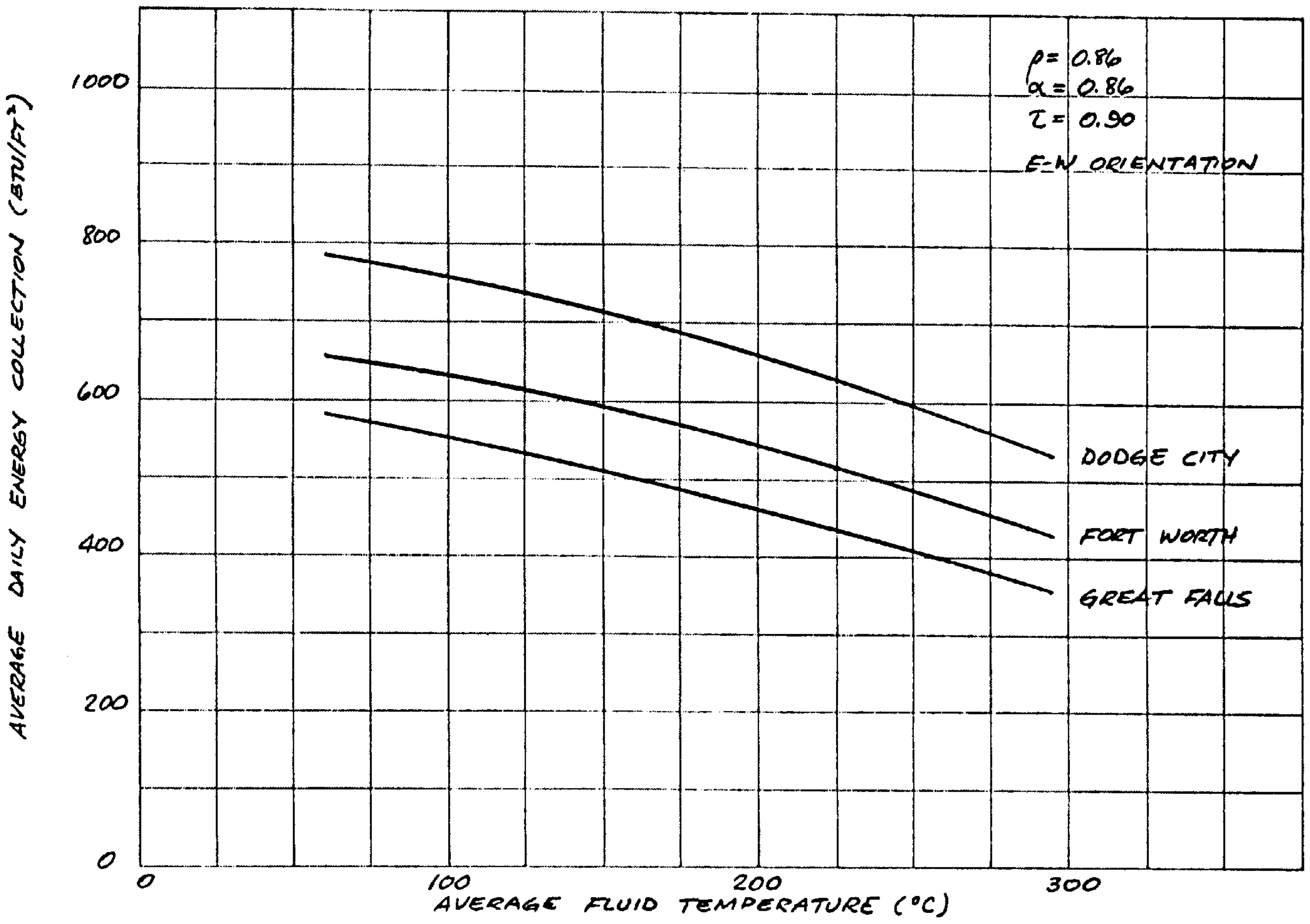

FIGURE 6 PARABOLIC TROUGH ANNUAL AVERAGE ENERGY COLLECTION

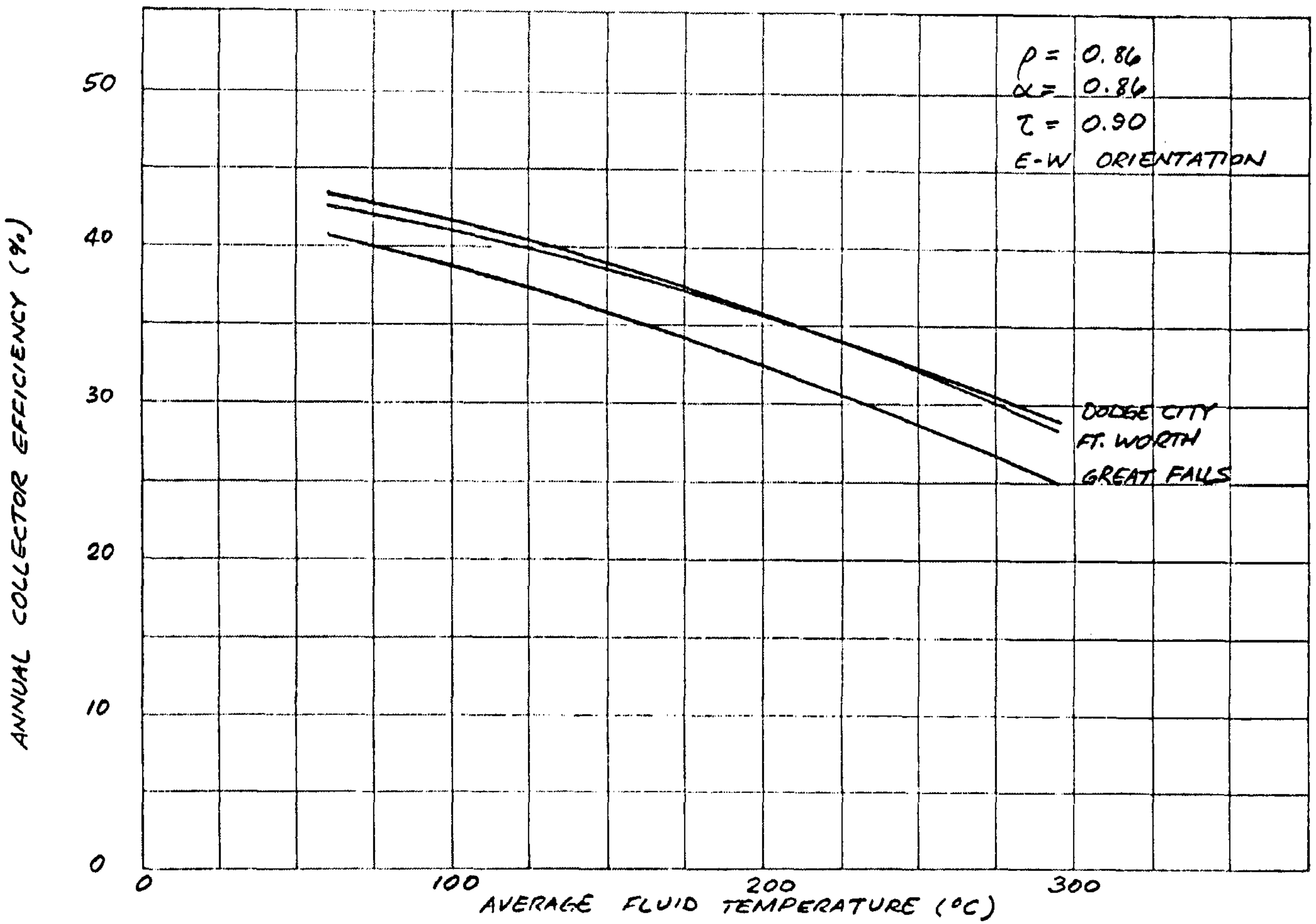

FIGURE 7 PARABOLIC TROUGH ANNUAL PERFORMANCE

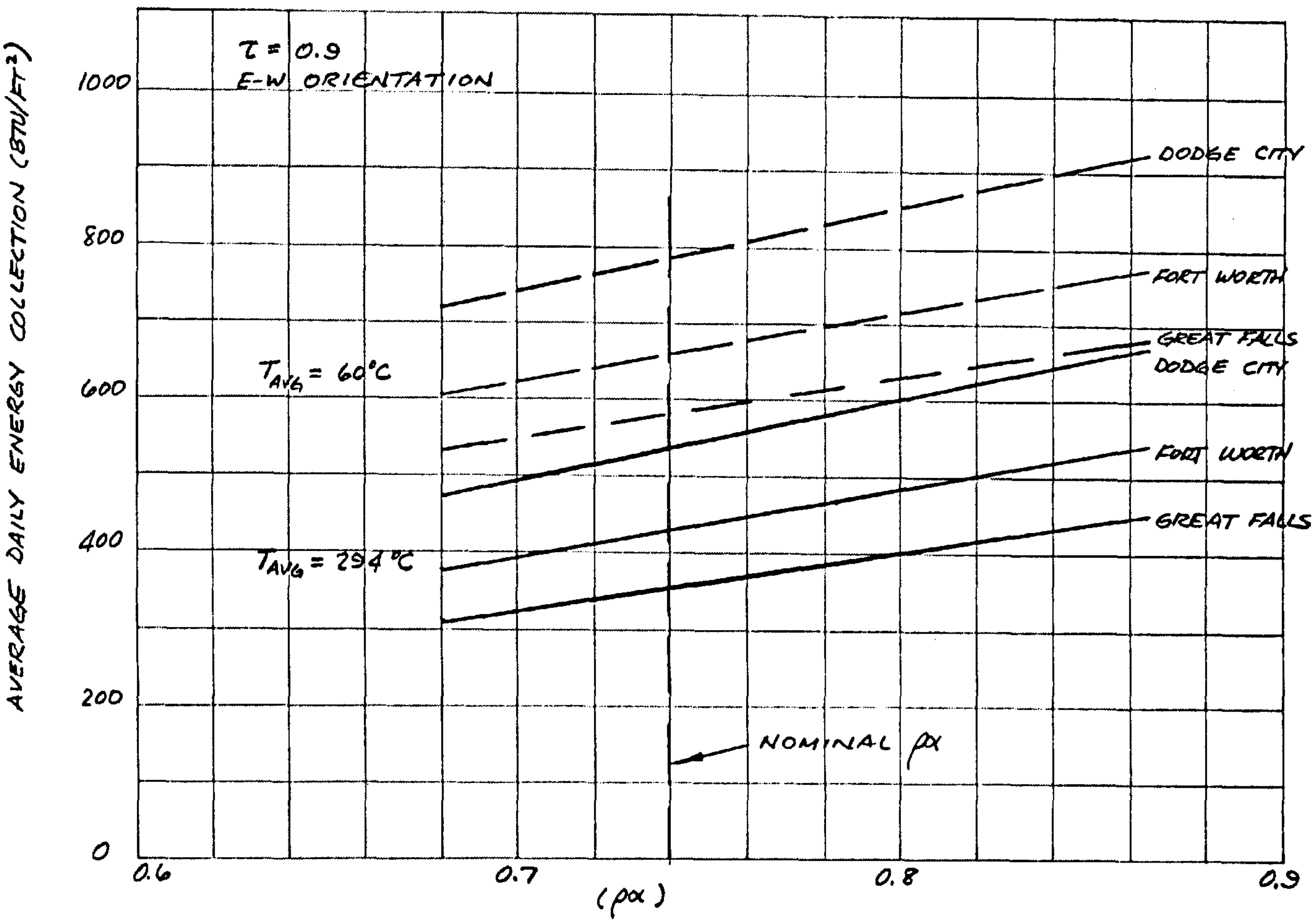

FIGURE 8 PARABOLIC TROUGH ENERGY COLLECTION SENSITIVITY TO ρα

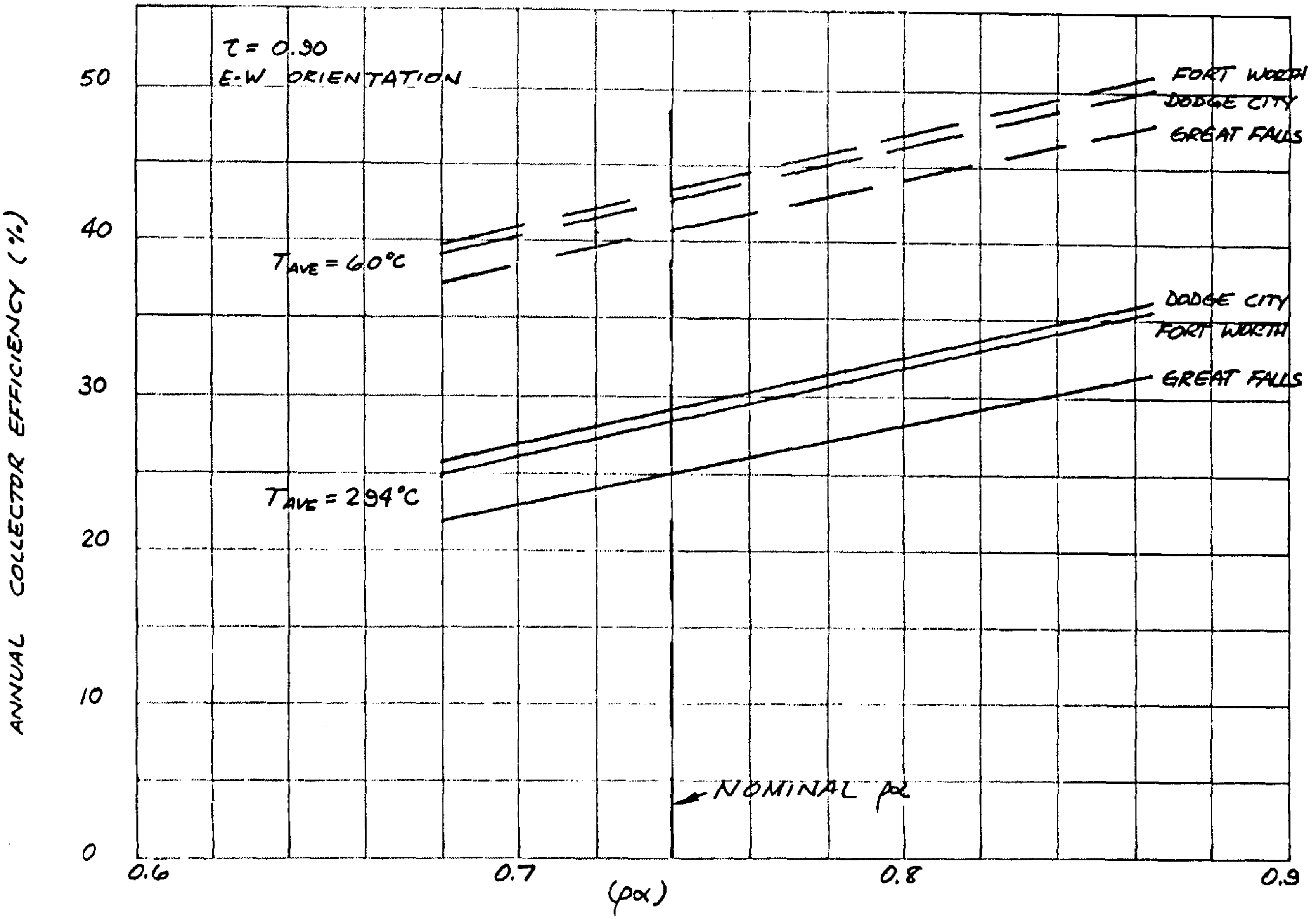

FIGURE 9 PARABOLIC TROUGH EFFICIENCY SENSITIVITY TO ρα

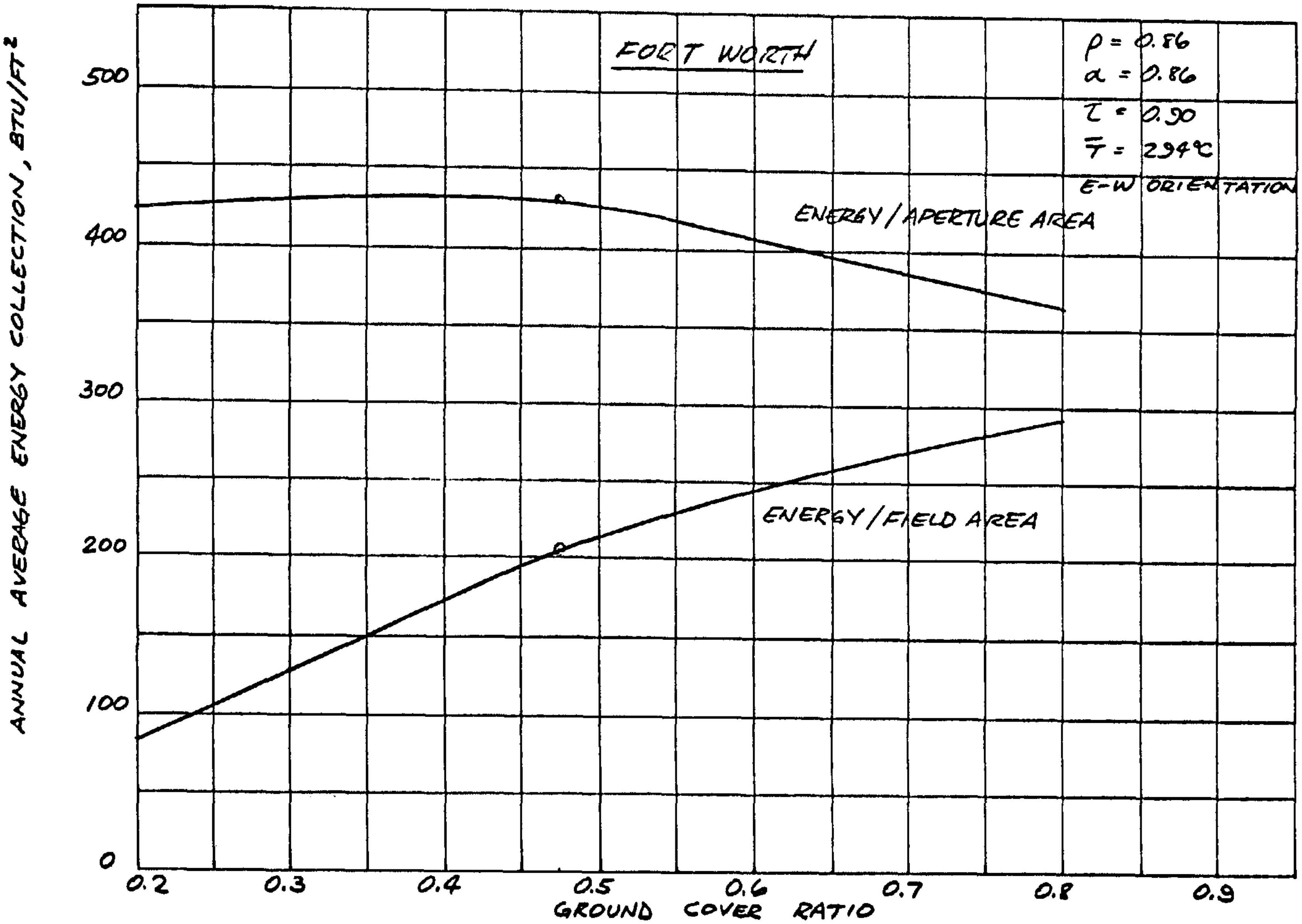

FIGURE 10 PARABOLIC TROUGH PACKING DENSITY VARIATION -- FORT WORTH

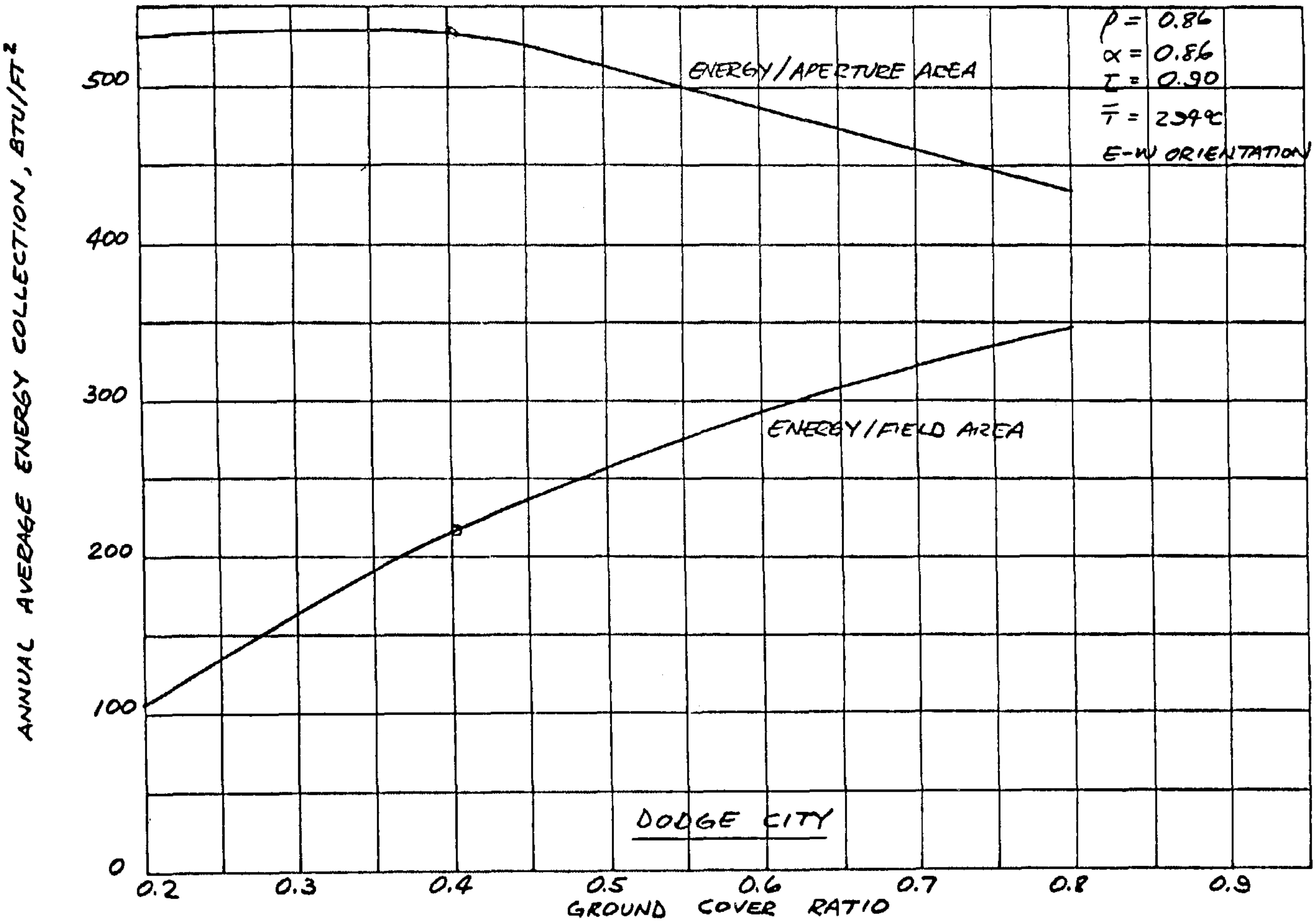

FIGURE 11 PARABOLIC TROUGH PACKING DENSITY VARIATION -- DODGE CITY

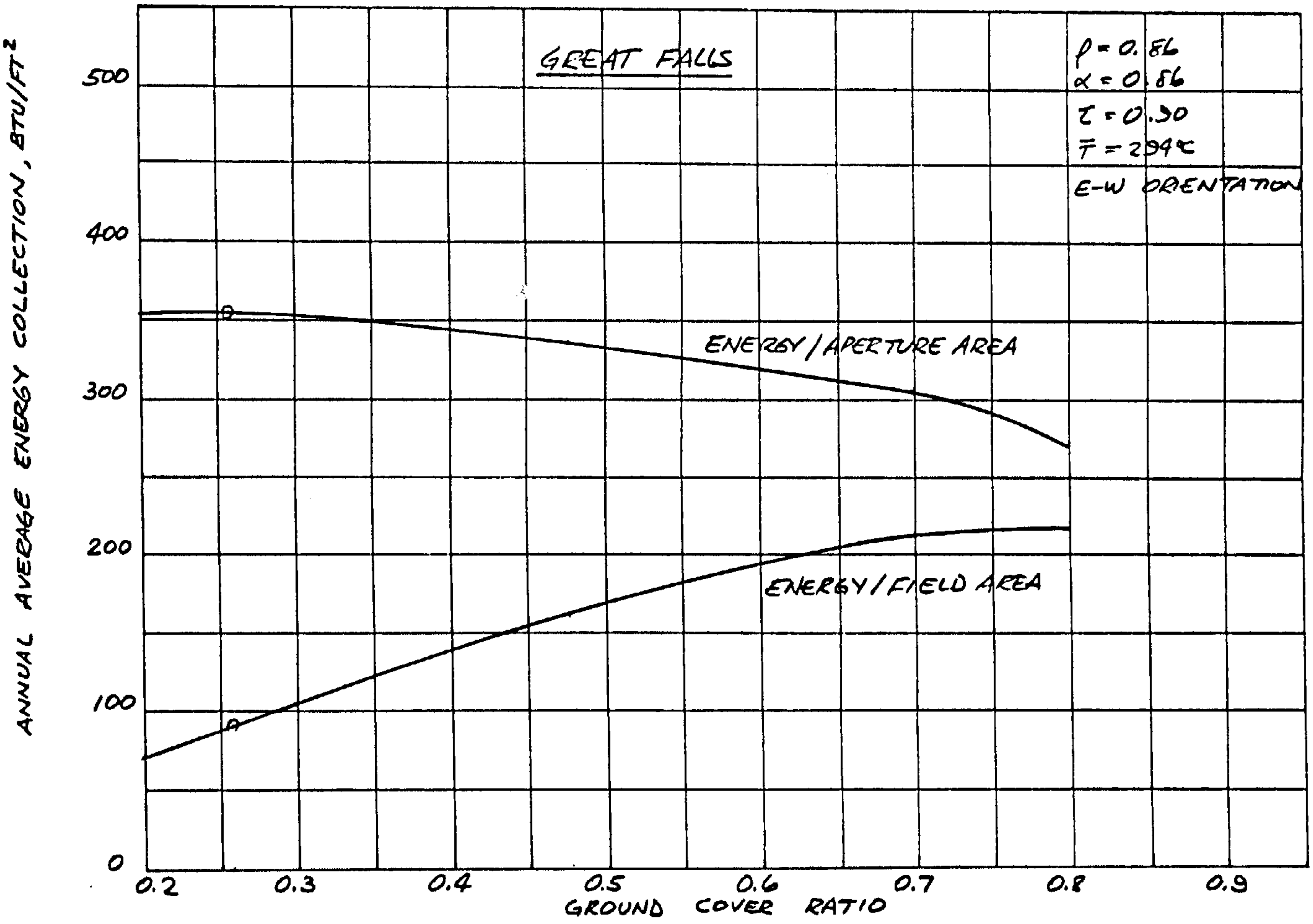

FIGURE 12 PARABOLIC TROUGH PACKING DENSITY VARIATION -- GREAT FALLS

at the required process temperature. Ideally this amounts to a 100% energy conversion efficiency. This means that the total energy supplied to the system is just the sum of the electrical and process heat loads.

The following example will illustrate

Assume an industrial plant requires the following:

Electrical load = 1 MW = 3.4×10^6 BTU/Hr

Process heat load = 13.6×10^6 BTU/Hr

Energy used with purchased electricity =

$$\frac{3.4 \times 10^6}{.30} + 13.6 \times 10^6 = 24.63 \times 10^6 \text{ BTU/Hr}$$

Energy used in a total energy system ±

$$3.4 \times 10^6 + 13.6 \times 10^6 = 17 \times 10^6 \text{ BTU/Hr}$$

This amounts to a saving of 31% in energy used for an equal output

Energy Conversion

The energy conversion subsystem basically includes the following:

- Prime mover and generator
- Process heat subsystem
- Refrigeration system

Although many methods of power conversion are available this study is limited to the investigation of Rankine cycles only for the following reasons:

A. Very adaptable to total energy systems

B. High cycle efficiency at solar collector temperatures

C. Most industries have processes using steam

D. Many sources of hardware are available

E. Tremendous experience accumulates in their design and operations

3.1.4 Cycle Analyses Methodology

For the purposes of the preliminary sizing phases of this study, the methodology used is discussed in detail below.

Turbines

A total energy system requires that a process heat system of some sort is used as a condenser for the Rankine cycle. This requires a turbine that operates efficiently at high back pressures. In general, provided the turbine is designed for the particular operating conditions required, a turbine increases in efficiency as the pressure ratio across it is reduced. On the other hand the high pressure section of a turbine is usually less efficient than lower pressure sections due to the reduced blade height as pressure is increased, resulting in a higher ratio of wheel clearance to blade height causing a greater percentage of leakage flow around the wheel edge.

Figure 13 shows the efficiency ranges of turbines as a function of shaft power. For this study it is assumed that the back pressure turbine performance follows the curve between the maximum and minimum efficiency values. This seems justified because of the increased efficiency attendant with back pressure turbines plus the large effect of efficiency on cycle performance dictates the use of high quality machines. In addition, pump work and system heat losses are considered negligible in that their values are well within the accuracy of the demand data.

Cycle Performance

The method of analysis is as follows (Reference 1):

Calculate the ratio of the turbine outlet heat of condensation to the mechanical work done.

$$r = \frac{Q_{cond}}{Q_{work}}$$

This ratio is also related to the Rankine cycle efficiency as follows:

$$r = \frac{1 - \eta_c}{c} \qquad \eta_c = \frac{1}{1 + r}$$

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COMPARISON OF STEAM TURBINE PERFORMANCE

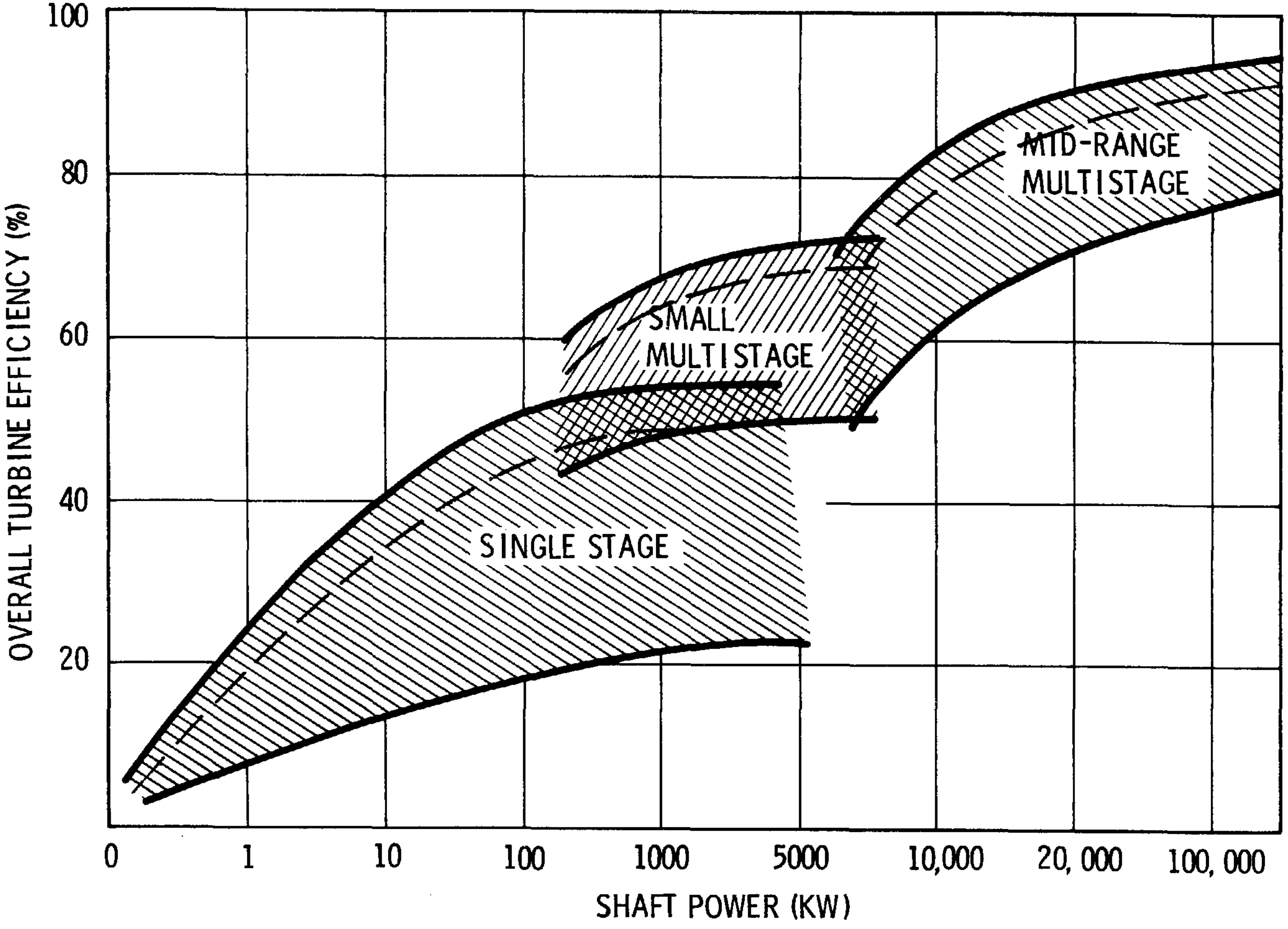

FIGURE 13

Thus, the required efficiency η_c can be obtained. Assume that in this particular case, the value of η_c is high enough to require too high a turbine inlet enthalpy for the storage and collector heat transport media available when a simple Rankine cycle is used.

There are two ways to increase the cycle efficiency of a steam rankine cycle without increasing the collection temperature. The first is to reduce the quality (X) of the steam leaving the turbine and the second is to use feed water regeneration when a constant process steam, or condenser, flow is required.

$$\dot{W}_{inlet} = \frac{\dot{W}_{cond}}{X(1-m)}$$

where

$\dot{W}_{inlet}$ = inlet flow, lb/hr

$\dot{W}_{cond}$ = condenser or process steam flow, lb/hr

X = turbine outlet steam quality

m = ratio of inlet flow extracted for feedwater regeneration

The analysis of an industrial total energy steam Rankine cycle differs from an ordinary cycle in one respect. The turbine outlet pressure and temperature are fixed by the process steam requirements, if it is assumed that a turbine discharge steam quality of less than 1.0 is obtained. It is desirable to have as low a turbine discharge steam quality as practical in that this increases the Rankine cycle efficiency. The efficiency is increased because any steam that is condensed internal to the cycle (e.g., within the turbine) represents heat that does not have to be condensed in the condenser/process steam system. Additionally, as shown above, for a given ratio r, the cycle efficiency η_c is fixed.

If the turbine discharge conditions, the cycle efficiency, and the process steam flow are fixed, the turbine inlet conditions are also fixed. The solution of this state point is iterative and is defined by any two of the following parameters: temperature, pressure, enthalpy, or entropy. If the turbine efficiency is known, the inlet entropy can be calculated for any assumed inlet enthalpy.

Another method of increasing cycle efficiency is the use of organic rankine cycles. These cycles have been investigated previously using freons and toluene. Toluene was found to have advantages for these types of application in terms of higher maximum allowable temperatures and higher cycle efficiency with the result that toluene was the only organic fluid analyzed in the study. The use of organic rankine cycles was limited to systems requiring less than 1 MW electric due to lack of turbine availability above that output. The major reason for the toluene organic rankine cycle superior performance is due to the ease with which the cycle can be regenerated due to the unique thermodynamic properties of toluene. Toluene, like many organic fluids, is a drying fluid; i.e., it increases in superheat during the turbine expansion process as opposed to steam that always loses superheat during the expansion. This superheat is removed in a regenerative heat exchanger and is used to partially reheat the fluid returning to the heat exchanger, thus reducing the heat required from the boiler and increasing the cycle efficiency.

It is also interesting to note that due to the differences in physical properties of toluene and steam, the efficiency of a toluene turbine is much higher than steam in the power range of interest in this study. In general turbines designed for organic fluids are larger for a given power output than those designed for steam. This is due in part to a lower sonic velocity, operating pressure, and density. The larger wheel diameter and larger weight flow not only reduce the percent of leakage caused by clearances, but also increase the effective Reynolds number of the turbine, all of which tend to increase the turbine efficiency.

Refrigeration

In most applications, refrigeration can be split into two distinct classifications and treated that way. Vapor cycle systems and absorption cycle systems have been competing head to head for years; however, when total energy systems require refrigeration, the two cooling methods can be used to complement each other.

Vapor cycle refrigeration is essentially another electrical generation requirement, while absorption refrigeration is really just another process steam requirement. By properly dividing the refrigeration load between vapor cycle and absorption cycles, the total system load can be minimized.

This method is illustrated as follows:

$$\text{Let } r = \frac{Q_{PROC}}{Q_{ELECT}} = \frac{1-\eta_c}{\eta_c}$$

where

Q_{PROC} = Process steam load

Q_{ELECT} = Electrical generation load

η_c = Rankine cycle efficiency

If refrigeration is added to the system

$$r = \frac{Q_{PROC} + Q_{ABS}}{Q_{ELECT} + Q_{VC}} = \frac{1-\eta_c}{\eta_c}$$

where

Q_{ABS} = Load into the absorption refrigeration unit

Q_{VC} = Load into the vapor cycle refrigeration unit

and,

$$Q_{COOL} = Q_{ABS}\,(COP)_{ABS} + Q_{VC}\,(COP)_{VC}$$

where

Q_{COOL} = Total cooling load

$(COP)_{ABS}$ = Coefficient of performance, absorption refrigeration

$(COP)_{VC}$ = Coefficient of performance, vapor cycle refrigeration

For a given set of inlet conditions, turbine efficiency, condensing temperature, and a system configuration, the Rankine cycle efficiency is set for a given working fluid. This in turn defines the value of r. Then Q_{ABS} and Q_{VC} can be split in such a way that $Q_{PROC} + Q_{ABS}/Q_{ELECT} + Q_{VC}$ is equal to the same r if the cooling load is large enough. This is defined as load matching. The power conversion thermodynamic cycle analysis has been programmed on a TI 59 calculator for rapid determination of cycle performance and state points.

3.2 PERFORMANCE EFFECTS

Investigation of the distribution of process heat requirements indicated that the majority of usage occurred in the region of 300-400°F. These data, shown in Figure 14, were obtained from Reference 5 and the industrial survey portion of this study. The cross-hatched bars are from Reference 5 and were derived from the data which included feed water heating from 60°F. The data points shown as circles were derived from the data included in Table 2 of this report (not included in the distribution or totals were the steam requirements for Husky Oil or Kaiser Steel because of the magnitude of the requirements compared to the total which would have tended to distort the distribution). This was further verified by the boiler sales curves and boiler usage curves shown in Figures 15, 16, and 17 (References 6 and 7). The power conversion codes (see Section 3.1.4) were then exercised to determine the amount of process heat which could be generated in this temperature range while systematically varying the electrical load from 200 KWe to 100 MWe as shown in Figure 18. This yielded system requirements as a function of both electrical and process steam loads for temperatures of 300°F, 350°F, and 400°F. This information was used to determine the field sizes required for the various load combinations. This was accomplished assuming nominal collector characteristics (i.e., $\rho = \alpha = 0.86$) and a duty cycle of 8 hours per day, 7 days per week, and 52 weeks per year. The results for Albuquerque are presented in Figure 19 while Appendix C contains the same information for all of the Sol-Met locations. (It should be noted that the turbine efficiency was varied with electrical load as indicated in Figure 13).

Collector characteristics were varied consistent with Section 3.1.2 to obtain the effect of these variables on field requirements. These results are presented in Figure 20.

Levelized energy costs were determined for a 350°F process steam requirement, an Albuquerque location, electrical loads from 2 to 10 MW; and a range of collector costs and performance. (The levelizing procedure will be discussed in detail in Section 4.0).

PROCESS HEAT DISTRIBUTION

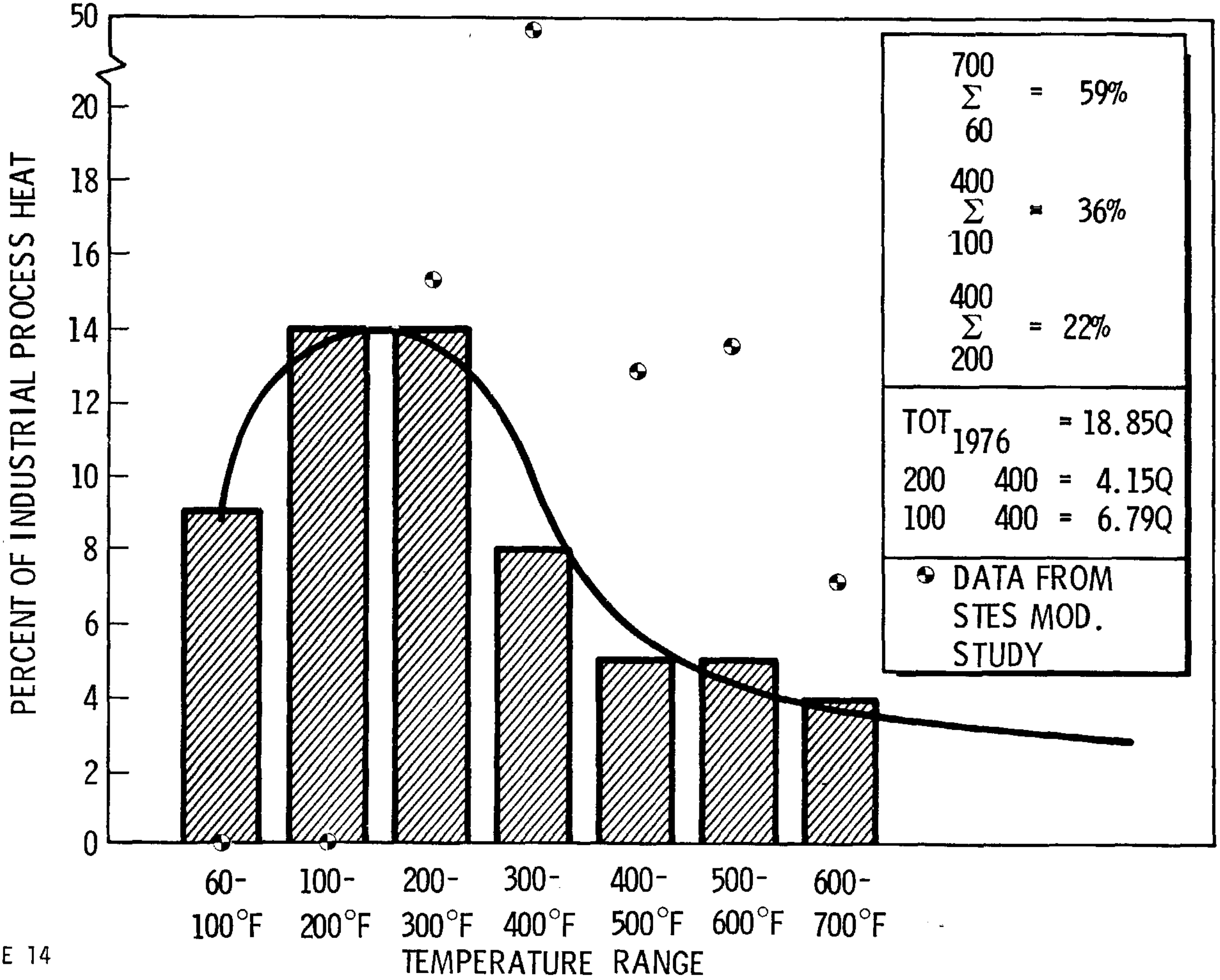

FIGURE 14

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BOILER USAGE IN THE PACIFIC NORTHWEST

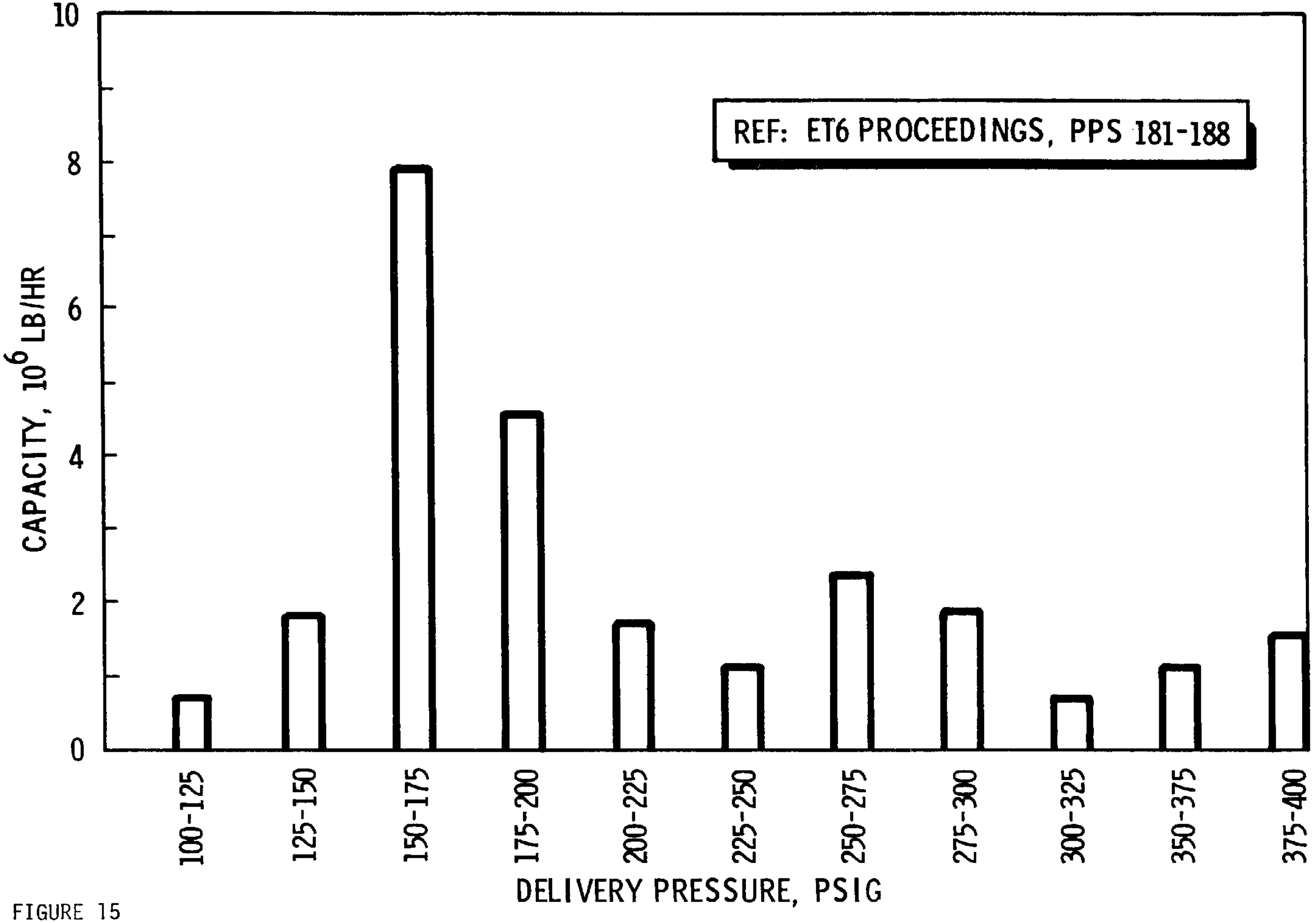
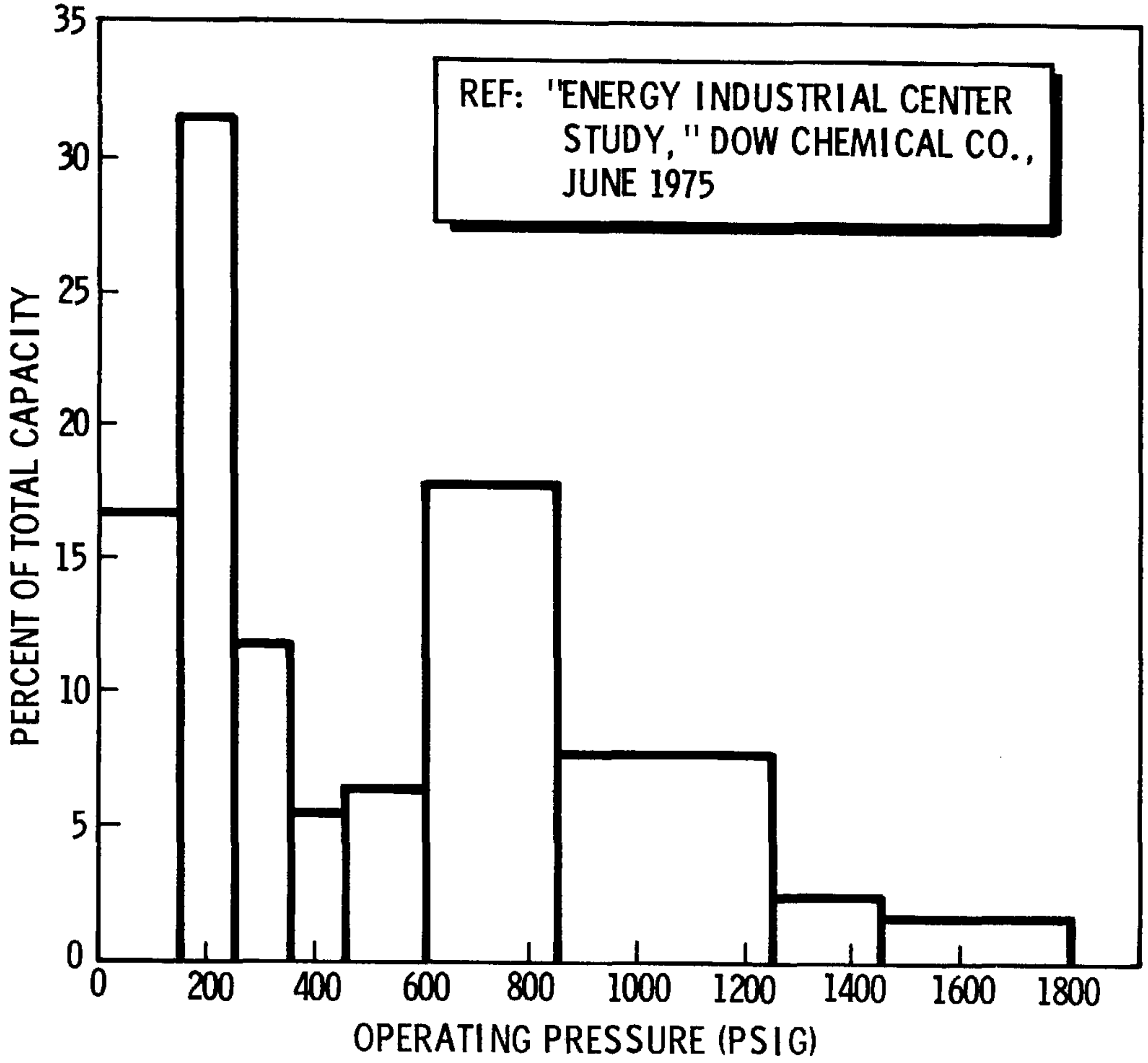

REF: ET6 PROCEEDINGS, PPS 181-188

FIGURE 15

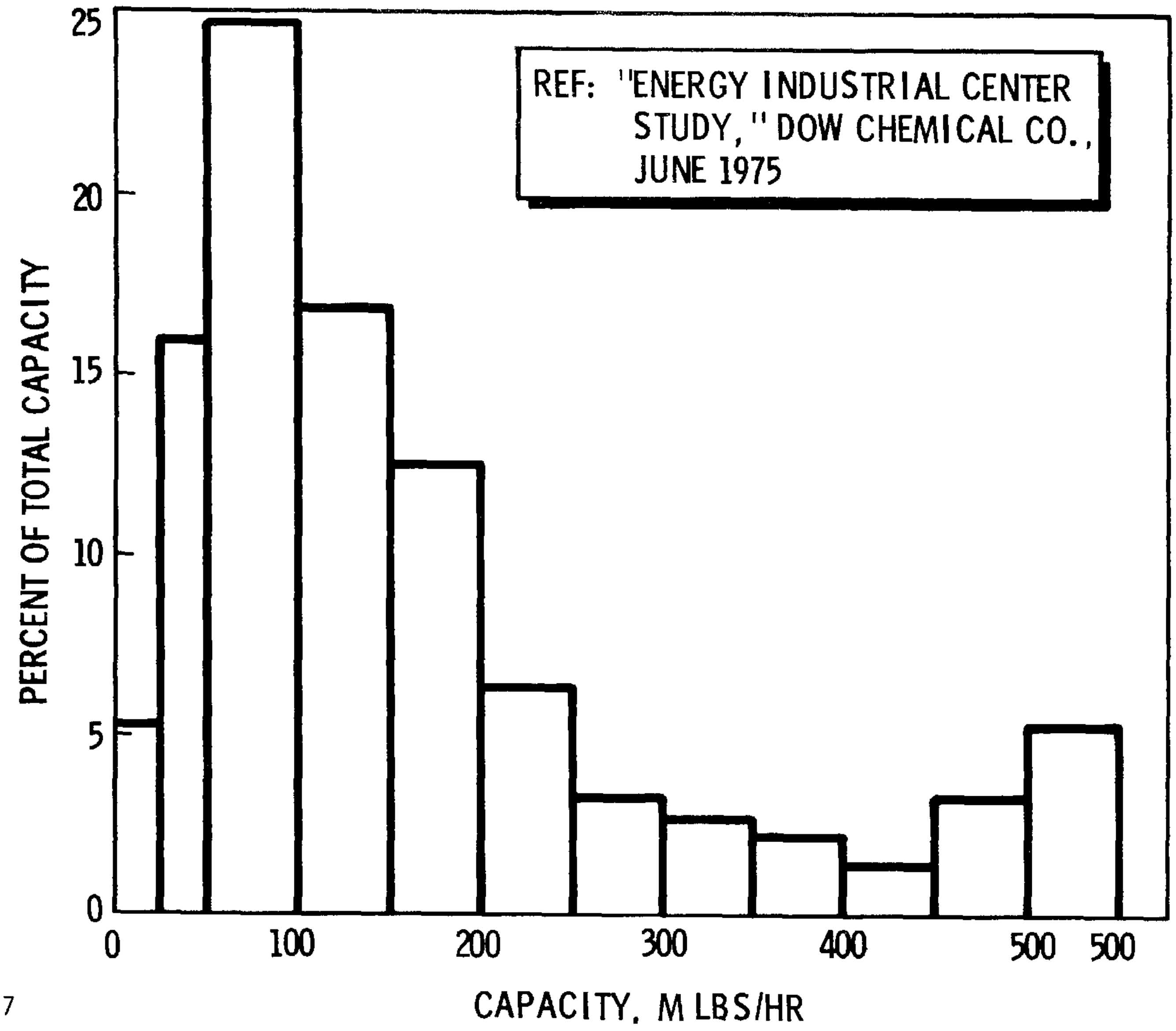
INDUSTRIAL TYPE BOILER SALES
1968-1972



REF: "ENERGY INDUSTRIAL CENTER STUDY," DOW CHEMICAL CO., JUNE 1975

FIGURE 16

INDUSTRIAL TYPE BOILER SALES
1968-1972



REF: "ENERGY INDUSTRIAL CENTER
STUDY," DOW CHEMICAL CO.,
JUNE 1975

FIGURE 17

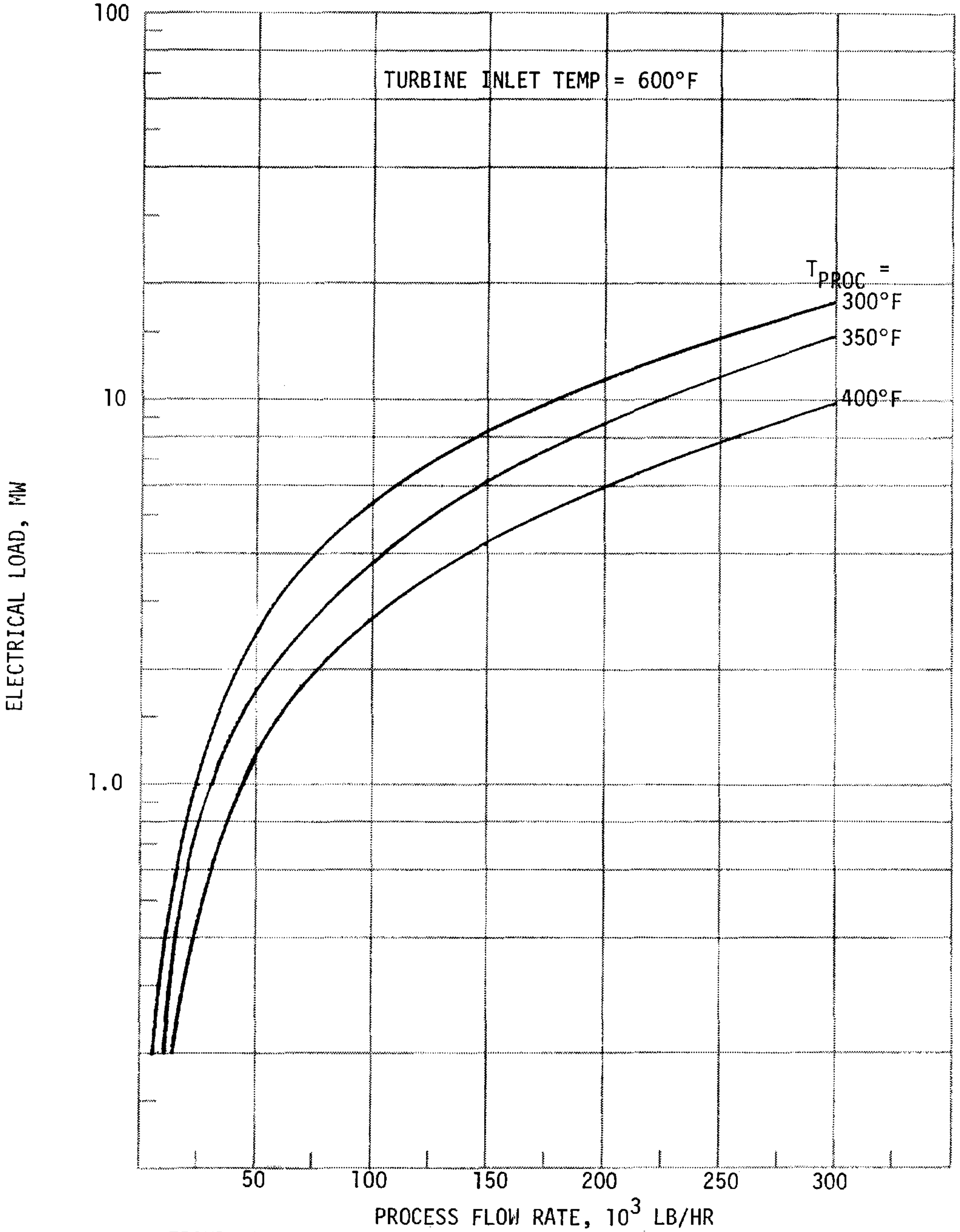


FIGURE 18

VARIATION OF PROCESS FLOW RATE WITH ELECTRICAL LOAD

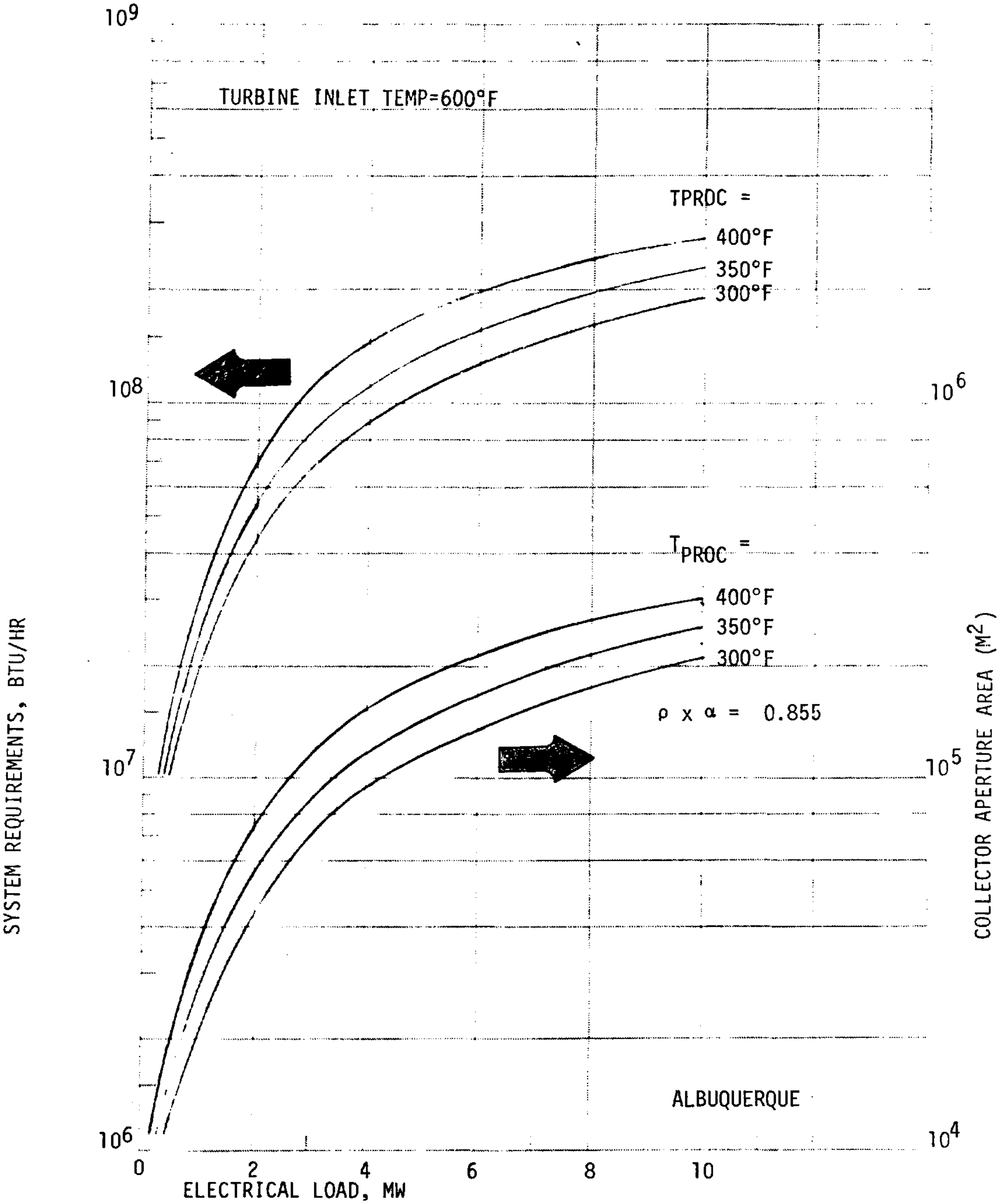
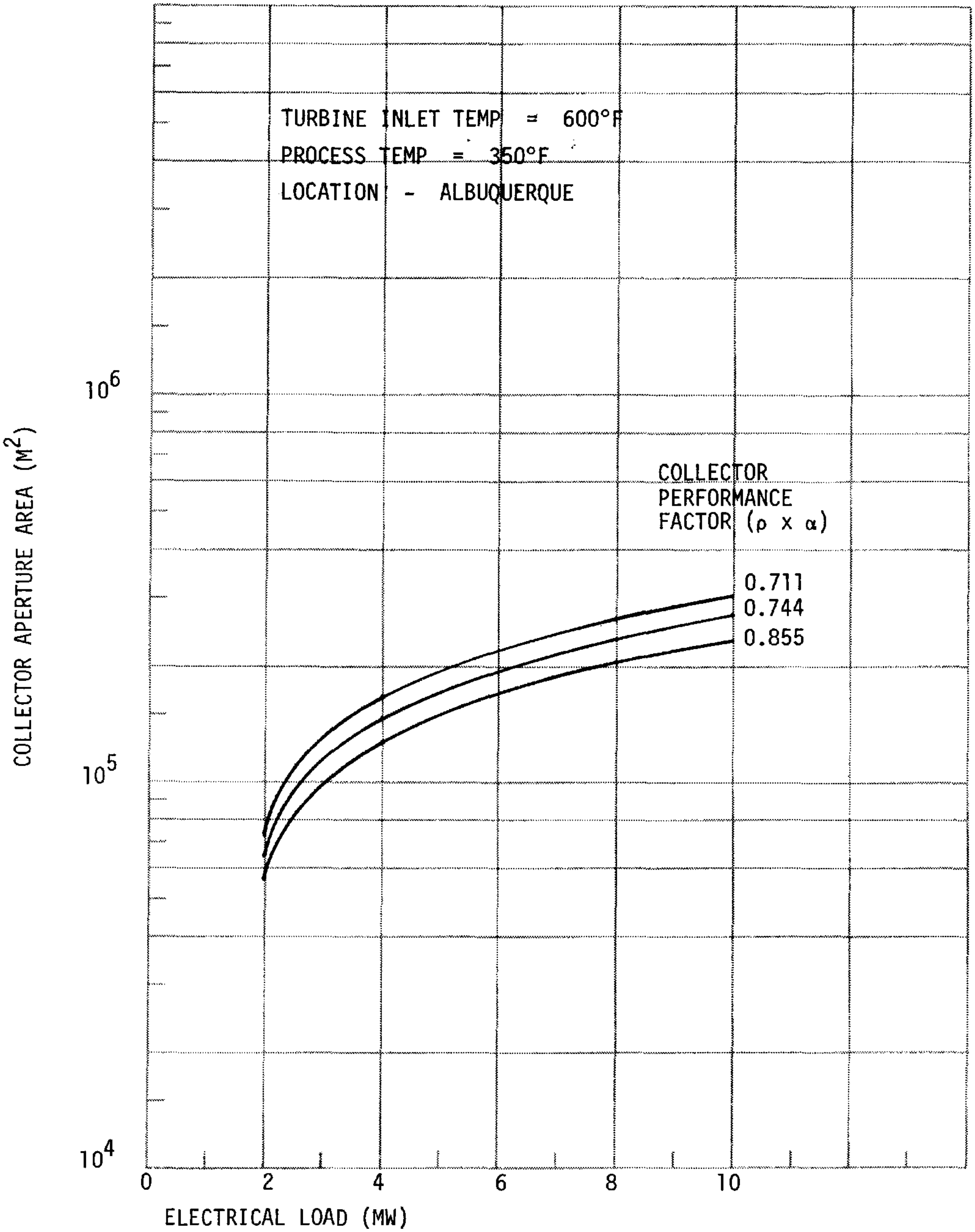


FIGURE 19 VARIATION OF SYSTEM REQUIREMENTS WITH ELECTRICAL LOAD



VARIATION IN FIELD SIZE WITH COLLECTOR PERFORMANCE
FIGURE 20

Levelized costs as a function of electrical load are shown in Figure 21 over the range of collector costs for three collector performances defined in terms of reflectivity (ρ) and absorptibity (α). As can be seen there is a definite benefit of scale when increasing the electrical load from 2 MW to 4 MW. However, beyond 4 MW there is only a small reduction in levelized cost for any given combination of collector cost and performance. In order to better assess the effects of collector performance and costs, curves were generated at 2, 4, 8 and 10 MW electrical loads showing the effects of cost and performance on levelized costs (Figures 22 through 25). It can be concluded that greater economic benefits can be obtained through cost reduction than performance imporvements independent of electrical load (system size).

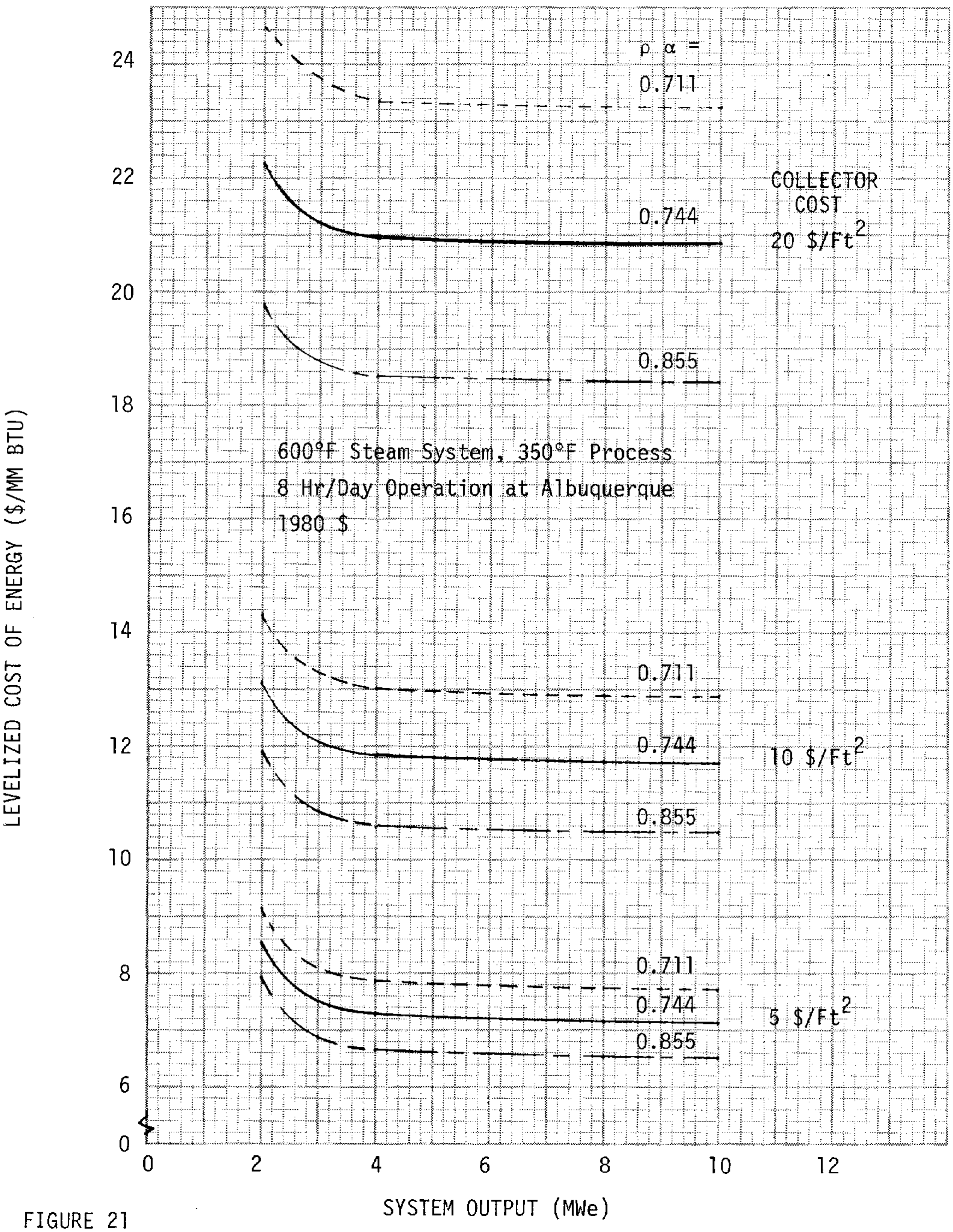


FIGURE 21

TOTAL ENERGY SYSTEM ECONOMICS - ρ α VARIATIONS

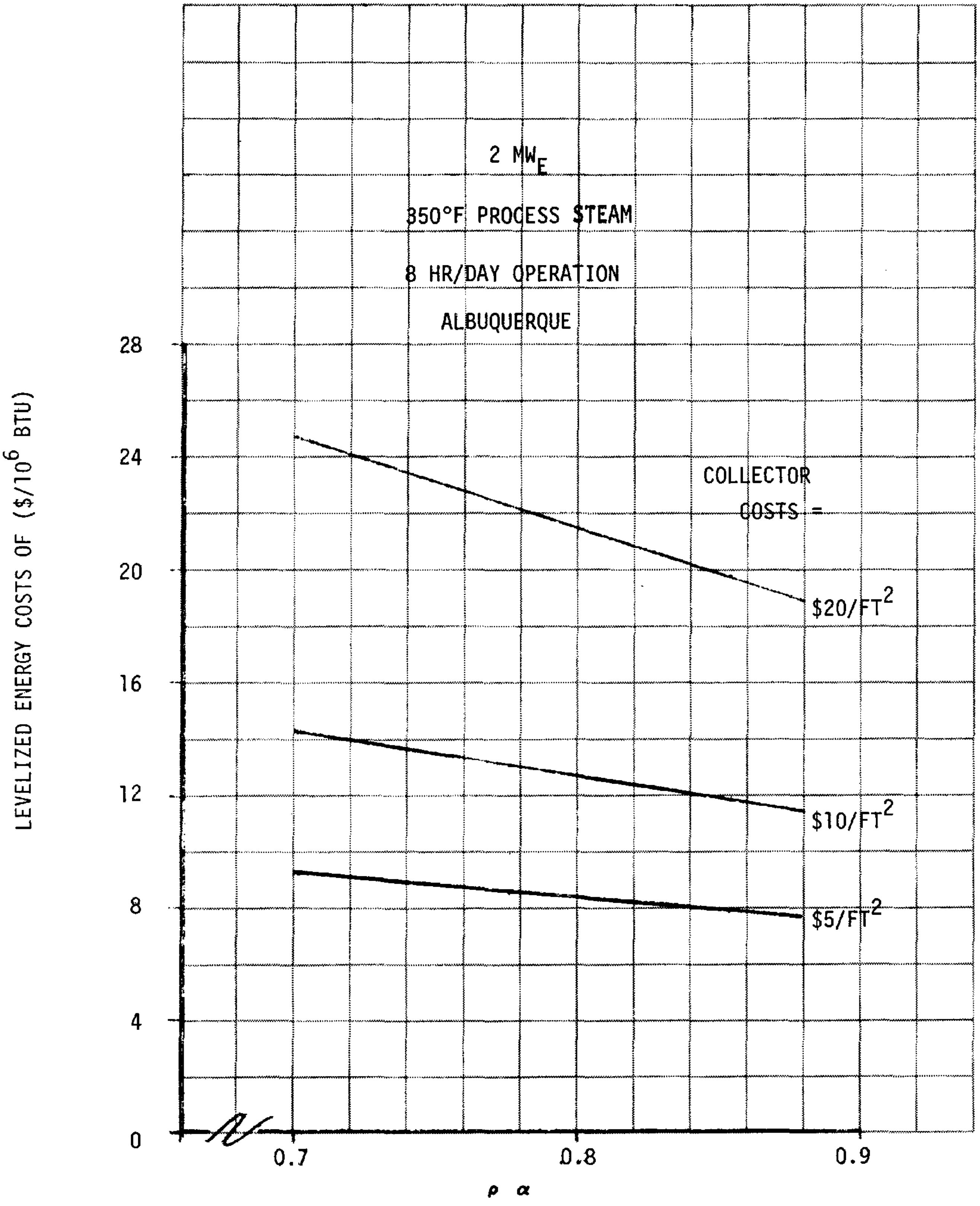


Figure 22 EFFECT OF $\rho\alpha$ ON LEVELIZED ENERGY COSTS - 2 MW_E

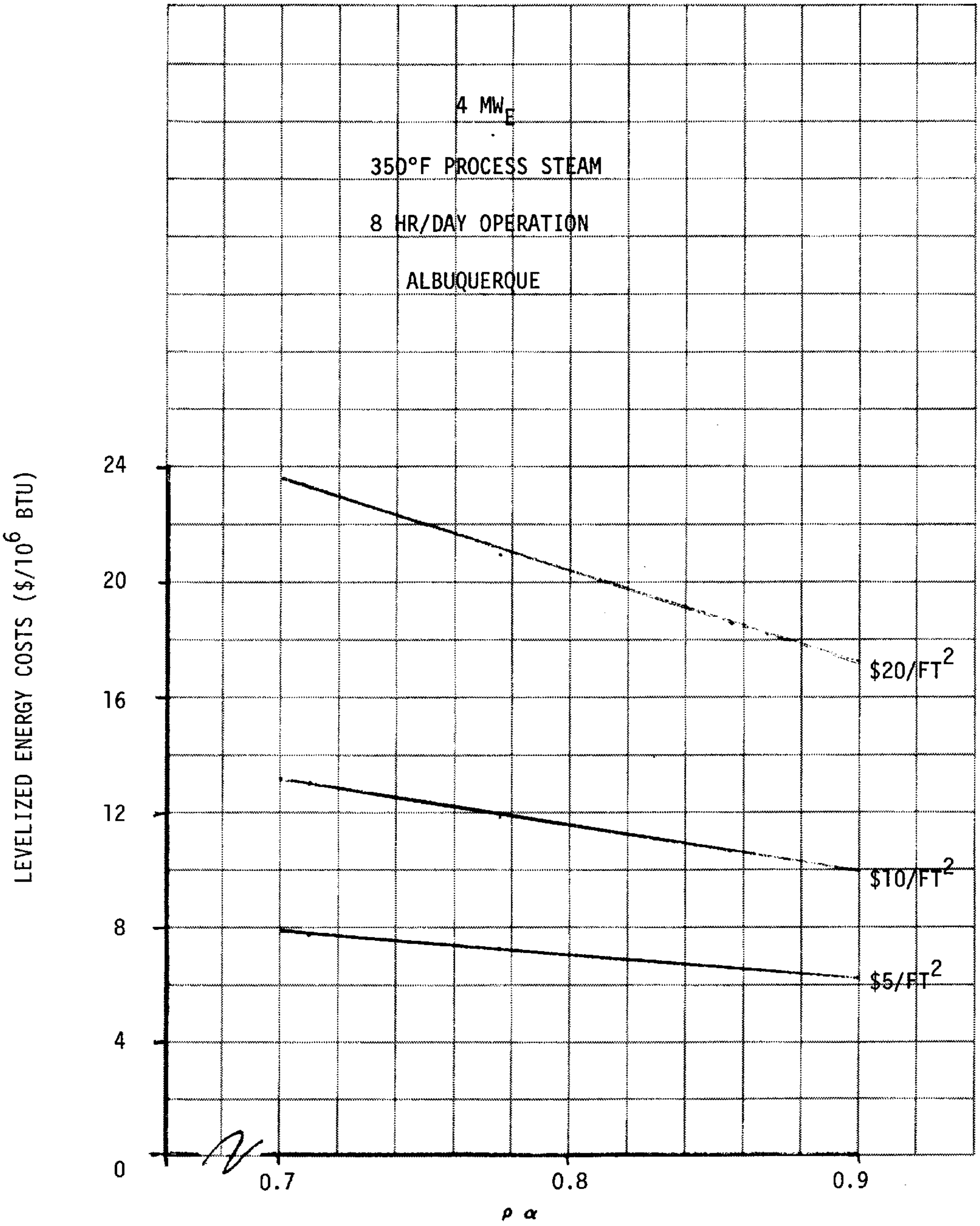


Figure 23 EFFECT OF $\rho\ \alpha$ ON LEVELIZED COSTS - $4MW_E$

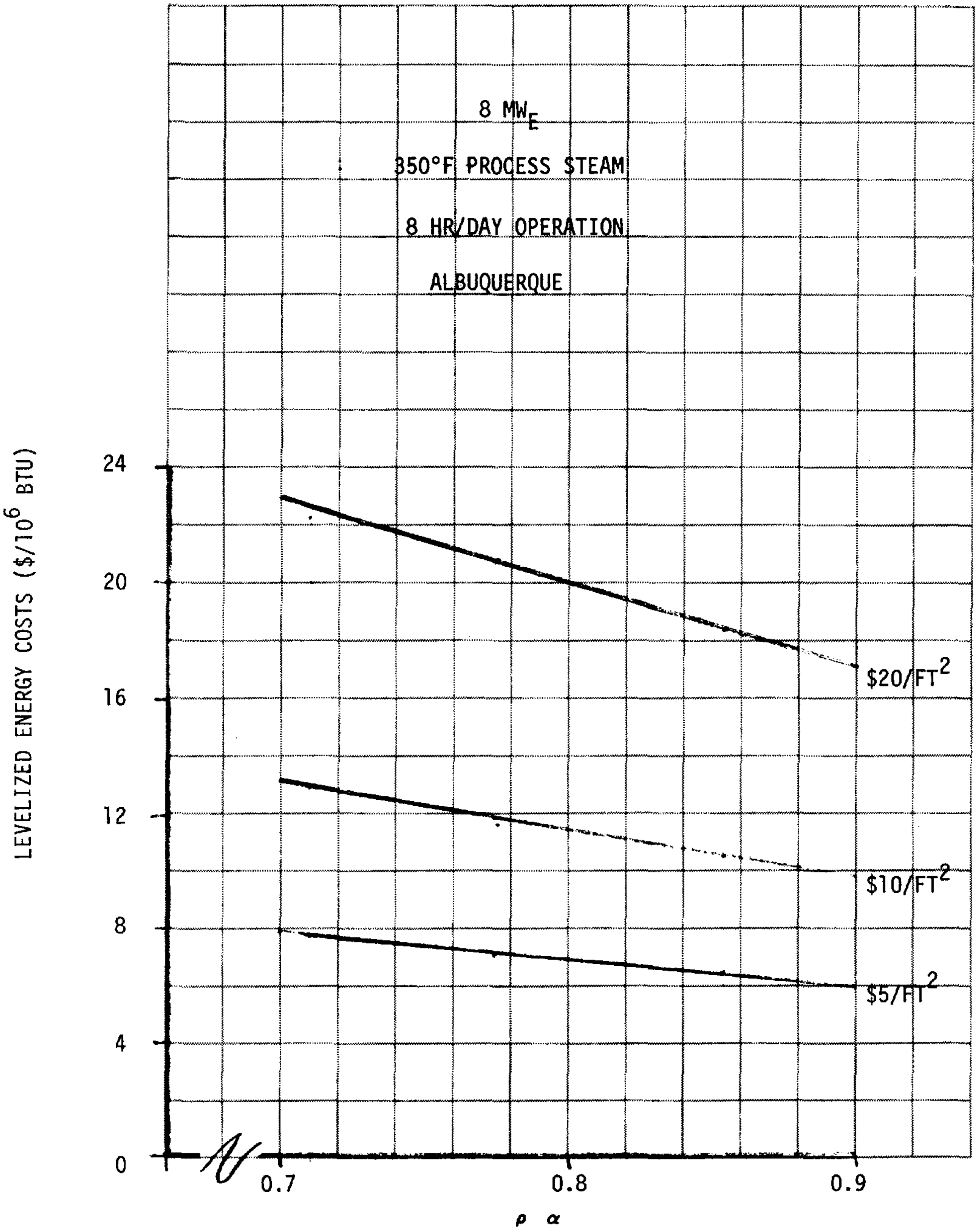


Figure 24 EFFECT OF $\rho\alpha$ ON LEVELIZED COSTS - 8 MW_E

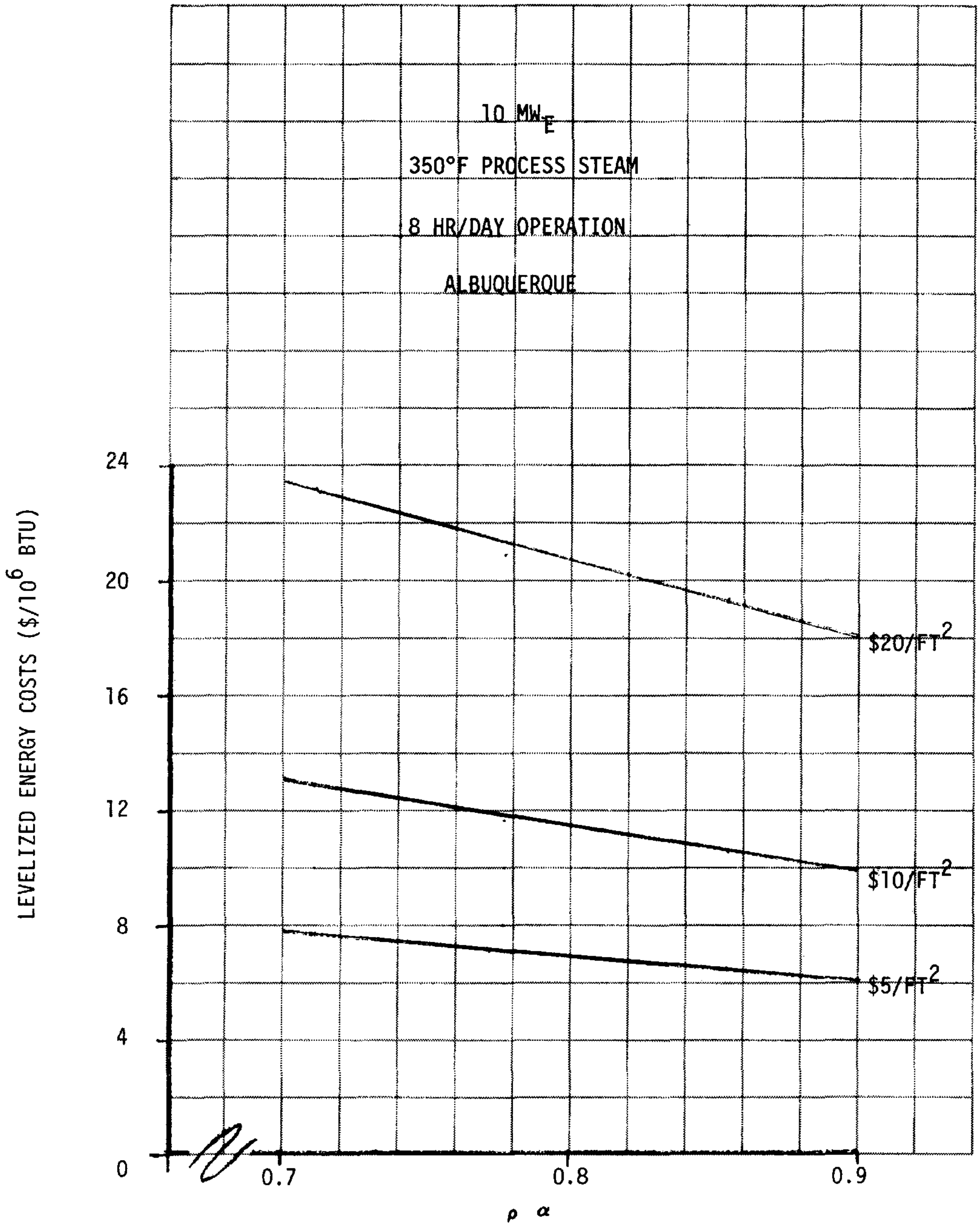


Figure 25 EFFECT OF $\rho\alpha$ ON LEVELIZED COSTS - 10 MW_E

3.3 System Designs

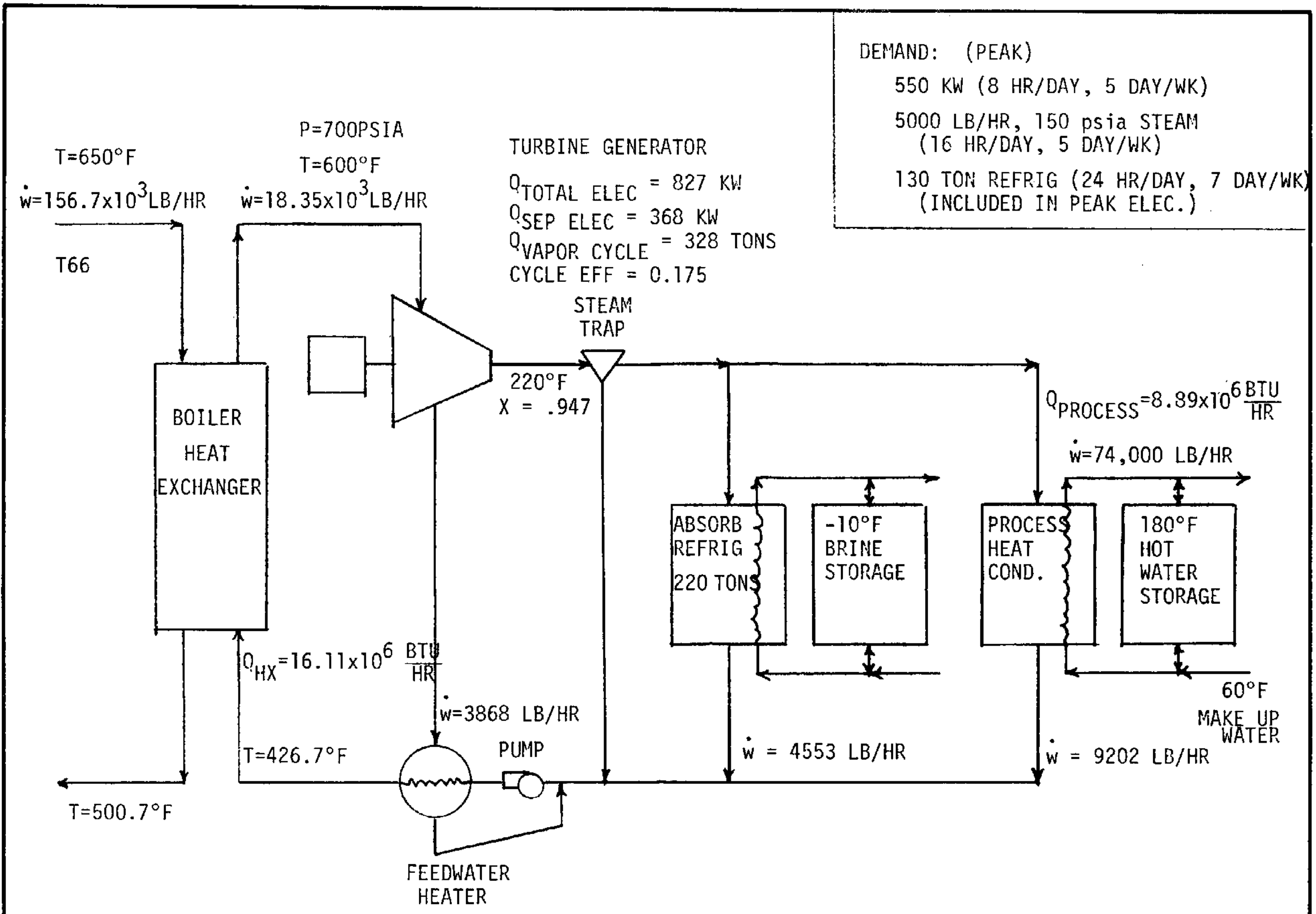
Solar Total Energy Systems have been defined for each of the sites to the level necessary to establish thermodynamic characteristics and identify the type and size of major components in the system. The thermodynamic data is used to determine collector field operating requirements and to allow the estimation of energy displacement for each of the systems on an annual basis. Components are sized to meet the thermodynamic requirements in terms of mass flows and energy exchange. The costs of the components along with the systems energy displacement characteristics were used as the basis for the system economics discussed in Section 4.2 of this report.

Collector fields were sized along with appropriate storage to provide 100 percent of the total energy system demand during the best collector performance season. Three levels of collector performance (in terms of varying reflectivity and absorbtivity) were used for each system sized. The week per season collector performance methodology described in Section 3.1.1 was used to define site specific collector performance.

ARMOUR MEAT PACKING, DIXON, CALIFORNIA SIC 2011

The primary process at this plant is the slaughter and butchering of lambs. In addition, they also slaughter and butcher beef. Their current demand for electricity includes a substantial amount of electricity used to power vapor compression refrigeration (130 tons) used for carcass cooling and cold storage. The 5,000 lb/hr of steam generated at the site is used to provide large amounts of 180° hot water used primarily for clean up during second shift.

The system is shown schematically in Figure 26. Also shown on the Figure is the facility's current demand and duty cycle. The system consists of a Rankine cycle that generates electricity to meet the electrical and refrigeration requirements during the first shift, cascaded over a process hot water and absorption refrigeration system. The system is designed to operate 5 days a week, eight hours a day. It produces enough extra refrigeration during this



DEMAND: (PEAK)
550 KW (8 HR/DAY, 5 DAY/WK)
5000 LB/HR, 150 psia STEAM (16 HR/DAY, 5 DAY/WK)
130 TON REFRIG (24 HR/DAY, 7 DAY/WK) (INCLUDED IN PEAK ELEC.)

Figure 26 MEAT PACKING; DIXON, CALIF. (SYS. OPER. 8 HR/DAY, 5 DAY/WK) this time (with both vapor compression and absorption units) to charge a low temperature brine storage tank, used, via heat exchangers, to provide the required cooling during the night and over the weekend. Similarly, enough hot water is produced to supply the necessary hot water for second shift cleanup. The hot water and absorption units act as condensing capacity for the Rankine cycle during system operation. The collector field was sized to provide 100 percent of the system weekly energy requirements during the summer. This requires the use of high temperature storage to enable the use of the collector on the weekend while the system is non-operating. During other seasons of the year the field is supplemented with the use of a fossil fired collector oil heater which is run in parallel with the field and storage system. A list of the major components and their pertainment size information (for use in this cost algorithms) is given in Table 4.

The energy displacement was calculted to be 71% per year. This amounted to 1, 344, 140 KWHR/Year of electrical displacement and 15, 359 MM BTU/Year of natural gas displacement, out of a current usage of 1,893,150 KW HR/Year and 21,632 MM BTU/Year.

COTTONSEED OIL PROCESSING, TEXAS SIC 2074

This facility's process involves the extraction of cottonseed oil. Cottonseed obtained from local cotton gins is first delinted, then the hulls are removed and finally the seed is steam pressure cooked to extract the oil. The bulk of their current electrical demand (4 MW) is used to drive the delinting and hulling machinery. Steam is generated on site at 150 psia at a rate of 18,000 lb/HR for use in the extraction process.

A schematic of the solar total energy system is shown in Figure 27 along with the plant's current energy demand and duty cycle. The system consists of a regenerated organic Rankine cycle. Toluene is used as the working fluid in the cycle. An organic Rankine cycle was selected because of its superior cycle efficiency at the allowable inlet temperature. The electrical output of the cycle is limited by the amount of condensing load (in this case the 18,000 LB/HR required steam flow) to 956 KW. A comparable steam Rankine cycle was analyzed and produced less than 600 KW with the same inlet temperature and

Table 4

SOLAR TOTAL ENERGY SYSTEM EQUIPMENT LIST

FACILITY: ARMOUR MEAT PACKING, DIXON, CALIFORNIA

EQUIPMENT	TYPE		SIZE (RATING)		
COLLECTORS	SINGLE-AXIS	$\rho \times \alpha$	0.855	0.774	0.711
	PARABOLIC TROUGH	FT^2	102,966	119,859	131,127
POWER CONVERSION	STEAM RANKINE			830 KW	
TURBINE GENERATOR SYSTEM	ORGANIC RANKINE			N/A	
STORAGE					
HIGH TEMPERATURE	DUAL MEDIA THERMOCLINE			30,800 FT^3	
HOT WATER	INSULATED ABOVE GROUND			4,753 FT^3	
COLD BRINE	INSULATED ABOVE GROUND			38,400 FT^3	
REFRIGERATION UNITS	CENTRIFUGAL ELECTRIC VAPOR COMPRESSION			367 TONS	
	ABSORPTION (STEAM)			220 TONS	
HEAT EXCHANGERS	COUNTERFLOW TUBE AND SHELL		ONE @ 2430 FT^2	ONE @ 435 FT^2	
FOSSIL OIL HEATER				16.11×10^6 BTU/HR	

DEMAND
4.0 MWe
18,000 LB/HR 150 PSIA STEAM
(24 HR/DAY, 7 DAY/WK)

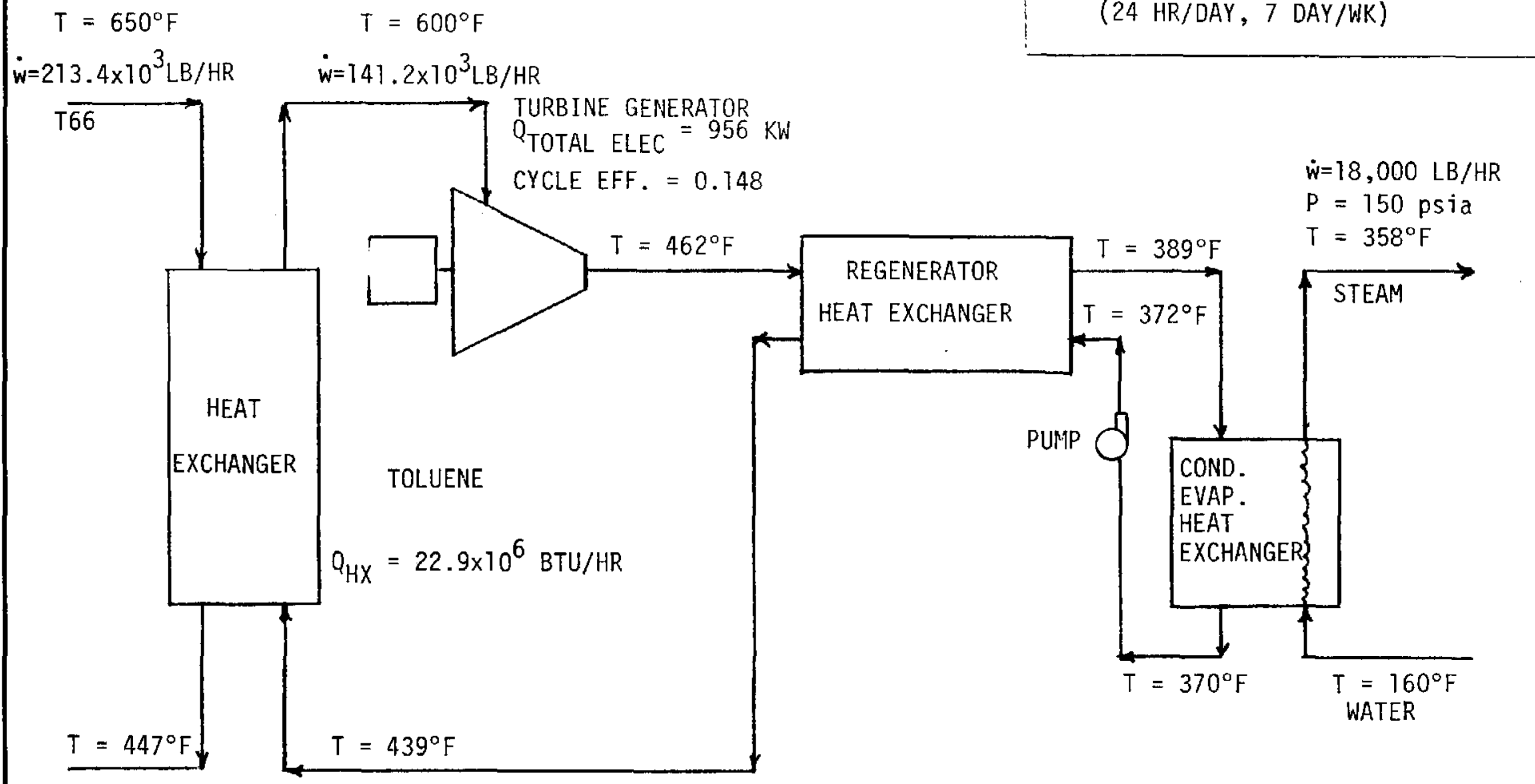


Figure 27 COTTONSEED OIL EXTRACTION, TEXAS (ORGANIC RANKINE CYCLE)
SYSTEM OPERATES 24 HR/DAY WITH STORAGE

condensing load , thus the selection of the organic Rankine cycle.

The collector field was sized with enough storage to run the system for 24 hours during the summer season (highest daily collector performance season). A fossil heater is used to augment the field (heating the T66 collector fluid) during periods of lessor field performance. A list of the major components and their pertainment size information (for use in the cost algorithms) is given in Table 5.

The energy displacement provided by the system is estimated to be 5.247 x 10^6 KW HR/Year or 21.4% of their current 24.53 x 10^6 KW HR/Year usage. Since the system cannot produce the required 4 MW of electrical power it was assumed that it would operate in parallel with the plants grid hookup. The natural gas displacement was estimated to be 154,959 MM BTU/Year or 89.5% of their current 173,139 MM BTU/Year boiler usage.

ARMOUR MEAT PACKING, HERFORD, TEXAS SIC 2011

This facility is engaged in the slaughtering and butchering of beef. In addition, their process includes an on site rendering plant. Current demand includes 2.3 MW electricity plus 37,000 lbs of 150 psia steam. The steam use is divided approximately in half between the rendering plant and the slaughter house. The slaughter house steam is ultimately used to produce approximately 130,000 lb/HR of 180° hot water used for equipment sterialization and plant cleanup. In addition to the above demand the facility requires 1000 tons of refrigeration cooling for carcass cooling and storage. This demand is currently supplied with natural gas fired internal combustion engines.

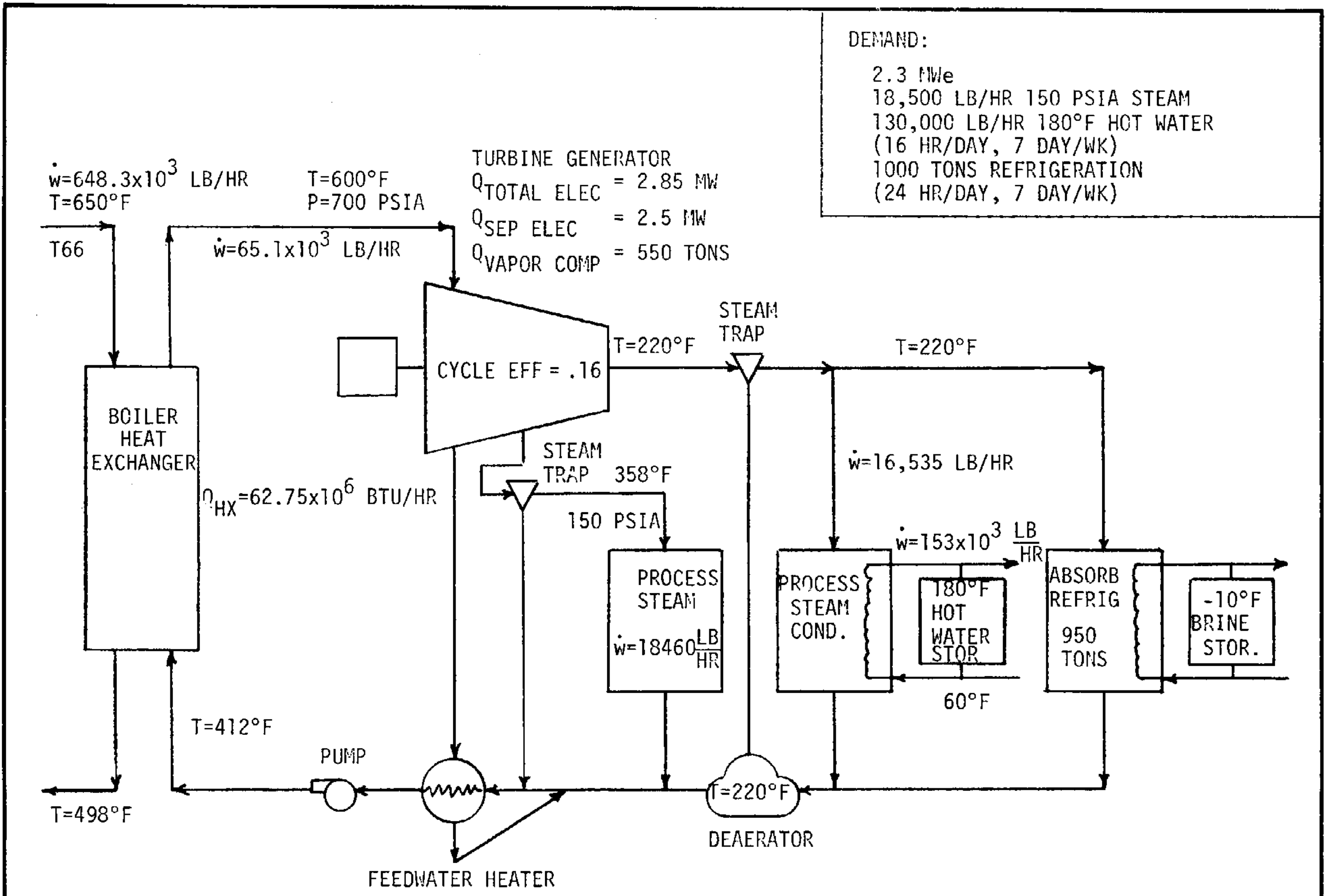
The system proposed for this facility is shown in Figure 28 along with the demand and duty cycle information. The system utilizes a dual extraction steam turbine using hot water production and absorption refrigeration units as the condensing load along with the extracted rendering plant steam flow. Excess refrigeration is produced in the form of chilled brine during the 16 hours of system operations to provide cooling during third shift. Hot water is also stored during first shift as the bulk of the clean up is during second shift. The system is capable of supplying essentially 100% of the plants requirements while operating 16 hours a day from either solar or a fossil fired T66 heater.

Table 5

SOLAR TOTAL ENERGY SYSTEM EQUIPMENT LIST

FACILITY: COTTONSEED OIL, TEXAS

EQUIPMENT	TYPE	SIZE (RATING)			
COLLECTORS	SINGLE-AXIS	$\rho \times \alpha$	0.855	0.774	0.711
	PARABOLIC TROUGH	FT^2	787,393	899,509	1,019,670
POWER CONVERSION	STEAM RANKINE			N/A	
TURBINE GENERATOR SYSTEM	ORGANIC RANKINE			956 KW	
STORAGE					
HIGH TEMPERATURE	DUAL MEDIA THERMOCLINE			39,683 FT^3	
HOT WATER	INSULATED ABOVE GROUND			N/A	
COLD BRINE	INSULATED ABOVE GROUND			N/A	
REFRIGERATION UNITS	CENTRIFUGAL ELECTRIC VAPOR COMPRESSION			N/A	
	ABSORPTION (STEAM)			N/A	
HEAT EXCHANGERS	COUNTERFLOW TUBE AND SHELL			1 @ 4514 FT^2	1@ 2725 FT^2
FOSSIL OIL HEATER				22.9×10^6 BTU/HR	



DEMAND:
2.3 MWe
18,500 LB/HR 150 PSIA STEAM
130,000 LB/HR 180°F HOT WATER
(16 HR/DAY, 7 DAY/WK)
1000 TONS REFRIGERATION
(24 HR/DAY, 7 DAY/WK)

Figure 28 MEAT PACKING, HEREFORD, TEXAS
(SYSTEM OPERATES 16 HR/DAY, 6 DAY/WK)

The collector field was sized along with enough storage capacity to provide 100% of the system requirement from solar during the highest performance season (summer season). A list of the major components characteristics used for costing is shown in Table 6.

The energy displacement at this facility was estimated at 90% or 9.67 x 10^6 KW HR/Year (out of 10.75 x 10^6 KW HR/Year) electrical and 263,400 MM BTU/Year (out of 304,820 MM BTU/Year) of natural gas.

VEGETABLE OIL PROCESSING, CALIFORNIA SIC 2079/2022/2035

This facility is involved in processing eatable oils, primarily vegetable, into cooking oil, salad dressings, margarine, and with the addition of milk solids into process cheeze. The peak electrical demand (1.4 MW) occurs during the first shift Monday through Friday and is associated with the packaging of finished products in addition to the 24 hour a day, 7 day a week basic processing demand. All of the steam load is associated with the basic process. Twenty-five percent or 3000 LB/HR of the average 12,000 LB/HR of steam is used at 220 psia for turbine drive to provide mechanical power to part of the process. The bulk of the remaining steam is used for oil heating and process cooking and is supplied at 150 psia (9000 LB/HR). The refrigeration load is associated with the basic process also and is essentially constant throughout the week.

T he proposed system (shown in Figures 29 and 30) shows the system in two operating modes (daytime,and nighttime and weekends). It consists of a triple extraction (one feedwater heating, and two different pressure requirements steam) turbine exhausting through an absorbtion chiller which acts as a condensing load for the lowest pressure turbine exhaust. The refrigeration load is split between electric drive vapor compression and the absorption unit. The reduction of the electrical load that takes place at the start of second shift changes the split in the refrigeration load from predominately absorption during the day to predominately vapor compression at night and on weekends while still meeting the constant process steam requirement. The reduced flow to the turbine at night due to the reduction in electrical load also reduces the system's input energy requirement (shown in the Figures as QHX) from 24 Million to 16 Million BTU/HR.

Table 6

SOLAR TOTAL ENERGY SYSTEM EQUIPMENT LIST

FACILITY: MEAT PACKING, HERFORD, TEXAS

EQUIPMENT	TYPE		SIZE (RATING)		
COLLECTORS	SINGLE-AXIS	$\rho \times \alpha$	0.855	0.774	0.711
	PARABOLIC TROUGH	FT^2	1,528,000	1,777,000	1,980,000
POWER CONVERSION	STEAM RANKINE			2,854	
TURBINE GENERATOR SYSTEM	ORGANIC RANKINE			N/A	
STORAGE					
HIGH TEMPERATURE	DUAL MEDIA THERMOCLINE			76,711 FT^3	
HOT WATER	INSULATED ABOVE GROUND			EXISTING	
COLD BRINE	INSULATE ABOVE GROUND			36,920 FT^3	
REFRIGERATION UNITS	CENTRIFUGAL ELECTRIC VAPOR COMPRESSION			550 TONS	
	ABSORPTION (STEAM)			980 TONS	
HEAT EXCHANGERS	COUNTERFLOW TUBE AND SHELL			10,079 FT^2	
FOSSIL OIL HEATER				62.75×10^6 BTU/HR	

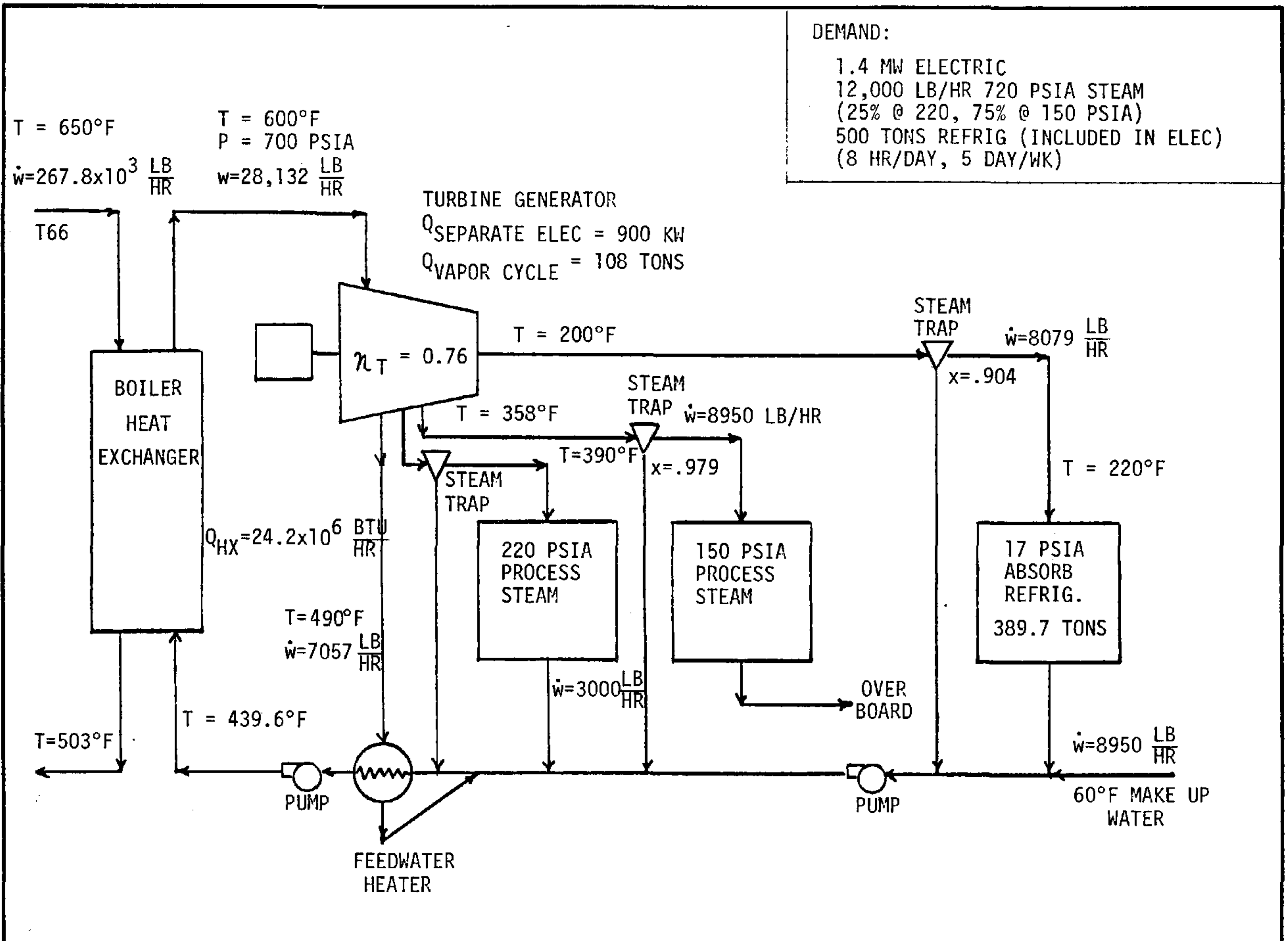


Figure 29 VEGETABLE OIL PROCESSING, CALIFORNIA - DAYTIME OPERATION
(8 HR/DAY, 5 DAY/WK)

DEMAND:

0.6 MW ELECTRIC
12,000 LB/HR 220 PSIA STEAM
(25% @ 220, 75% @ 150 PSIA)
500 TONS REFRIG (INCLUDED IN ELEC)
(16 HR/DAY, 5 DAY/WK + 24 HR/DAY
WEEKENDS)

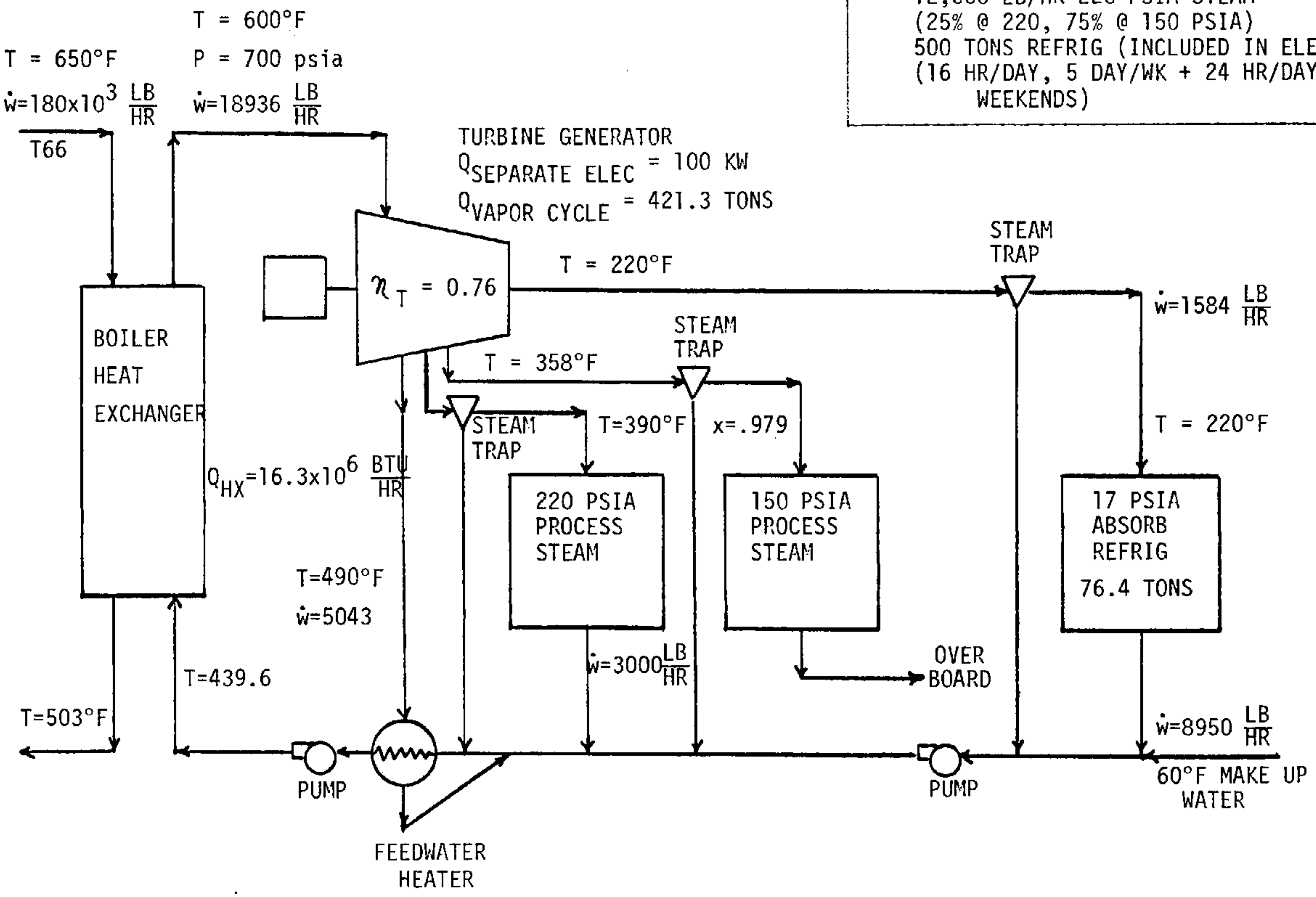


Figure 30 VEGETABLE OIL PROCESSING, CALIFORNIA - NIGHTTIME AND WEEKEND OPERATION
(16 HR/DAY, 5 DAY/WK + 24 HR/DAY WEEKENDS)

The collector field was sized to provide enough energy in a seven day collection period to supply the systems variable load (day, night and weekend) for a week during the best collector performance week (summer season). This required the use of high temperature thermal storage to accummulate enough energy to run the system at night. The characteristics of the major components as required for cost estimating are shown in Table 7.

The energy displacement estimates for this facility are based on an estimate of 71% solar operation of the total energy system. With the system sized to provide 100% of the facility's demand, current usage is estimated to be 5.503×10^6 KW HR/Year electrical and 153,300 MM BTU/Year natural gas giving a displacement of 3.907×10^6 KW HR/Year and 108,800 MM BTU/Year.

SEAFOOD PROCESSING, CALIFORNIA SIC 2047/2091

This facility processes seafood, cleaning, cooking and canning of fish for human consumption along with producing pet food as a by-product. Fish is brought in fresh or frozen by boat and put in short term storage allowing the near continuous 12 hr/day, 6 day/week operation of the plant. The peak electrical demand is near 6 MW including 1500 tons of refrigeration load. Steam is used at varying pressures at a rate of 106,000 lb/hr, purchased from a steam co-op which is majority-owned by the facility. Part of this steam demand (approx. 11,000 lb/hr) is used to provide mechanical energy by expansion through existing turbines entering the turbines at 260 psia and 525°F. The remainder is used at 150 psia or less. All of the above demand is for 12 hours during the daytime. At night and on Sundays, the process demand is zero with the only substantial demand coming from a 540 ton refrigeration load.

The proposed system (Figures 31 and 32) consists of a single feedwater heater extraction turbine exhausting to 150 psia. Part of the steam during the daytime operation is bypassed around the turbine and throttled adiabatically to 260 psia and 525°F for use in the existing turbines. Condensing for the turbine flow is provided by the large 150 psia process heat requirement, augmented by a 1400 ton absorption chiller. This system provides all of the facility's demand during the daytime 12 hour operation. Refrigeration loads are split between electric vapor compression and absorption units sized to

Table 7

SOLAR TOTAL ENERGY SYSTEM EQUIPMENT LIST

FACILITY: VEGETABLE OIL, CALIFORNIA

EQUIPMENT	TYPE		SIZE (RATING)		
COLLECTORS	SINGLE-AXIS	$\rho \times \alpha$	0.855	0.774	0.711
	PARABOLIC TROUGH	FT^2	481,084	571,129	626,030
POWER CONVERSION	STEAM RANKINE			1009 KW	
TURBINE GENERATOR SYSTEM	ORGANIC RANKINE			N/A	
STORAGE					
HIGH TEMPERATURE	DUAL MEDIA THERMOCLINE			60,000 FT^3	
HOT WATER	INSULATED ABOVE GROUND			N/A	
COLD BRINE	INSULATED ABOVE GROUND			N/A	
REFRIGERATION UNITS	CENTRIFUGAL ELECTRIC VAPOR COMPRESSION			422 TONS	
	ABSORPTION (STEAM)			390 TONS	
HEAT EXCHANGERS	COUNTERFLOW TUBE AND SHELL			3757 FT^2	
FOSSIL OIL HEATER				24.2×10^6 BTU/HR	

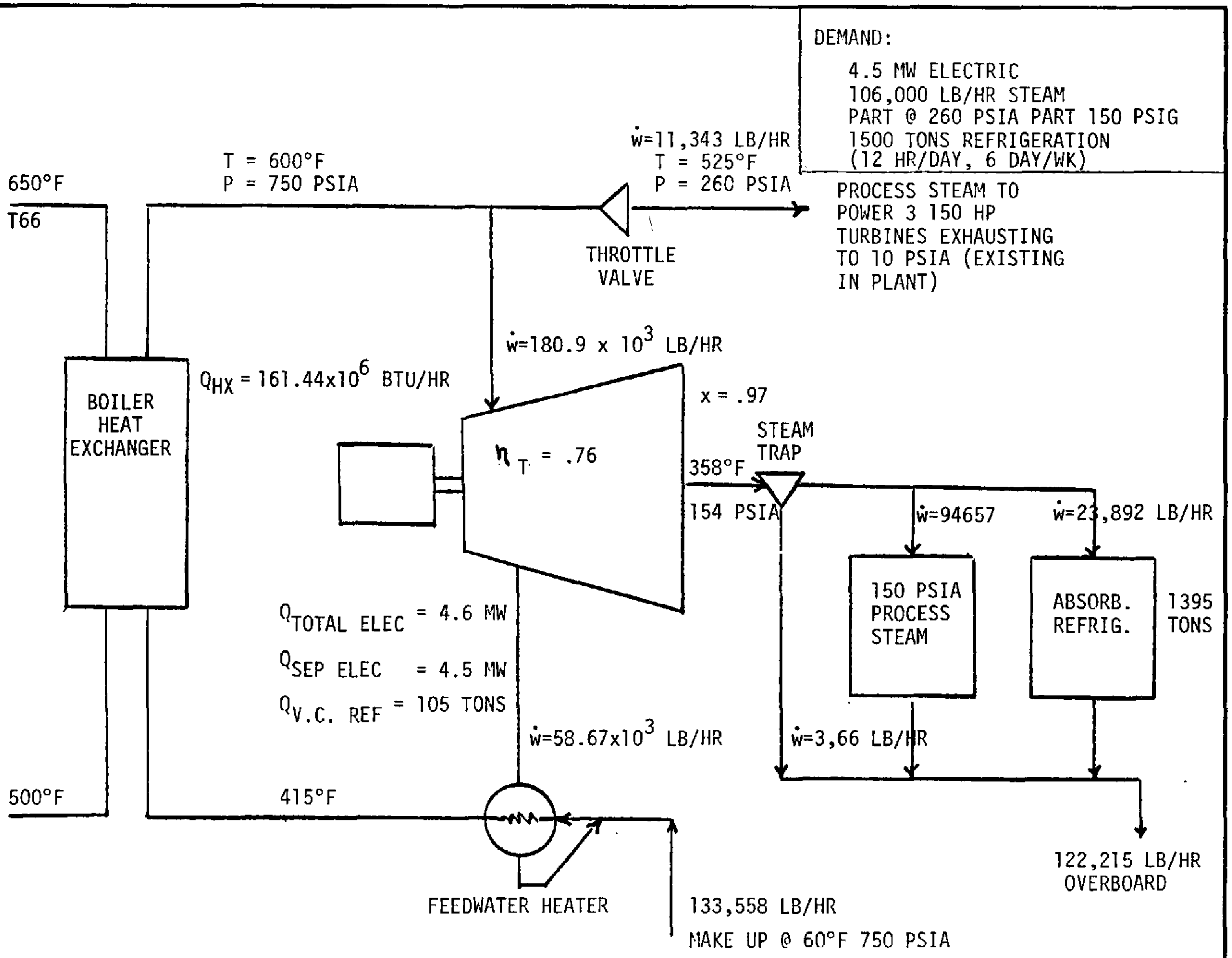


Figure 31 SEAFOOD PROCESSING, CALIFORNIA - DAYTIME OPERATION
(12 HR/DAY, 6 DAY/WK)

DEMAND: NIGHTTIME

540 TONS REFRIGERATION
(12 HR/DAY, 6 DAY/WK, 24 HR SUN.)

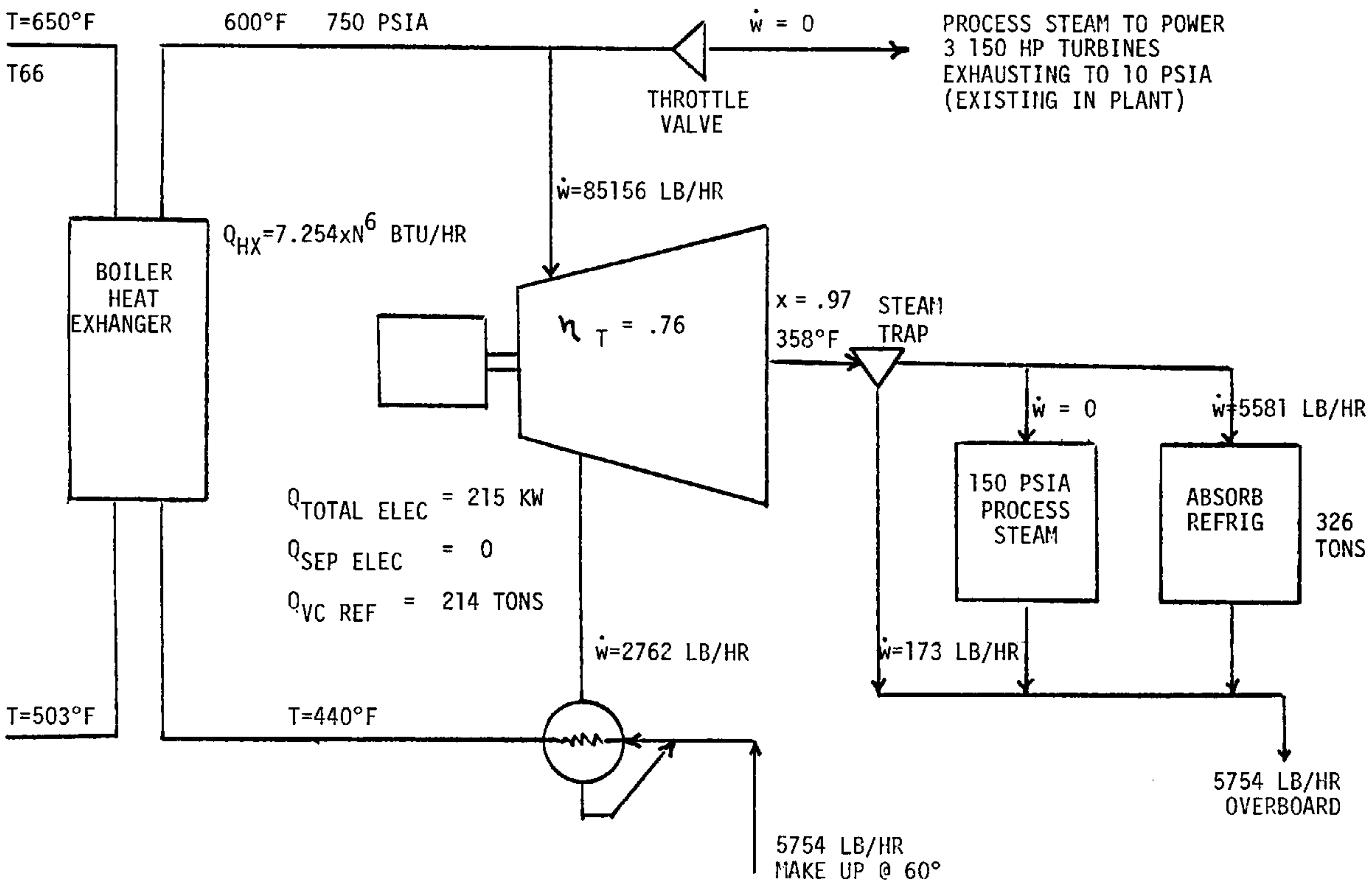


Figure 32 SEAFOOD PROCESSING, CALIFORNIA - NIGHTTIME OPERATION (12 HR/DAY, 6 DAY/WK, 24 HR ON SUNDAY)

balance the load. During nighttime and Sunday operation in the absence of process electrical and heat requirements the system provides all of the required refrigeration load (540 tons) by reducing the absorption chiller load and increasing the vapor compression load to the point where the system is again balanced without the process heat or additional separate electrical load. The overall system energy requirement drops substantially during the evening (from 161 x 10^6 to 7.2 x 10^6 BTU/hr).

As in other systems with daily variation in system load the collector field was sized using average summer daily performance to collect enough energy in seven days to supply 100% of the systems total weekly energy demand. This necessitated the use of high temperature storage to distribute the energy at the required rate throughout the weekly duty cycle. The peak storage capacity requirement occurs at sundown on Sunday where the daily collection capacity most exceeds the daily system demand. The pertinent sizes and ratings of the major components are given in Table 8 and are the basis of the system costs used in the economic analyses.

The system displacement is based on providing 81% of the total energy systems demand with solar. This amounts to 19.44 x 10^6 KWHR of electricity (out of an estimated current usage of 24 x 10^6 KWHR per year) and 35,600 MMBTU/year of natural gas (out of an estimated 44,000 MMBTU/year usage).

GULF URANIUM MINE AND MILL, SAN MATEO, NEW MEXICO

The primary process at this facility will be the mining and processing of uranium ore. The mine has two 3400 foot shafts in place at this time. The mill is to be in operation by 1982. The mill is designed to process 4200 tons of blended ore per day to yield 25,000 lb/day of U_3O_8 as finished yellow cake product, operating 24 hours per day. Current demand for electricity includes approximately 6 MW to power pumps used to remove subterranean water from the mine. Once the mine and mill are in operation that demand will increase to include, among other things, mine air conditioning and mill process steam. The air conditioning load peaks during the summer and is reduced to zero load during the winter. The steam load peaks during the winter at 116,900 lb/hr and drops to a minimum of 51,200 lb/hr during the month of June. The required steam quality is 150 psia saturated. The steam is used at several points in the

Table 8

SOLAR TOTAL ENERGY SYSTEM EQUIPMENT LIST

FACILITY: SEAFOOD PROCESSING, CALIFORNIA

EQUIPMENT	TYPE		SIZE (RATING)		
COLLECTORS	SINGLE AXIS	$\rho \times \alpha$	0.855	0.774	0.711
	PARABOLIC TROUGH	10^6 FT^2	2.539	2.931	3.310
POWER CONVERSION	STEAM RANKINE		4600 KW		
TURBINE GENERATOR SYSTEM	ORGANIC RANKINE		NA		
STORAGE					
HIGH TEMPERATURE	DUAL MEDIA THERMOCLINE		265,300 FT^3		
HOT WATER	INSULATED ABOVE GROUND		NA		
COLD BRINE	INSULATED ABOVE GROUND		NA		
REFRIGERATION UNITS	CENTRIFUGAL ELECTRIC VAPOR COMPRESSION		214 TONS		
	ABSORPTION (STEAM)		1395 TONS		
HEAT EXCHANGERS	COUNTERFLOW TUBE AND SHELL		26,264 FT^2		
			$161.44 \times 10^6 \frac{BTU}{HR}$		
FOSSIL OIL HEATER					

mill process to provide hot ore slurry for more efficient chemical reactivity and to pre-heat boiler feed water.

The system is shown schematically in figures 33 through 35 for each of the seasons (summer, fall and spring, and winter). It was assumed that both the steam and air conditioning demand varied linearly throughout the year. Demand during each season is shown on the figure. The system consists of a steam rankine cycle that generates electricity to meet the mine pump requirements using the mill process steam and an absorption chiller providing the air conditioning as condensing load for the cycle. The system is designed to operate 24 hr/day, 7 day/week, operating out of storage during the nighttime. The total flow through the system is constant throughout the year. The condensing flow is split proportionally between the mill process steam load and the absorption chiller with the mill demand setting the flow split during the year. A list of the major components and their sizes and ratings are shown in table 9. These values were used in the appropriate cost algorithms as input data for the economic analyses done for this facility.

The energy displacement was calculated by season and amounted to 67% of the plant's annual electrical demand. The electrical demand was assumed to include the 6 MW mine pump requirement plus the electric demand to supply the same cooling capacity as the STES calculated at a COP of 3.5 for a vapor compression refrigeration system. This amounted to 46.64×10^6 KWHR/yr supplied from the STES out of a forecasted use of 69.58×10^6 KWHR/yr to supply mine pumping and cooling. The STES supplies 75% of the mill steam requirements in a year which amounts to 817,757 MMBTU/yr or 140,993 barrels of oil. The mill is scheduled to use #6 fuel oil as its primary fuel.

U.S. BORAX PLANT, BORON, CALIFORNIA

This facility is one of the largest producers of borax products in the world. The Boron plant provides over 80% of the free world's borax from a huge open pit mine. The plant's peak electrical demand is 21 MW, using over 150 million KWHR per year. The peak steam demand is 466,000 lb/hr. The average demand is slightly over 300,000 lb/hr. The steam is currently produced at 150 psia saturated with a condensate return of approximately 25%.

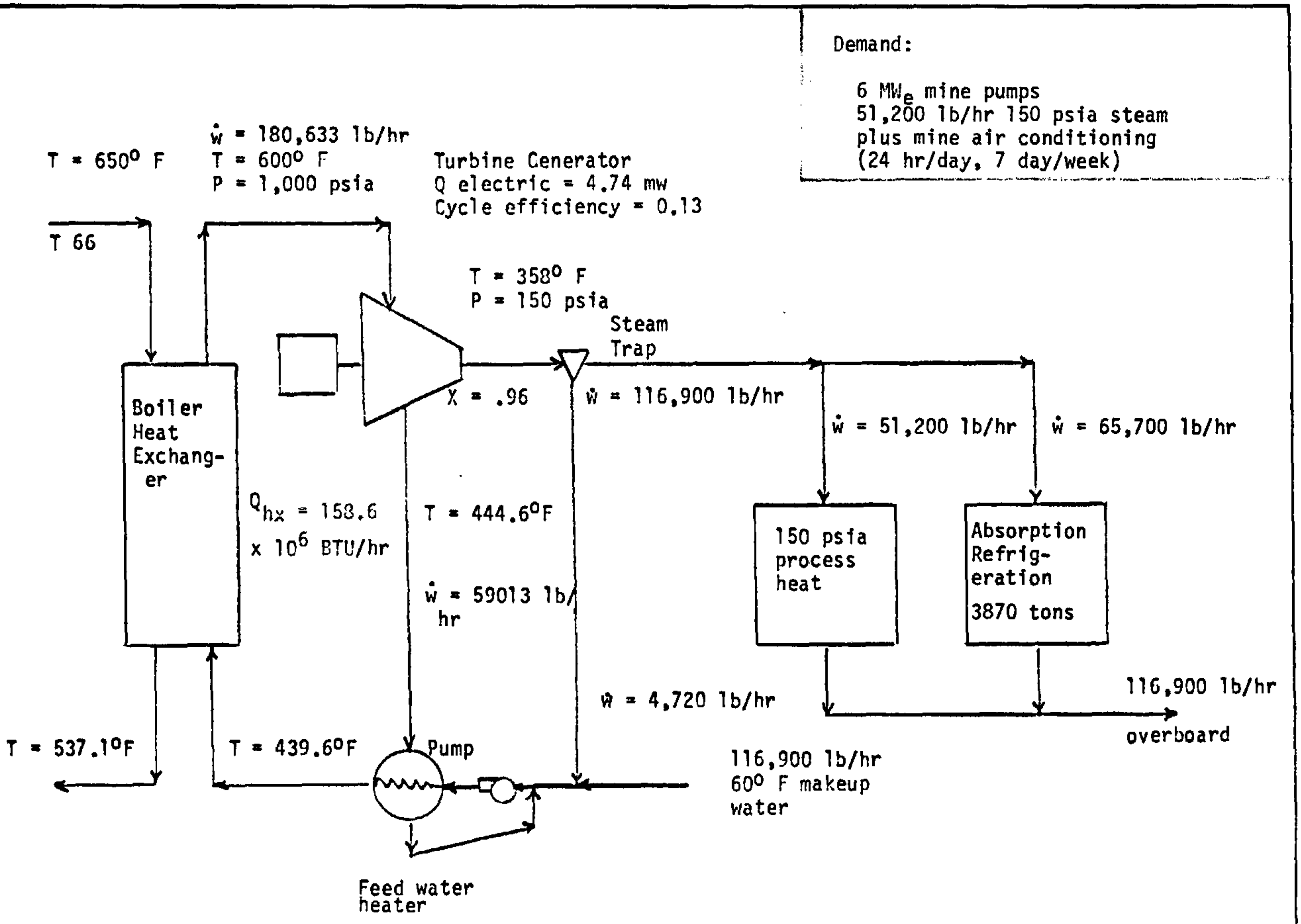
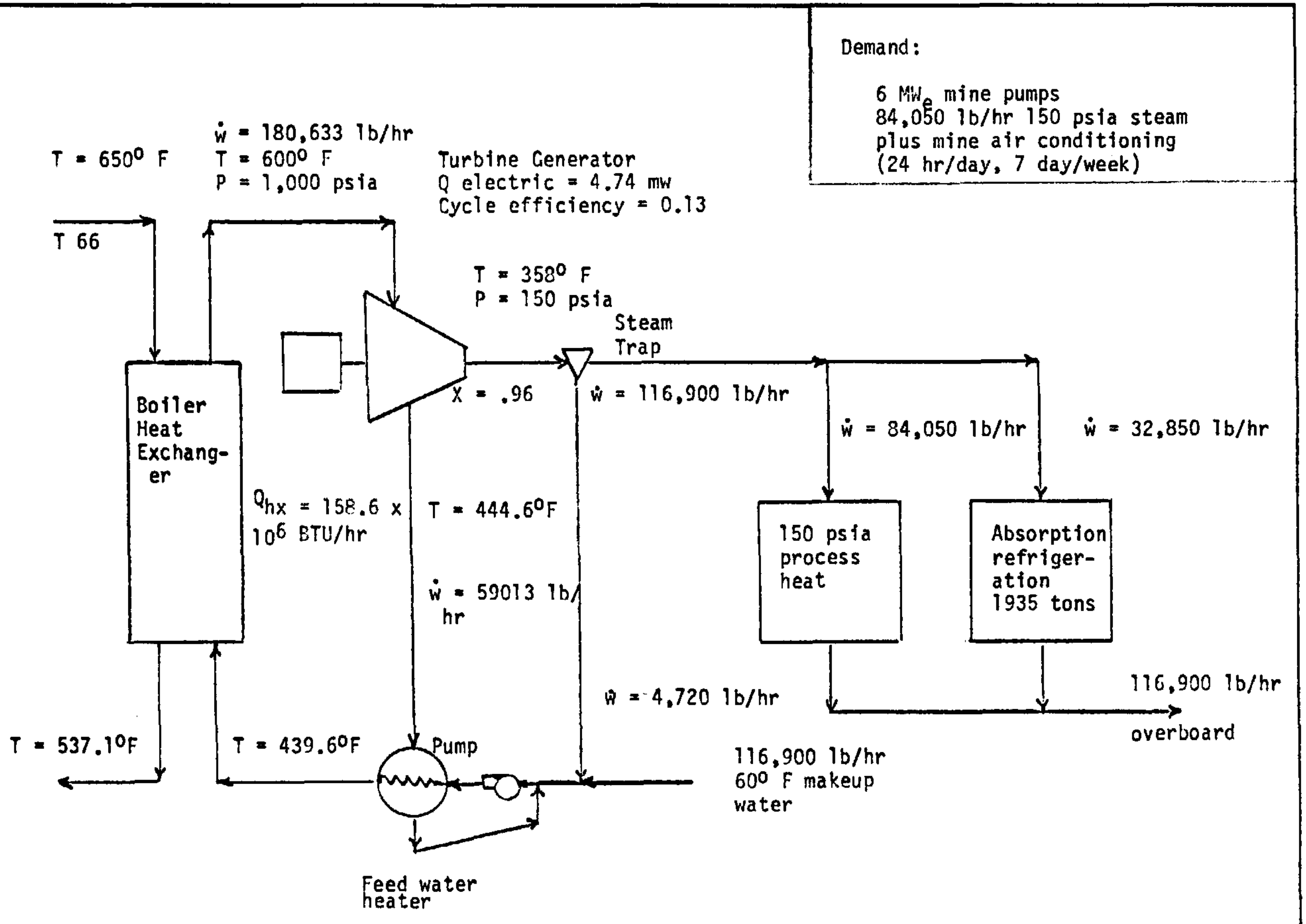


FIGURE 33

GULF URANIUM MINE AND MILL, NEW MEXICO

Summer Operation - 24 hr/day)



Demand:

6 MW_e mine pumps
84,050 lb/hr 150 psia steam
plus mine air conditioning
(24 hr/day, 7 day/week)

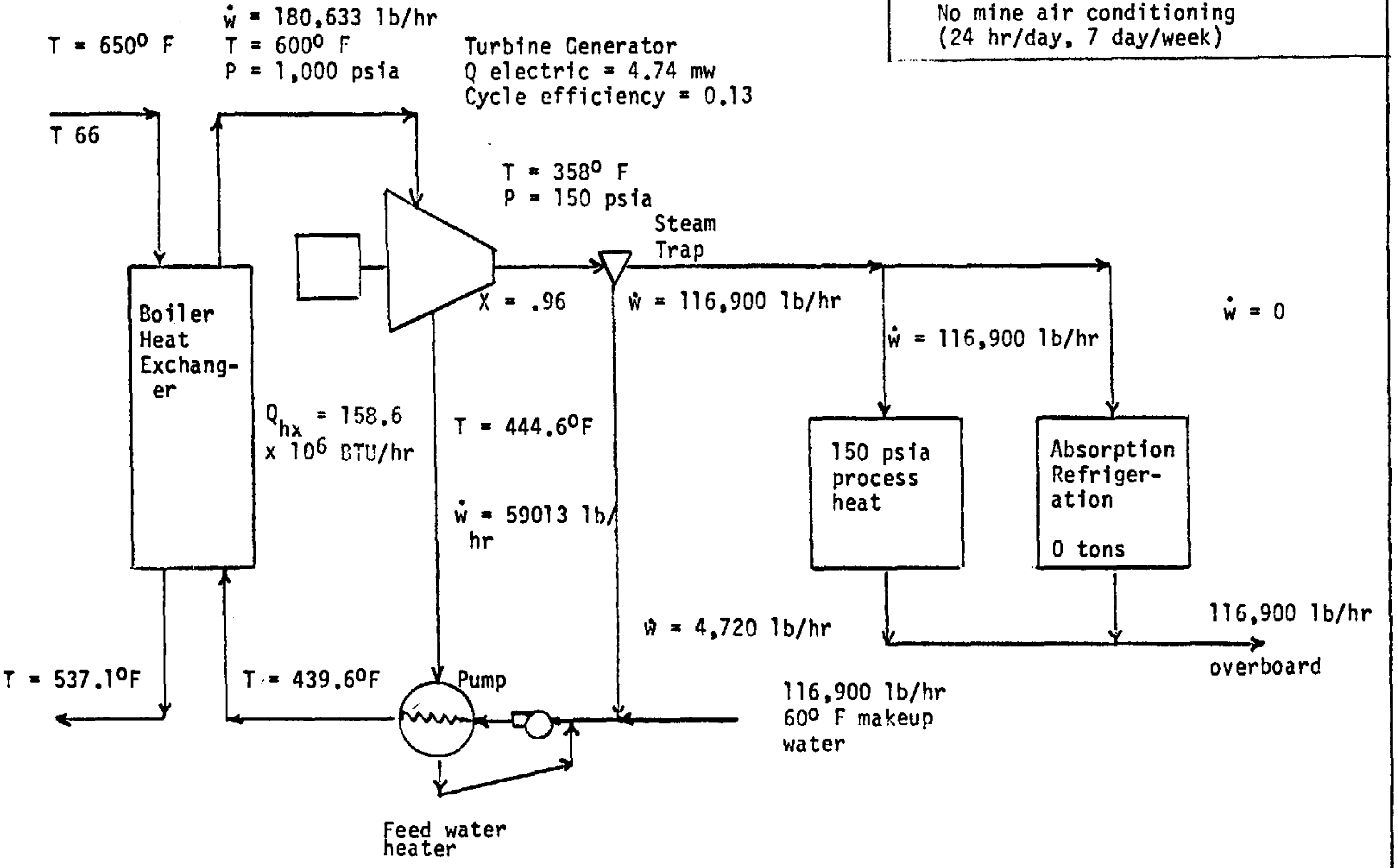
FIGURE 34

GULF URANIUM MINE AND MILL, NEW MEXICO

Spring and Fall operation - 24 hr/day

Demand:

6 MW_e mine pumps
116,900 lb/hr psia steam
No mine air conditioning
(24 hr/day, 7 day/week)



GULF URNAIUM MINE AND MILL, NEW MEXICO

Winter Operation - 24 hr/day)

FIGURE 35

Table 9

SOLAR TOTAL ENERGY SYSTEM EQUIPMENT LIST

FACILITY: GULF URANIUM MINE & MILL, NEW MEXICO

EQUIPMENT	TYPE		SIZE (RATING)		
COLLECTORS	SINGLE AXIS	$\rho \times \alpha$	0.855	0.774	0.711
	PARABOLIC TROUGH	10^6 FT^2	4.012	4.665	5.199
POWER CONVERSION TURBINE GENERATOR SYSTEM	STEAM RANKINE		4740 kW		
	ORGANIC RANKINE		NA		
STORAGE					
HIGH TEMPERATURE	DUAL MEDIA THERMOCLINE		592,043 FT^3		
HOT WATER	INSULATED ABOVE GROUND		NA		
COLD BRINE	INSULATED ABOVE GROUND		NA		
REFRIGERATION UNITS	CENTRIFUGAL ELECTRIC VAPOR COMPRESSION		NA		
	ABSORPTION (STEAM)		3870 TONS		
HEAT EXCHANGERS	COUNTERFLOW TUBE AND SHELL		25,831 FT^2		
FOSSIL OIL HEATER			160×10^6 BTU/HR		

A schematic of the solar total energy system is shown in figure 36 along with the plant's current energy demand. The proposed system is a steam rankine cycle capable of producing 12.87 MWe using the 300,000 lb/hr process steam demand as a condensing load. The collector field was sized to provide 24 hour STES operation with adequate storage to operate the system during non solar hours. Table 10 contains a listing of the major components and their size/rating which were used in determining capital costs for use in the economic analyses.

The displacement analyses showed that the solar system could displace 61.9% of the facility's electrical demand (92.79×10^6 KWHR/yr) and 82.3% of the process steam requirements, or 2.43×10^6 mm BTU/yr of their natural gas requirement. This was based on a current usage of 150×10^6 KWHR/yr and 2.68×10^6 lbs of steam per year.

Demand:

21 MW electric
300,000 lb/hr, 150 psia steam
(24 hr/day, 7 day/week)

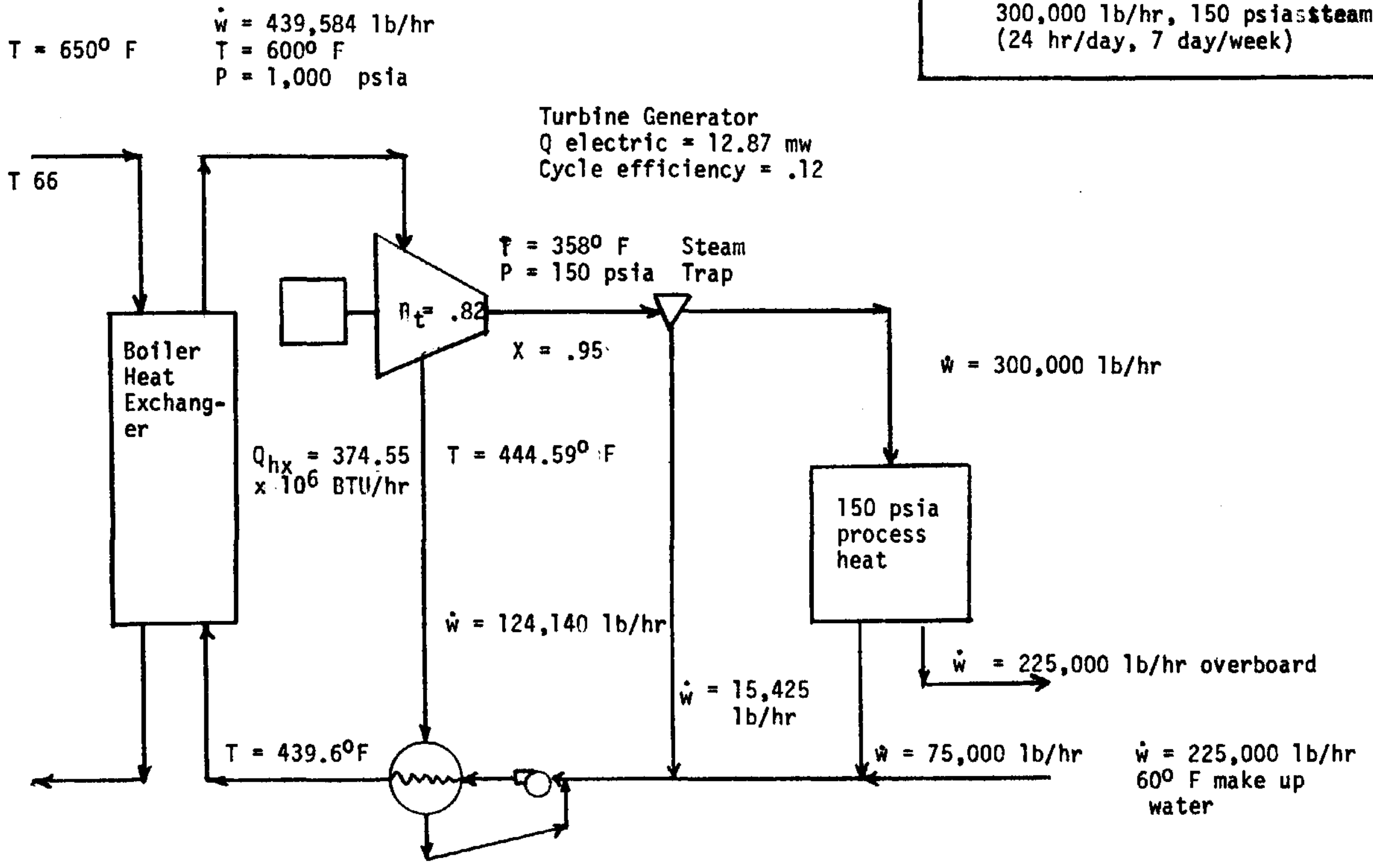


FIGURE 36

U. S. BORAX PLANT, BORAN, CALIFORNIA

(24 hr/day, 7 day/week)

TABLE 10
SOLAR TOTAL ENERGY SYSTEM EQUIPMENT LIST

FACILITY: U.S. BORAX, BORON, CALIFORNIA

EQUIPMENT	TYPE	SIZE (RATING)			
COLLECTORS	SINGLE AXIS	$\rho \times \alpha$	0.855	0.774	0.711
	PARABOLIC TROUGH	10^6 FT^2	10.404	12.066	13.558
POWER CONVERSION TURBINE GENERATOR SYSTEM	STEAM RANKINE	12,900 KW			
	ORGANIC RANKINE	NA			
STORAGE					
HIGH TEMPERATURE	DUAL MEDIA THERMOCLINE	1.334×10^6 FT^3			
HOT WATER	INSULATED ABOVE GROUND	NA			
COLD BRINE	INSULATED ABOVE GROUND	NA			
REFRIGERATION UNITS	CENTRIFUGAL ELECTRIC VAPOR COMPRESSION	NA			
	ABSORPTION (STEAM)	NA			
HEAT EXCHANGERS	COUNTERFLOW TUBE AND SHELL	61,214 FT^2			
FOSSIL OIL HEATER		375×10^6 BTU/HR			

4.0 ECONOMICS

4.1 Economic Analysis Methodology

The economic analysis performed for this study considers cash flows, energy outputs, and the various financial parameters that will have an impact on system economics. System size, usage, and efficiencies are used to determine solar energy output along with the amount of conventional energy required and conserved by solar energy in order to compute the cost and plant performance assumptions. These assumptions along with the assumed financial paramters were used to compute the annual cash flows needed to determine the return on investment and payback period.

Typically, a solar system used for industrial total energy has cash outflows associated with the purchase and operation of the solar system and the equivalent of cash "inflows" associated with the savings of annual operating costs due to reductions in conventional energy requirements.

MDAC's pro forma discounted cash flow model using the JPL methodology has been used to project actual cash flows associated with the solar total energy system investment. The model takes into account cash outflows which include actual cash expenditures for capital equipment (including tax credits), debt payments (if any), O&M, fuel costs (for hybrid systems), and also takes into account incremental tax liabilities which are affected by changes in operating expenses such as interest, depreciation, O&M costs, and savings in conventional fuel costs.

The principal cash "inflow" is the savings associated with the displacement of conventional energy by the solar system. In the case of total energy systems, it is the cost of the fuel that would have been necessary to power the fossil fired boiler, and purchased electricity for an equivalent duty cycle. The energy displaced takes into account the efficiency of the equipment that is being displaced. The critical parameters here are the cost of fuel and electricity and their anticipated escalation rates.

Once the annual cash flows are tabulated for the baseline system, the model projects the internal (discounted) rate of return and payback period (non-discounted) using standard capital budgeting formulae. The comparison of such results corresponding to the costs for alternate energy operation (variations in performance of financial parameters) can be used to provide the basis for rating relative economic merit.

4.2 System Economics

An economic analyses was done for each of the site specific designs. Capital costs were derived for all of the major components of the solar total energy systems using cost estimating relationships (CER's) (shown in Table 11) developed during the Commercial Applications of Solar Total Energy Systems* and escalated to current (1980) year values. The types and sizes of the components are discussed in Section 3.3 of this report. These costs included not only the costs of the solar equipment and electrical generation equipment, but the cost of any new process equipment necessary to modify the plant to operate in an efficient total energy mode (i.e., the conversion of the process to absorption chillers).

The economic parameters used in the analyses are given in Table 12. These parameters are similar to those being used in a current MDAC Industrial Retrofit Solar Energy Study. Sensitivities of system economics to these parameter assumptions will be discussed later in this section. In all the analyses collector performance and cost were treated as a parametric variable.

The following figures and tables (Figures 37 through 43, Tables 13 through 19) give the results of the analyses in terms of return on investment (ROI) as a function of collector cost ($\$/Ft^2$) and performance (reflectivity x absorptivity - $\rho \times \alpha$) for each of the sites analyzed. The ROI's range from less than 10% to over 30% depending on the site. In all cases the ROI is a much stronger function of collector cost than of performance. In general the system with higher displacement ratios showed the highest ROI's as expected. Due to sizing methodology, locations with the least seasonal variation in collector performance have the highest displacements. These sites were also most sensitive to variation in collector costs because, although the seasonal variation was small, the peak or sizing collector performance was relatively low.

Figure 44 shows the relationship of ROI to payback period for 5 of the sites. The expected trend of reduced payback with increasing ROI is evident in the

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*Commercial Applications of Solar Total Energy Systems, ERDA Contract No. E(04-3)-1210, Rockwell Report No. AIBD ERDA 75-15, Final Briefing, June 1977.

TABLE 11

COST ALGORITHMS

(CAPITAL EQUIPMENT - INSTALLED COSTS)
(1980)

UNIT	SIZE RANGE	ALGORITHM
STORAGE		
a. HOT STORAGE	150-150,000 ft^3	$\text{Cost} = \$453\ (\text{Vol, ft}^3)^{0.515} + 815\ (\text{Vol, ft}^3)$
b. COLD STORAGE	150-150,000 ft^3	$\text{Cost} = \$453\ (\text{Vol, ft}^3)^{0.515}$
REFRIGERATION		
a. CENTRIFUGAL CHILLERS (VAPOR COMPRESSION)	250-2000 Tons	$\text{Cost} = \$5455\ (\text{Tons/Unit})^{0.61}$
b. ABSORPTION CHILLERS	250-1200 Tons	$\text{Cost} = \$2823\ (\text{Tons/Unit})^{0.7}$
POWER CONVERSION SYSTEMS		
a. SUNSTRAND ORGANIC RANKINE CYCLE	100-1000 KW	$\text{Cost} = \$4908\ (\text{KW/Unit})^{0.66}$
b. RANKINE CYCLE-STEAM	1-1000 KW	Cost = \$29,203 + 450 (KW)
c. RANKINE CYCLE-STEAM	1000-1,000,000 KW	$\text{Cost} = \$1608\ (\text{KW})^{0.825}$
SHELL AND TUBE HEAT EXCHANGERS	20-2000 ft^2	$\text{Cost/Unit} = \$386\ (\text{Area, ft}^2)^{0.56}$

Ref: Rockwell International Report #76-019-49-72
Atomics International Division

TABLE 12

BASELINE ECONOMIC PARAMETERS

ESCALATION FOR CAPITAL COSTS	.0650
INVESTMENT TAX CREDIT FACTOR	.2000
ESCALATION RATE FOR O&M	.0650
EFFECTIVE TAX RATE	.5000
DESIRED RETURN ON OWNERS EQUITY	.1500
DEBT TO CAPITAL RATIO	.2500
INTEREST RATE	.0900
NUMBER OF YEARS FOR REPAYMENT	30.
NUMBER OF YEARS OF DEPRECIATION	7.0000
REPORTING YEAR	1980
STARTING PERIOD OF LOAN	1984
FIRST YEAR OF OPERATION	1985
YEARS OF OPERATION	30.
FUEL COST	
ELECTRICITY	50 MILLS/KW HR
NATURAL GAS	$3.50/MMBTU
OIL	$5.00/MMBTU
GENERAL ESCALATION RATE FOR FUEL	.1050

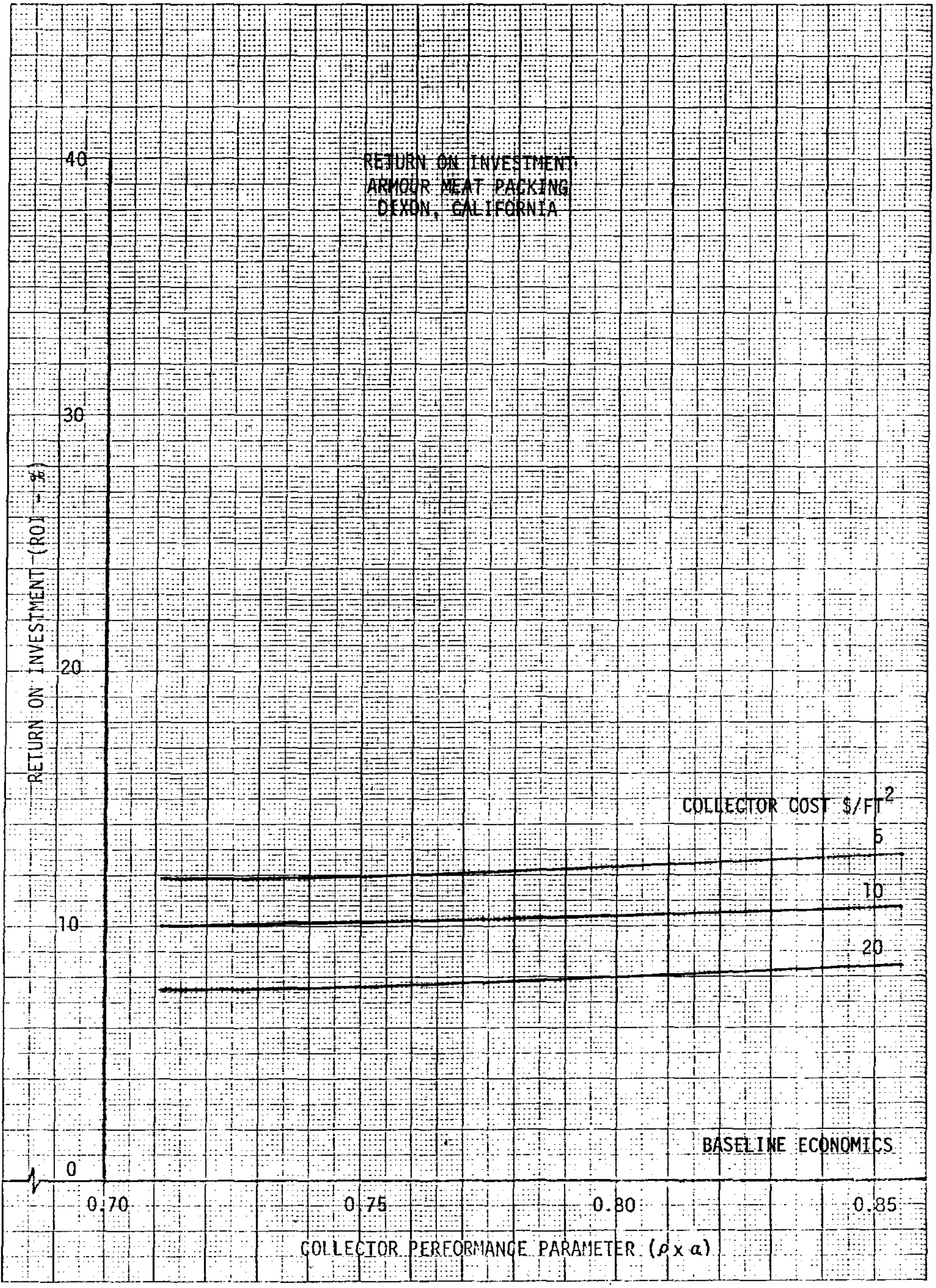

RETURN ON INVESTMENT
ARMOUR MEAT PACKING
DIXON, CALIFORNIA
RETURN ON INVESTMENT (ROI - %)
40
30
20
10
0
COLLECTOR COST $/FT^2
5
10
20
BASELINE ECONOMICS
0.70
0.75
0.80
0.85
COLLECTOR PERFORMANCE PARAMETER ($\rho \times \alpha$)

FIGURE 37

TABLE 13
ECONOMICS
ARMOUR MEAT PACKING
DIXON, CALIFORNIA

COLLECTOR COST

		$5 / FT^2		$10 / FT^2		$20 / FT^2	
$\rho \times \alpha$	FIELD SIZE (FT^2)	ROI %	PAYBACK YRS	ROI %	PAYBACK YRS	ROI %	PAYBACK YRS
.855	102,966	12.4	12.3	10.7	14.0	8.4	16.8
.774	119,854	12.1	12.6	10.3	14.5	7.8	17.6
.711	131,127	11.9	12.8	10.0	14.8	7.5	18.1

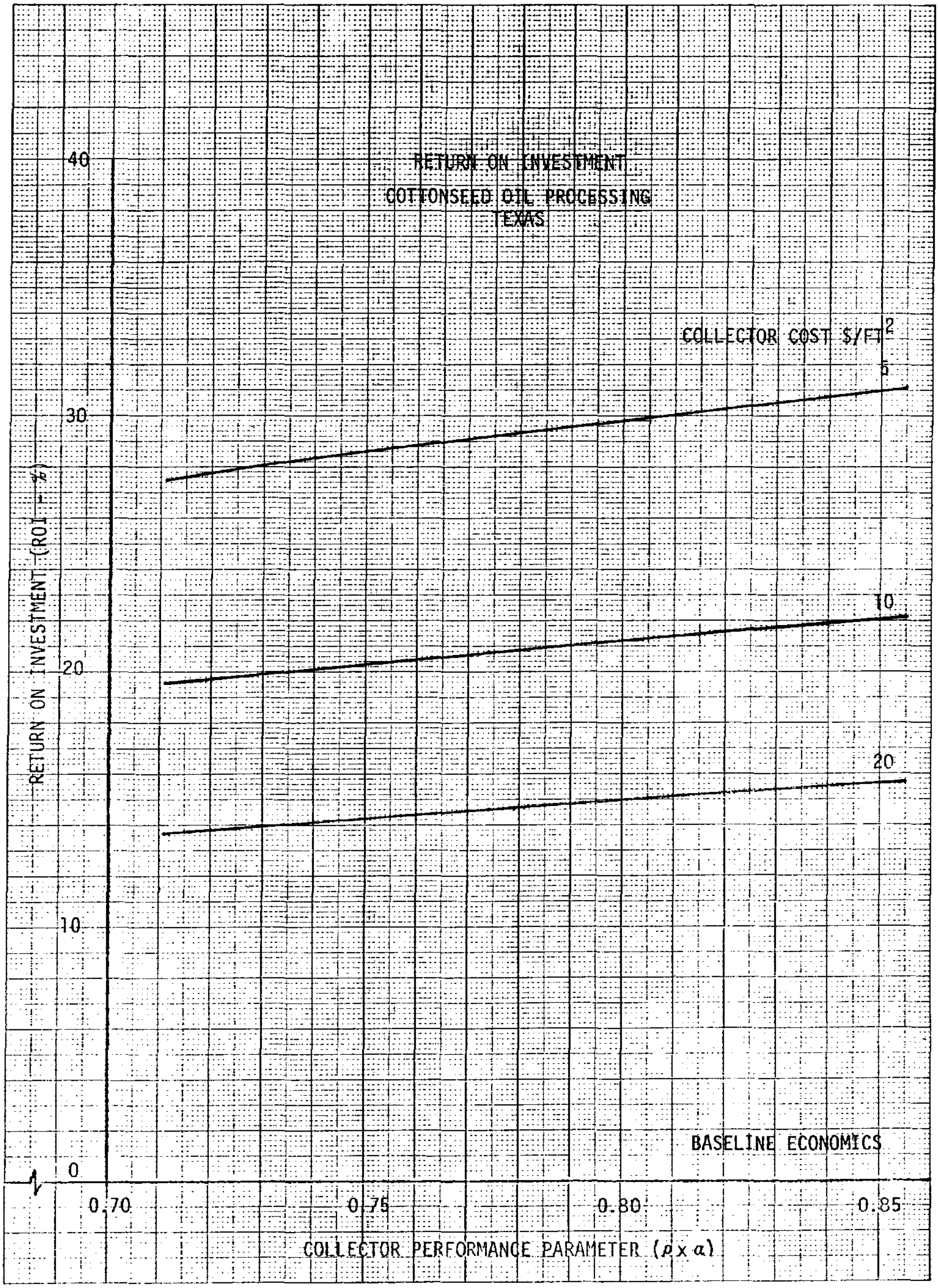

RETURN ON INVESTMENT
COTTONSEED OIL PROCESSING
TEXAS
COLLECTOR COST $/FT^2
5
10
20
RETURN ON INVESTMENT (ROI - %)
40
30
20
10
0
0.70
0.75
0.80
0.85
COLLECTOR PERFORMANCE PARAMETER ($\rho \times \alpha$)
BASELINE ECONOMICS

FIGURE 38

TABLE 14
ECONOMICS
COTTONSEED OIL PROCESSING
TEXAS

$\rho \times \alpha$	FIELD SIZE (FT^2)	COLLECTOR COST $5 / FT^2 ROI %	PAYBACK YRS	$10 / FT^2 ROI %	PAYBACK YRS	$20 / FT^2 ROI %	PAYBACK YRS
.855	787,393	31.1	3.7	22.2	5.0	15.7	6.3
.774	899,509	29.2	3.9	20.8	5.2	14.6	6.5
.711	1,019,670	27.5	4.1	19.6	5.4	13.7	6.7

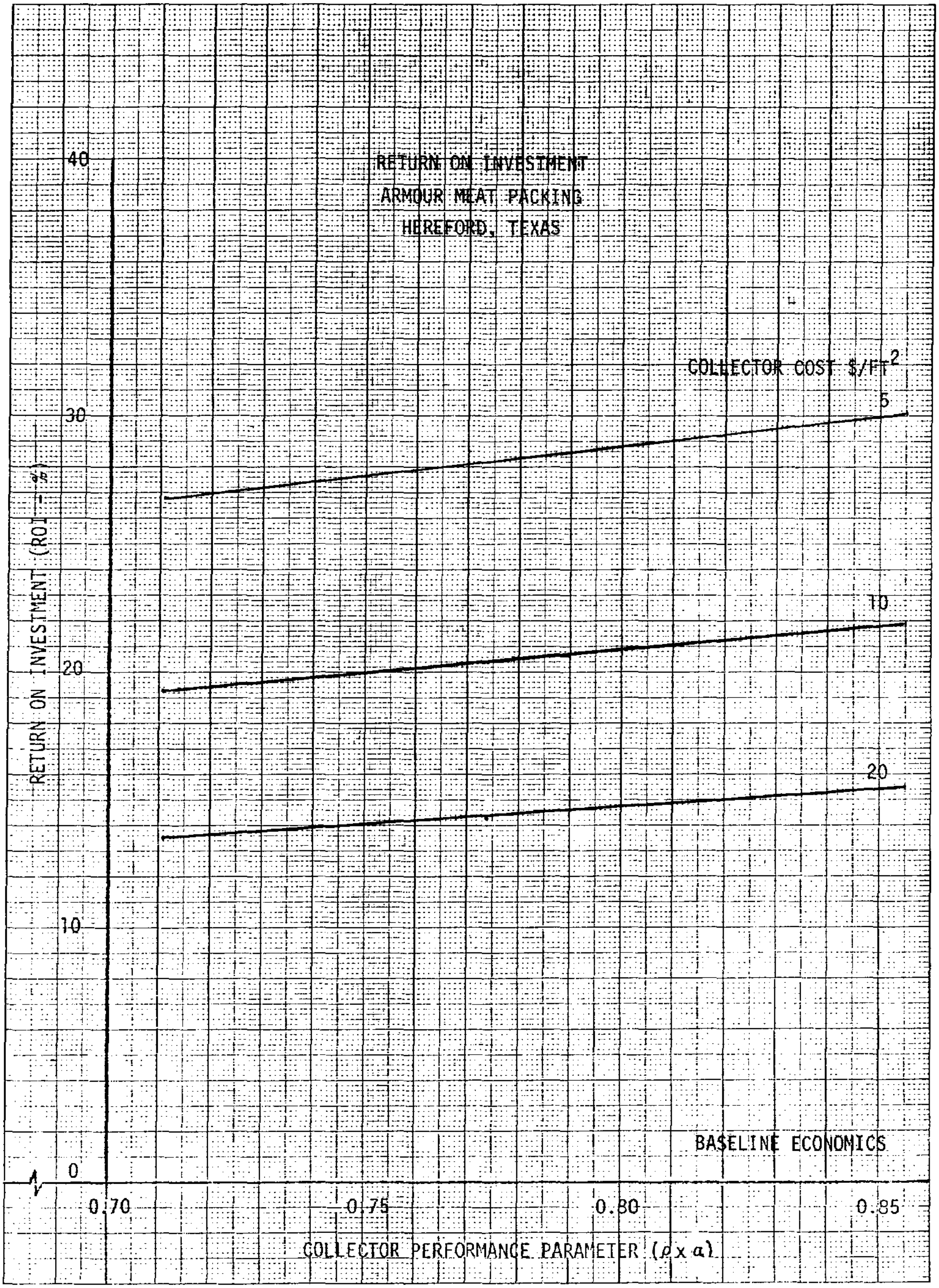

RETURN ON INVESTMENT
ARMOUR MEAT PACKING
HEREFORD, TEXAS
COLLECTOR COST $/FT²
5
10
20
BASELINE ECONOMICS
RETURN ON INVESTMENT (ROI - %)
40
30
20
10
0
0.70
0.75
0.80
0.85
COLLECTOR PERFORMANCE PARAMETER (ρ x α)

FIGURE 39

TABLE 15
ECONOMICS
ARMOUR MEAT PACKING
HEREFORD, TEXAS

		COLLECTOR COST					
		$\$5 / FT^2$		$\$10 / FT^2$		$\$20 / FT^2$	
$\rho \times a$	FIELD SIZE (FT^2)	ROI %	PAYBACK YRS	ROI %	PAYBACK YRS	ROI %	PAYBACK YRS
.855	1,528,000	30.1	3.8	21.9	5.0	15.5	6.2
.774	1,777,000	28.1	4.0	20.4	5.2	14.3	6.5
.711	1,980,000	26.8	4.2	19.3	5.4	13.5	6.7

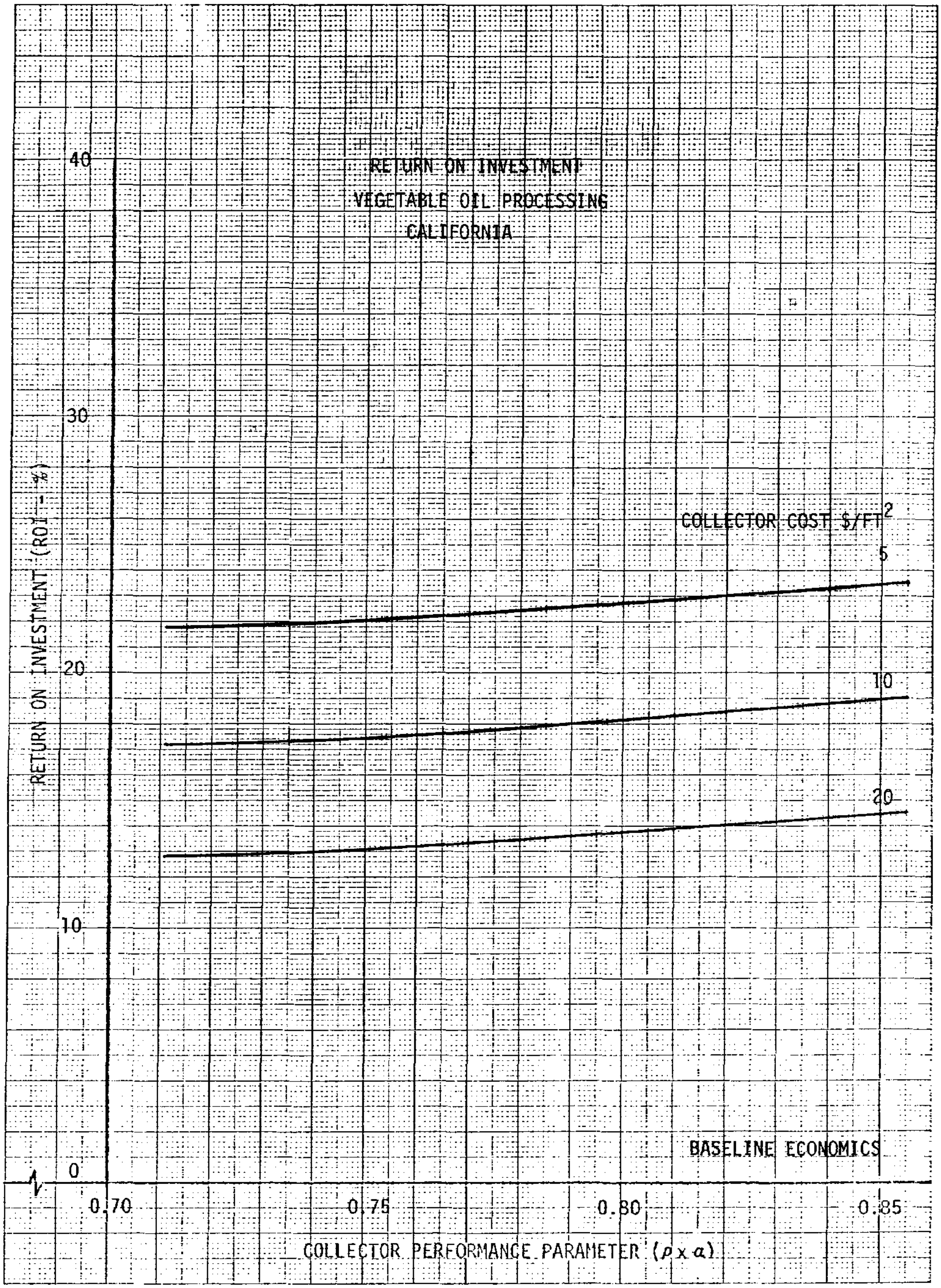

RETURN ON INVESTMENT
VEGETABLE OIL PROCESSING
CALIFORNIA
RETURN ON INVESTMENT (ROI - %)
40
30
20
10
0
COLLECTOR COST $/FT^2
5
10
20
BASELINE ECONOMICS
0.70
0.75
0.80
0.85
COLLECTOR PERFORMANCE PARAMETER ($\rho \times \alpha$)

FIGURE 40

TABLE 16
ECONOMICS
VEGETABLE OIL PROCESSING
CALIFORNIA

		COLLECTOR COST					
		\$5 / FT^2		\$10 / FT^2		\$20 / FT^2	
ρ x a	FIELD SIZE (FT^2)	ROI %	PAYBACK YRS	ROI %	PAYBACK YRS	ROI %	PAYBACK YRS
.855	481,084	23.5	4.9	19	5.7	14.5	6.7
.774	571,129	22.4	5.1	17.8	6.0	13.4	6.9
.711	626,030	21.8	5.2	17.2	6.1	12.8	7.4

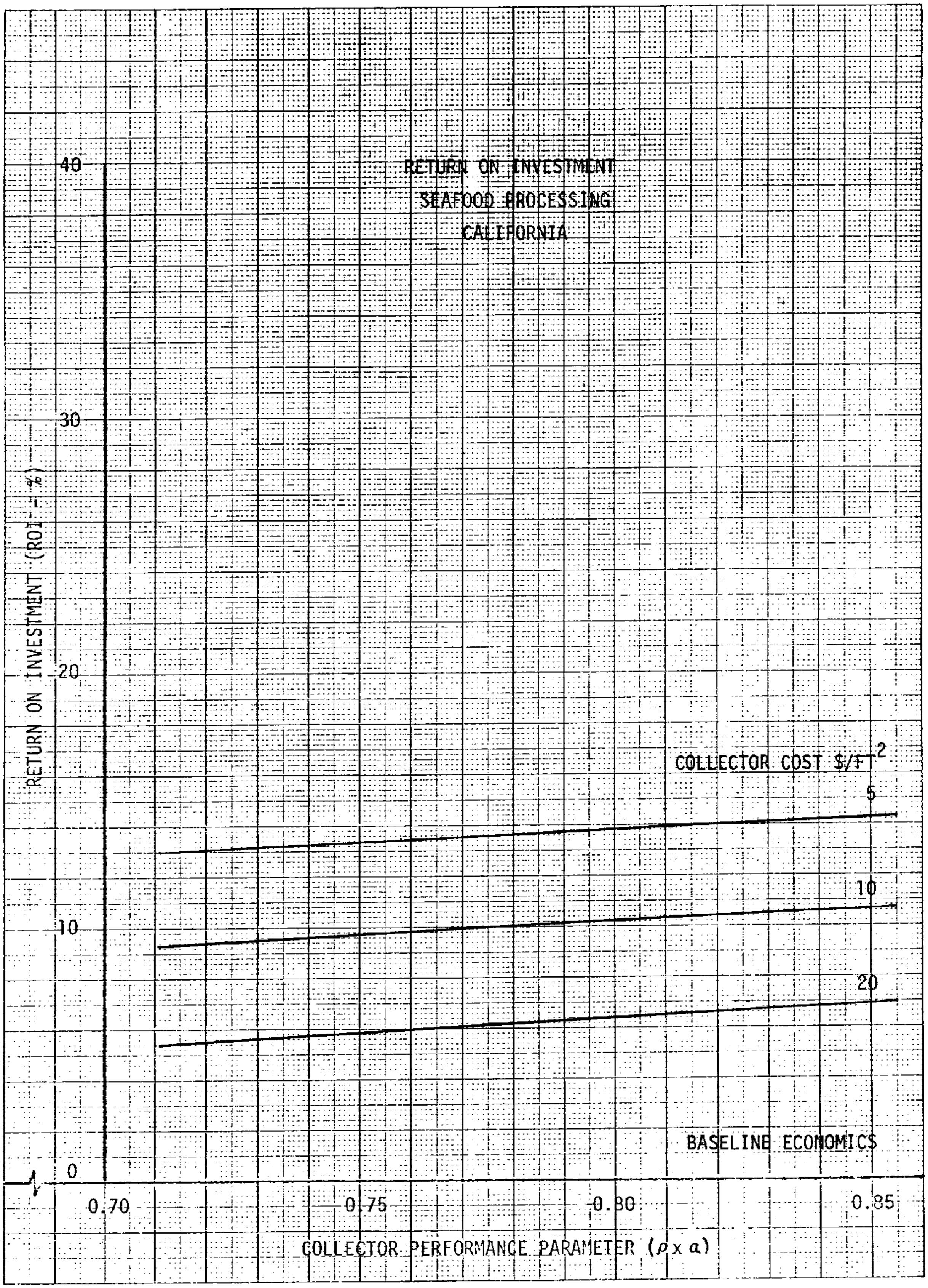

RETURN ON INVESTMENT
SEAFOOD PROCESSING
CALIFORNIA
RETURN ON INVESTMENT (ROI - %)
40
30
20
10
0
COLLECTOR COST $/FT^2
5
10
20
BASELINE ECONOMICS
0.70
0.75
0.80
0.85
COLLECTOR PERFORMANCE PARAMETER ($\rho \times \alpha$)

FIGURE 41

TABLE 17
ECONOMICS
SEAFOOD PROCESSING
CALIFORNIA

		COLLECTOR COST					
		$5 / FT^2		$10 / FT^2		$20 / FT^2	
ρ x a	FIELD SIZE (FT^2)	ROI %	PAYBACK YRS	ROI %	PAYBACK YRS	ROI %	PAYBACK YRS
.855	2,539,000	14.3	6.9	10.7	10.6	7.0	16.8
.774	2,931,000	13.6	7.1	10.0	11.8	6.1	18.3
.711	3,310,000	13.0	7.8	9.3	12.8	5.4	19.6

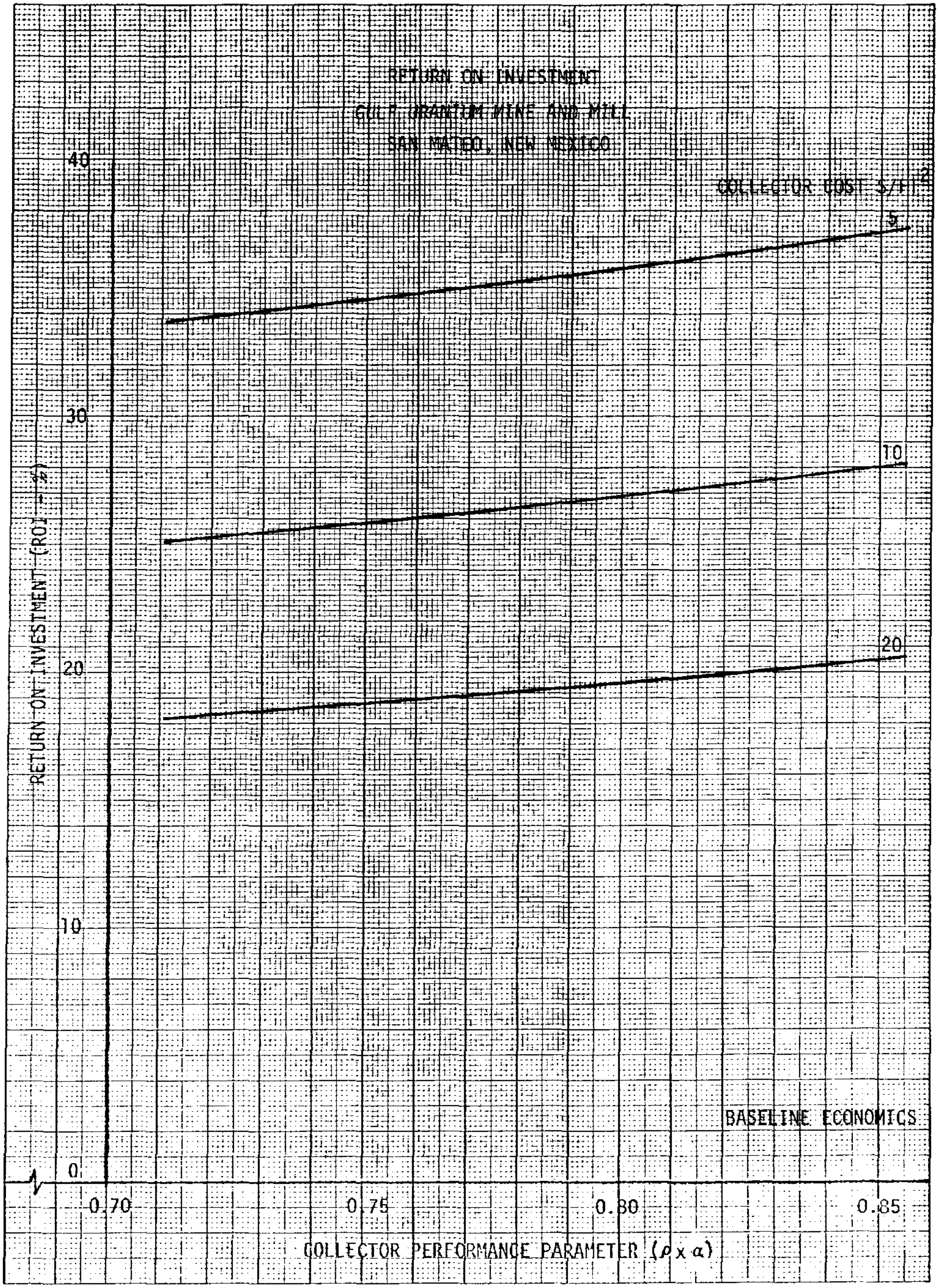

RETURN ON INVESTMENT
GULF URANIUM MINE AND MILL
SAN MATEO, NEW MEXICO
COLLECTOR COST $/FT^2
5
10
20
BASELINE ECONOMICS
RETURN ON INVESTMENT (ROI - %)
0
10
20
30
40
0.70
0.75
0.80
0.85
COLLECTOR PERFORMANCE PARAMETER ($\rho \times \alpha$)

FIGURE 42

TABLE 18
ECONOMICS
GULF URANIUM MINE MILL, NEW MEXICO

COLLECTOR COST

		$\$5/\text{ft}^2$		$\$10/\text{ft}^2$		$\$20/\text{ft}^2$	
$\rho \times \alpha$	FIELD SIZE (10^6 FT)	ROI	PAYBACK YRS	ROI	PAYBACK YRS	ROI	PAYBACK YRS
0.855	4.012	37.3%	3.0	28.1%	4.0	20.6%	5.2
0.774	4.665	35.1%	3.2	26.3%	4.2	19.2%	5.4
0.711	5.199	33.7%	3.4	25.1%	4.4	18.2%	5.6

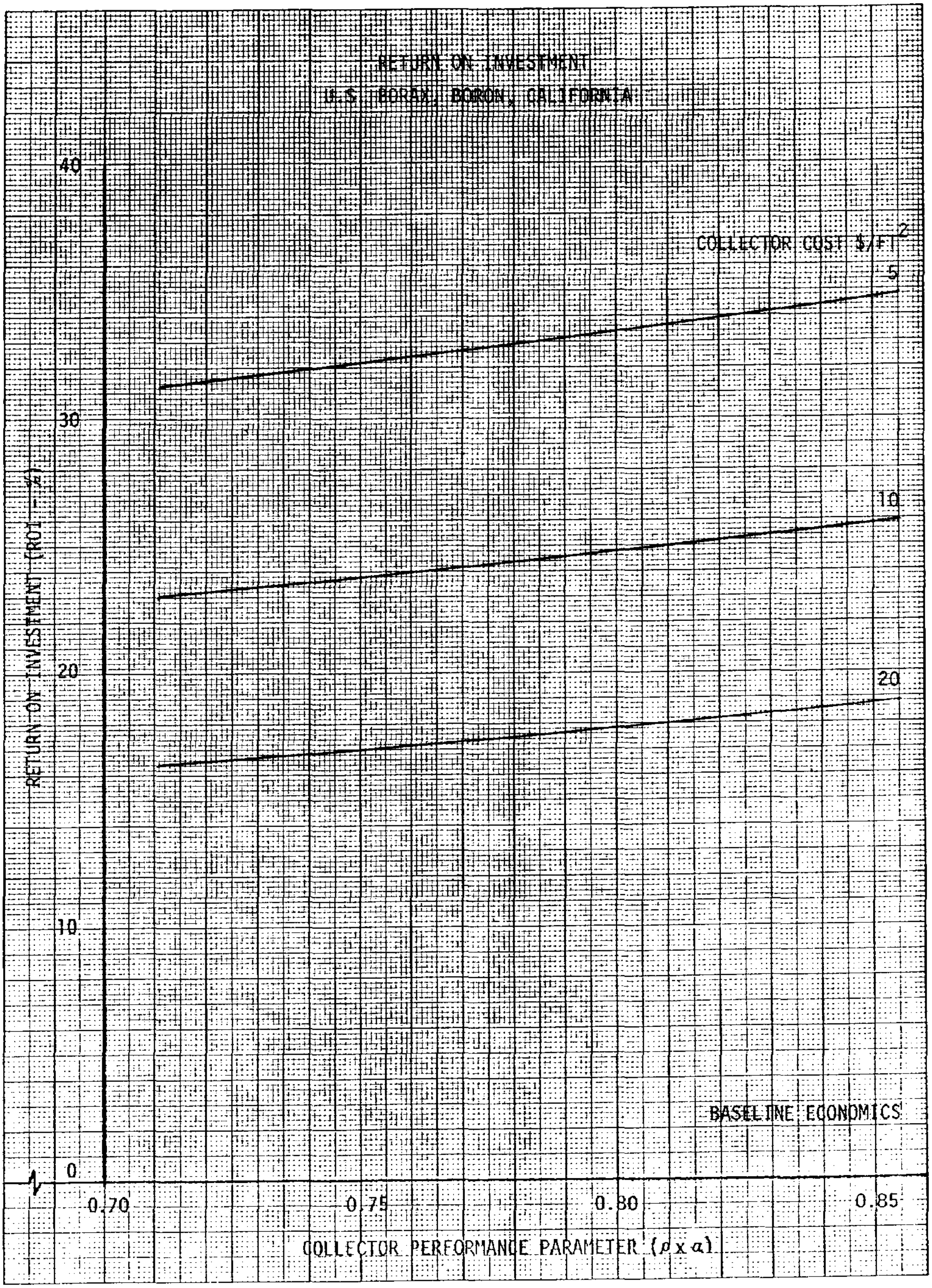
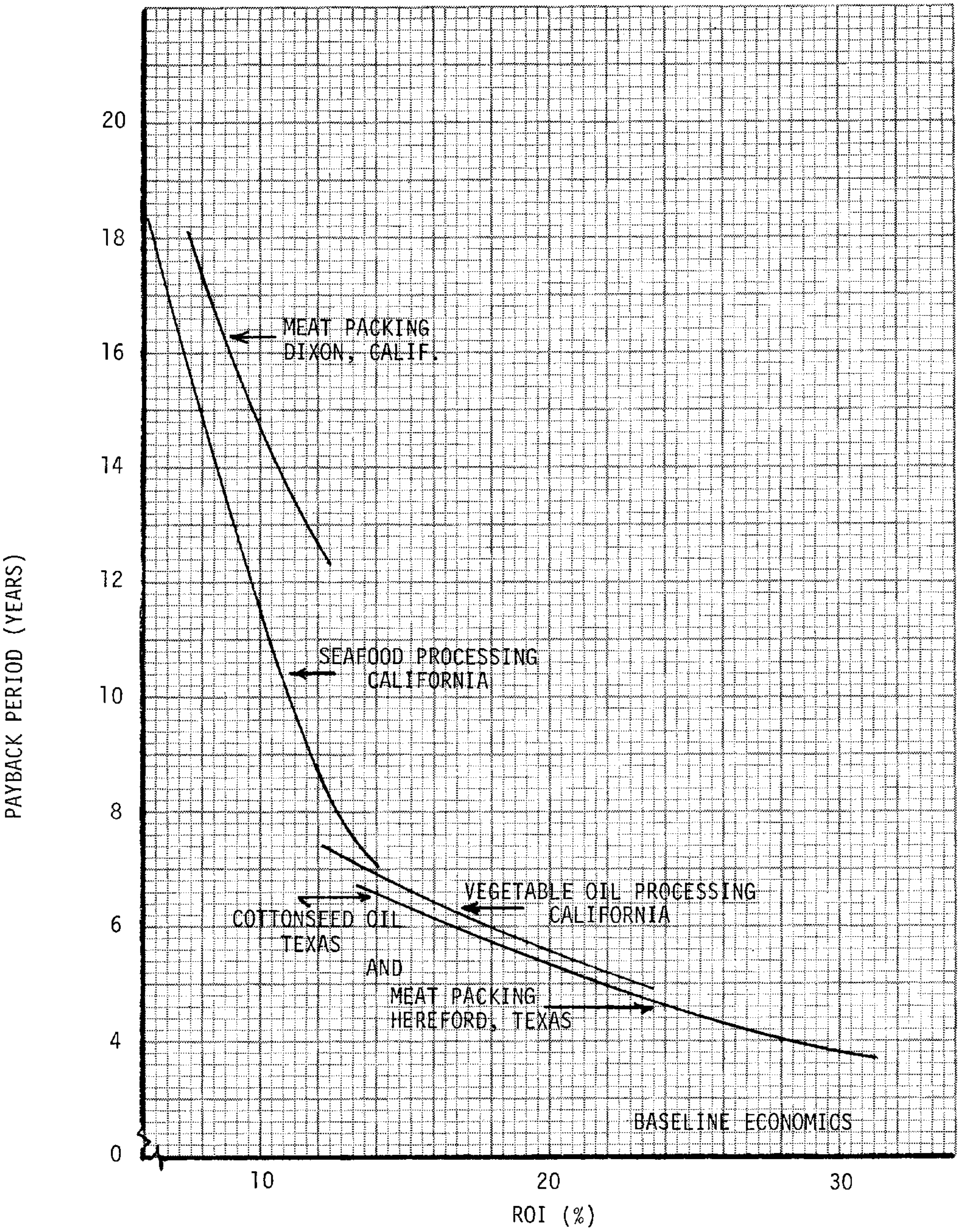

RETURN ON INVESTMENT
U.S. BORAX, BORON, CALIFORNIA
RETURN ON INVESTMENT (ROI - %)
40
30
20
10
0
COLLECTOR COST $/FT^2
5
10
20
BASELINE ECONOMICS
0.70
0.75
0.80
0.85
COLLECTOR PERFORMANCE PARAMETER ($\rho \times \alpha$)

FIGURE 43

TABLE 19
ECONOMICS
U.S. BORAX, BORON, CALIFORNIA

COLLECTOR COST

		$5/FT^2$		$10/FT^2$		$20/FT^2$	
ρ x α	FIELD SIZE (10^6 FT)	ROI	PAYBACK YRS	ROI	PAYBACK YRS	ROI	PAYBACK YRS
0.855	10.404	34.8%	3.2	25.9%	4.3	18.8%	5.5
0.774	12.066	32.8%	3.4	24.2%	4.5	17.4%	5.8
0.711	13.588	31.2%	3.6	23.0%	4.7	16.4	6.0



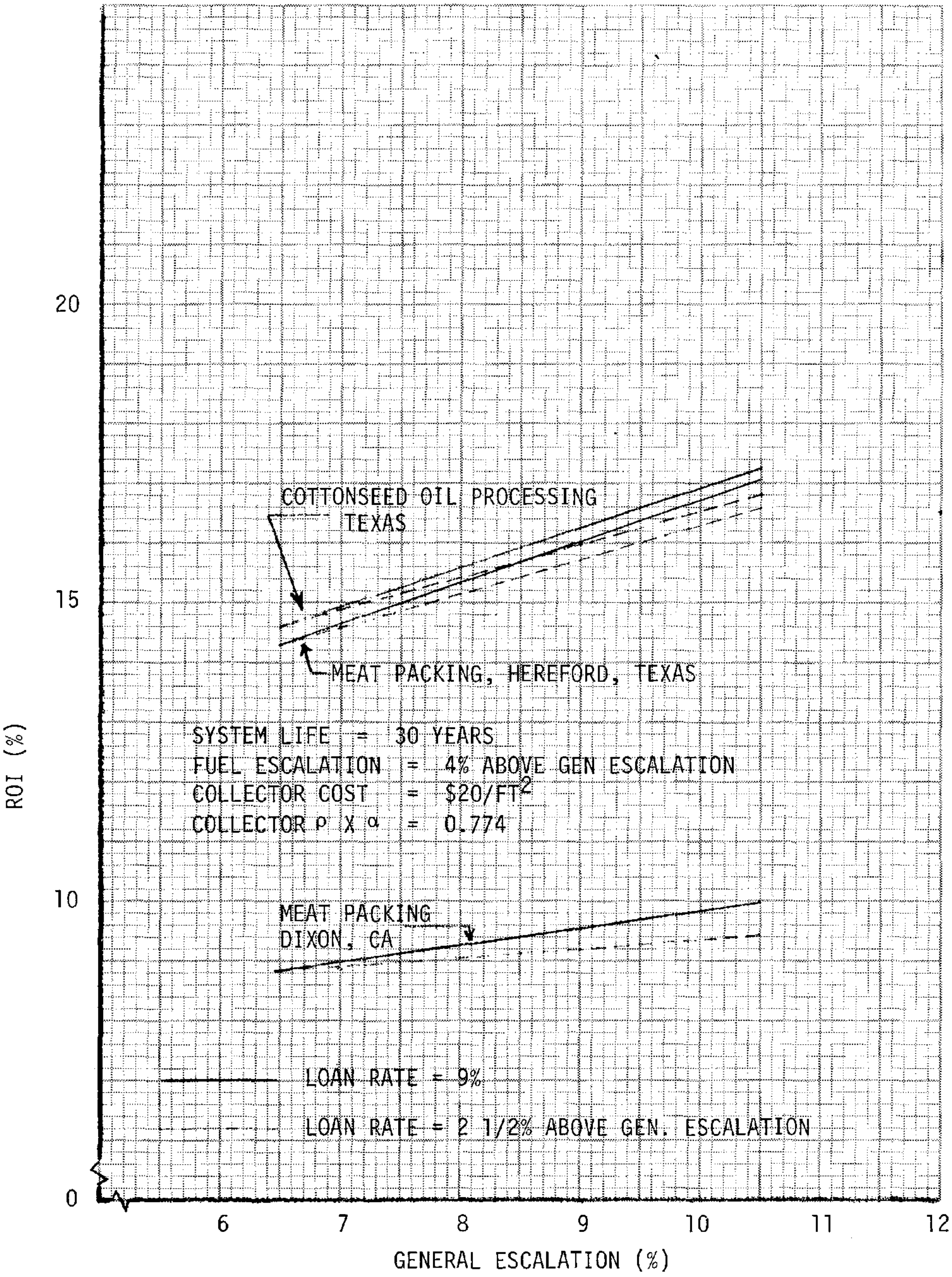
RELATIONSHIP OF PAYBACK PERIOD TO RETURN ON INVESTMENT

FIGURE 44

figure.

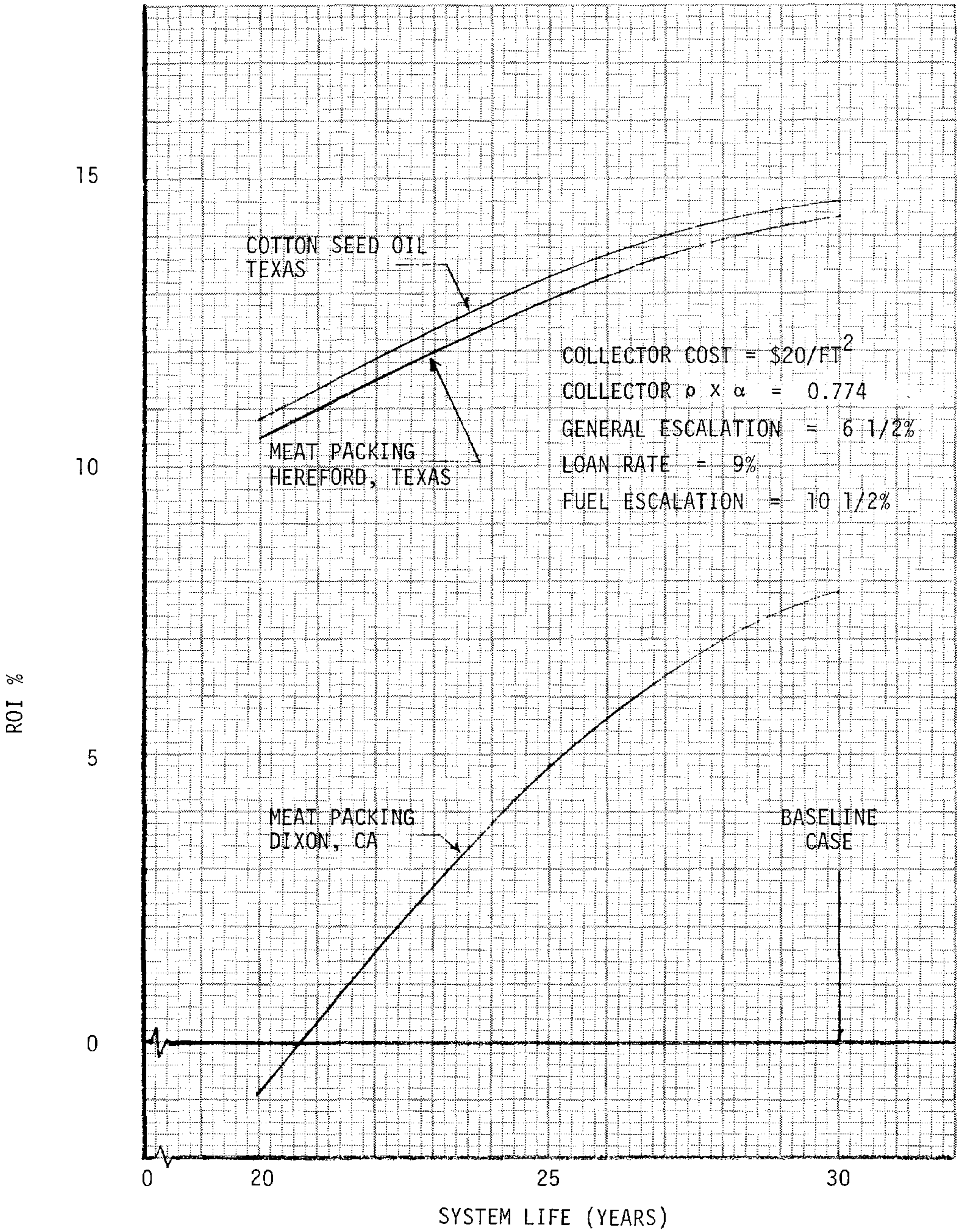
In order to establish the sensitivity of ROI to the basic economic assumptions an analyses was done which varied the general escalation and load rates. As can be seen in Figure 45, the basic assumptions for these parameters were conservative. Increasing either or both erected higher ROI. The two systems with higher ROI showed slightly higher sensitivity 18% increase vs. 14% for the lower return system.

Sensitivities to system life are shown in Figure 46. As can be seen the systems are much more sensitive to system life than to the other parameters analyses. Each of the plants analyzed expects to continue in business into this time frame, therefore, the determination of system life is a direct function of the design life of the solar total energy system and not related to plant life.



EFFECT OF GENERAL ESCALATION AND LOAD RATE ON ROI

FIGURE 45



SYSTEM ECONOMICS SENSITIVITY TO SYSTEM LIFE

FIGURE 46

5.0 CONCLUSIONS AND RECOMMENDATIONS

Industrial Survey

The most effective approach in establishing industry contacts was through personal contacts made at energy related conferences. This approach maximizes contact with industrial personnel who have responsibilities within a company associated with energy. The use of industrial associations in establishing contacts is also helpful in that they often have access to specific company representatives with interest or responsibility in energy use or conservation. The random approach to establishing contacts proved ineffective. In general people contacted at the local plant level often lacked authority to release the desired information. When making random contact with people at the corporate level one is often confronted with a bureaucratic maze making it difficult to obtain useful information. It was apparent from some of the successful contacts made that the data obtained, although valid, might not be representative, as certain biases favoring solar applications were made by the responder in selecting a site. These bias were generally in the area of available sunshine and usable land. One of the strongest conclusions to be made from the data included in the survey was that the majority of process heat applications are in the 350°F temperature range.

System Designs and Economics

One of the major conclusions in this area was that although turbine and collector performance have a noticeable effect on system economics this effect is small when compared to the effect of collector cost on system economics. The sensitivity of the system economics to the basic economic assumptions was minimal with the exception of system life. Decreasing the economic life from 30 years to 20 years resulted in a marked decrease in predicted rate of return. It should be pointed out, however, that although most of the companies usually did not assume a 30 year life when doing economic worth analyses, none of the companies forecasted closing their plants during the next 30 years. In general the larger systems provided better economics (higher rates of return). One exception to this was the seafood processing plant which had a large feedwater preheat requirement which tends to lower the solar system effectivity. It was also concluded that a major contributor to the relative high rates of return for the solar total energy systems was due to the conservation effects of utilizing a total energy system in place of the existing systems. Particularly where electric refrigeration systems were replaced with waste heat fired absorption units.

Modularity

Primarily because of the benefits of scale obtainable in turbine generation systems it was concluded that the modular approach appears to be more applicable to the collector field than to the turbine generator. This conclusion is further amplified when one acknowledges in the design the discreet difference in systems necessary to meet site specific demand requirements. From analyzing the parametric system data the minimum module size appears to be at about the 4 MWe size (350° process temperature, 5.5×10^4 m^2 aperture area at Albuquerque). The economics of systems smaller than this tend to deteriorate rapidly due in part to the fixed cost portion of the assumed O&M cost model.

REFERENCES

1. Industrial Applications of Solar Total Energy. Final Report, Volume II, Technical. McDonnell Douglas Astronautics Company Report No. SAN-1132-2. April 1977.

2. Addendum to Availability of Direct, Total, and Diffuse Solar Radiation to Fixed and Tracking Collectors in the USA. SAND 77-0885. January 30, 1978.

3. Solar Total Energy System, Large Scale Experiment. Final Report, Volume I, Facility Concept Design. Stearns-Roger Report No. C-19650. October 1977.

4. Performance Testing of the Hexcel Parabolic Trough Solar Collector. SAND 78-0381, March 1978.

5. High-Temperature Industrial Process Heat. The Aerospace Corp. ATR-78 (7691-03)-2, March 1978, pp A-4, Figure A-1.

6. ET6 Proceedings, pp 181-188.

7. "Energy Industrial Center Study," DOW Chemical Co. June 1975.

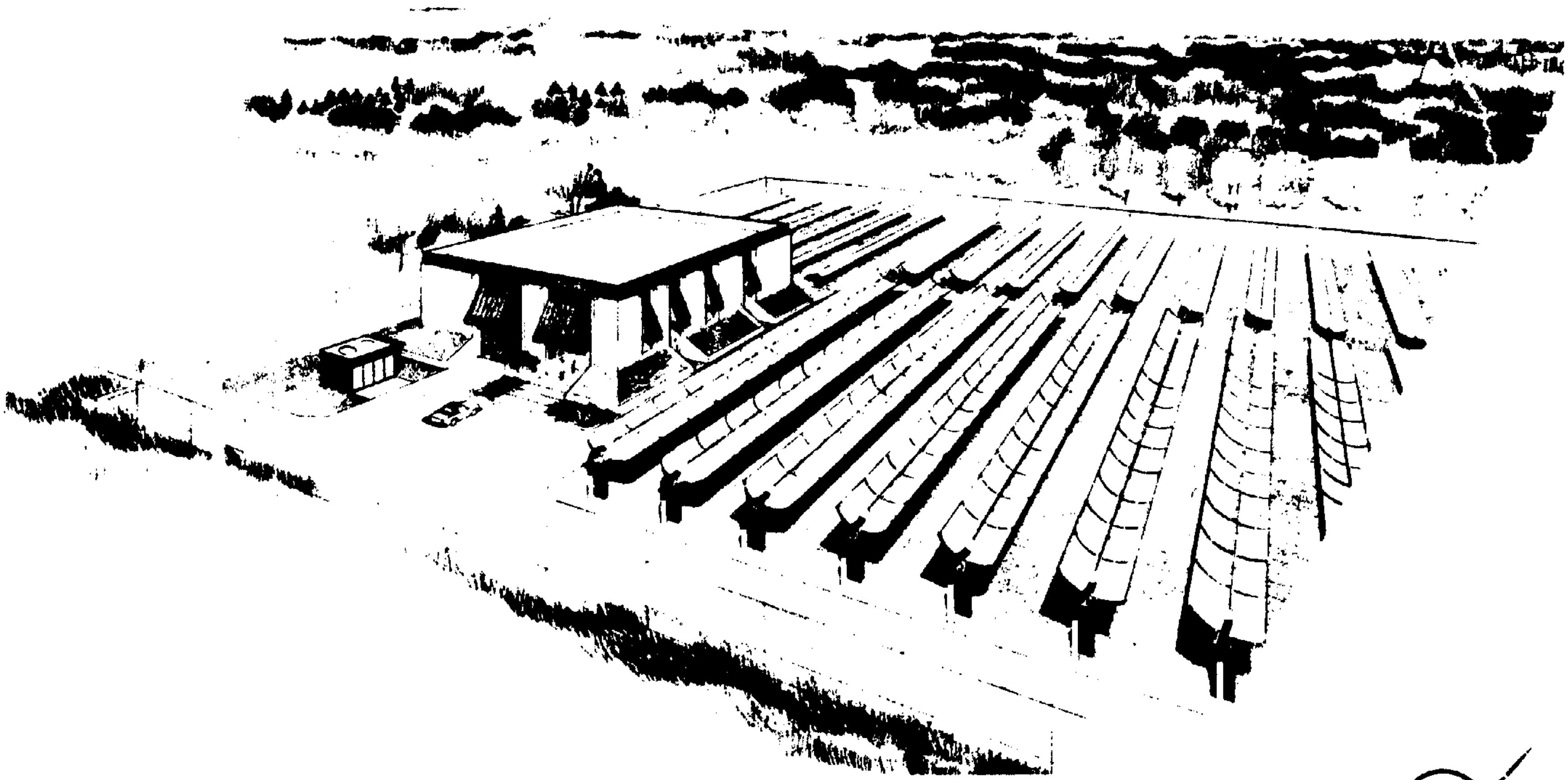
APPENDIX A

INDUSTRY BRIEFING AND SURVEY QUESTIONNAIRES

55027

SOLAR TOTAL ENERGY MODULARITY STUDY

SANDIA CONTRACT NO. 07-7164



MCDONNELL DOUGLAS

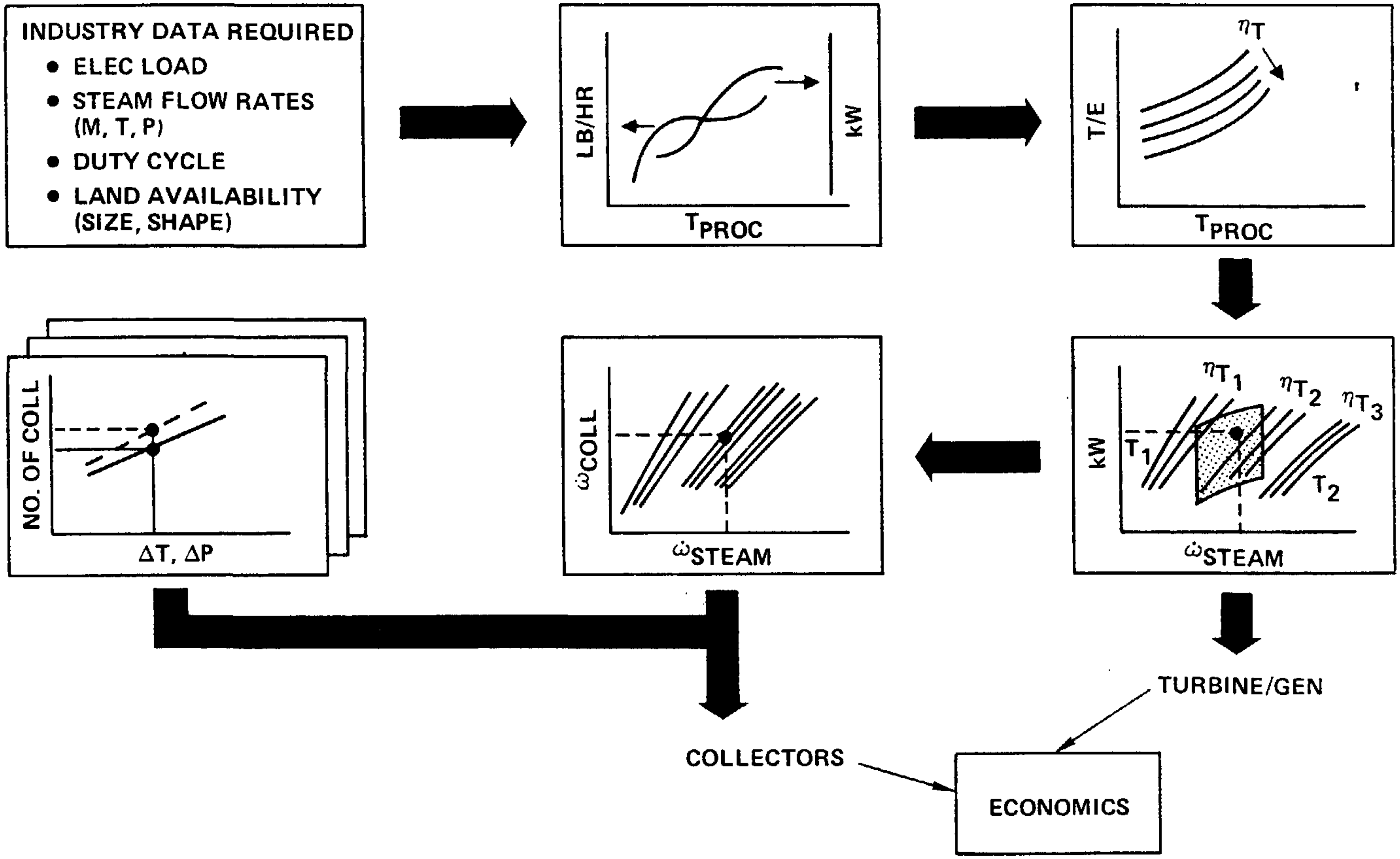
SOLAR TOTAL ENERGY MODULARITY STUDY OBJECTIVES

46486

- TO ESTABLISH A CREDIBLE INDUSTRIAL DEMAND DATA BASE ($\dot{\omega}_{STEAM}$, KW, DUTY CYCLE, LAND AVAILABILITY)
- ESTABLISH A RANGE OF DEMAND LOADS WHERE A MODULAR APPROACH APPEARS FEASIBLE
- DETERMINE COMPONENT MODULE SIZES
- ENSURE THAT MODULAR APPROACH DOES NOT ADVERSELY AFFECT SYSTEM ECONOMICS
- RECOMMEND AREAS FOR TECHNICAL DEVELOPMENT

46271

STUDY APPROACH



INDUSTRY DATA REQUIRED
- ELEC LOAD
- STEAM FLOW RATES (M, T, P)
- DUTY CYCLE
- LAND AVAILABILITY (SIZE, SHAPE)

TURBINE/GEN

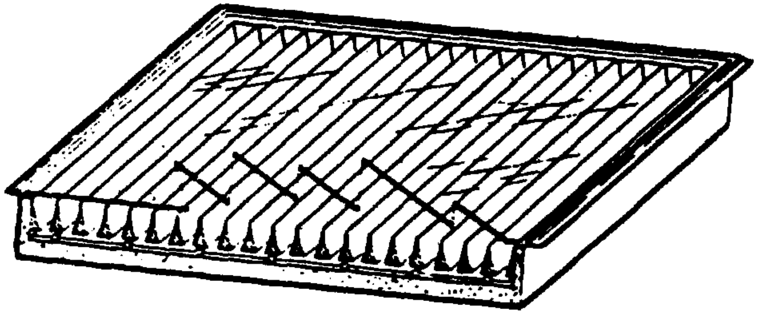
COLLECTORS

ECONOMICS

54982

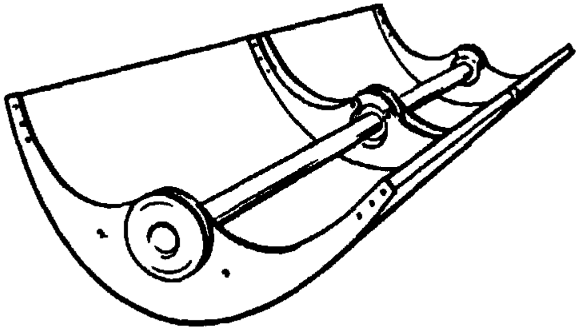
SOLAR CANDIDATES

NON-TRACKING



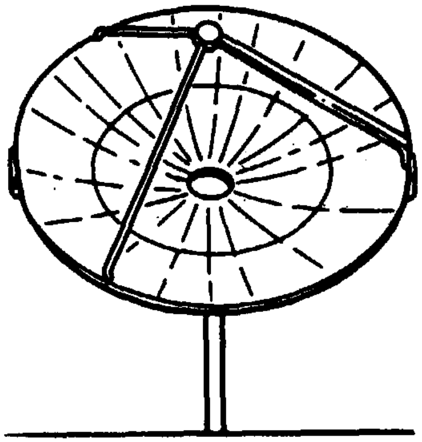
FLAT PLATE COLLECTORS

SINGLE-AXIS TRACKING



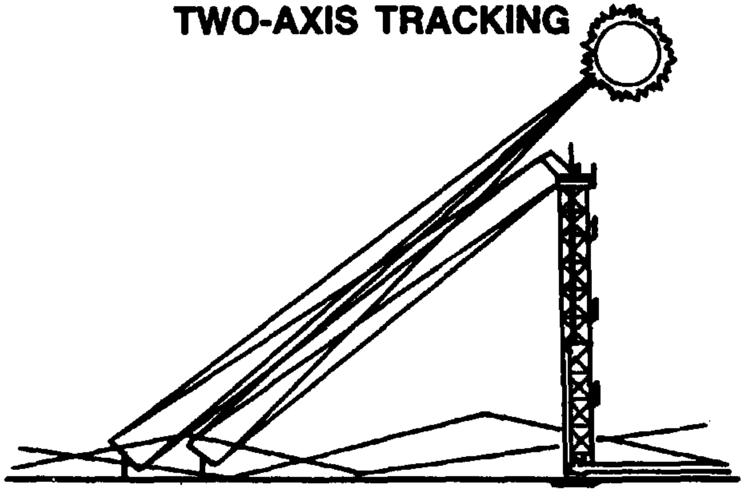
PARABOLIC TROUGHS

TWO-AXIS TRACKING



PARABOLIC DISHES

TWO-AXIS TRACKING

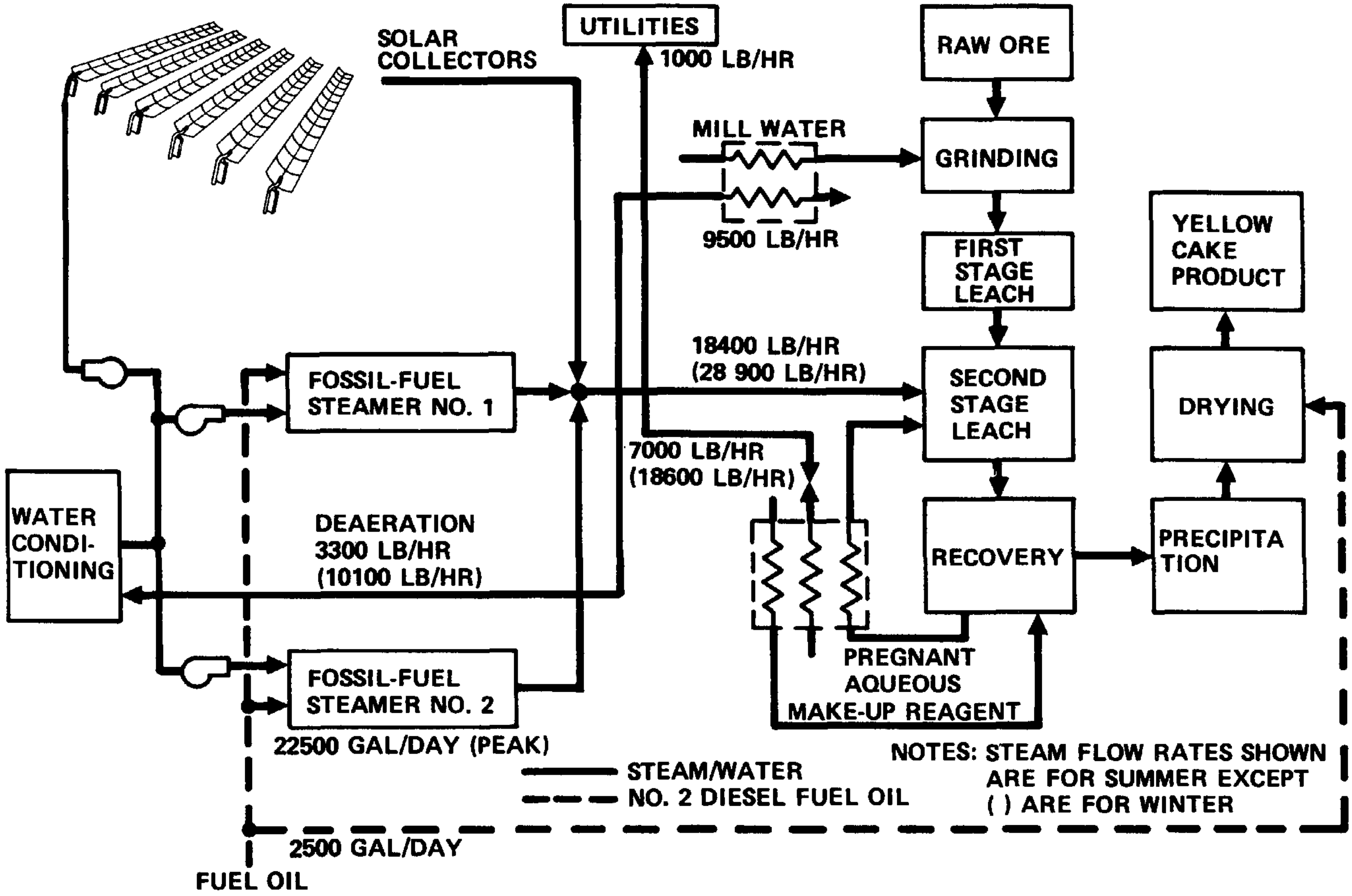


CENTRAL RECEIVERS

SOLAR OPTIONS

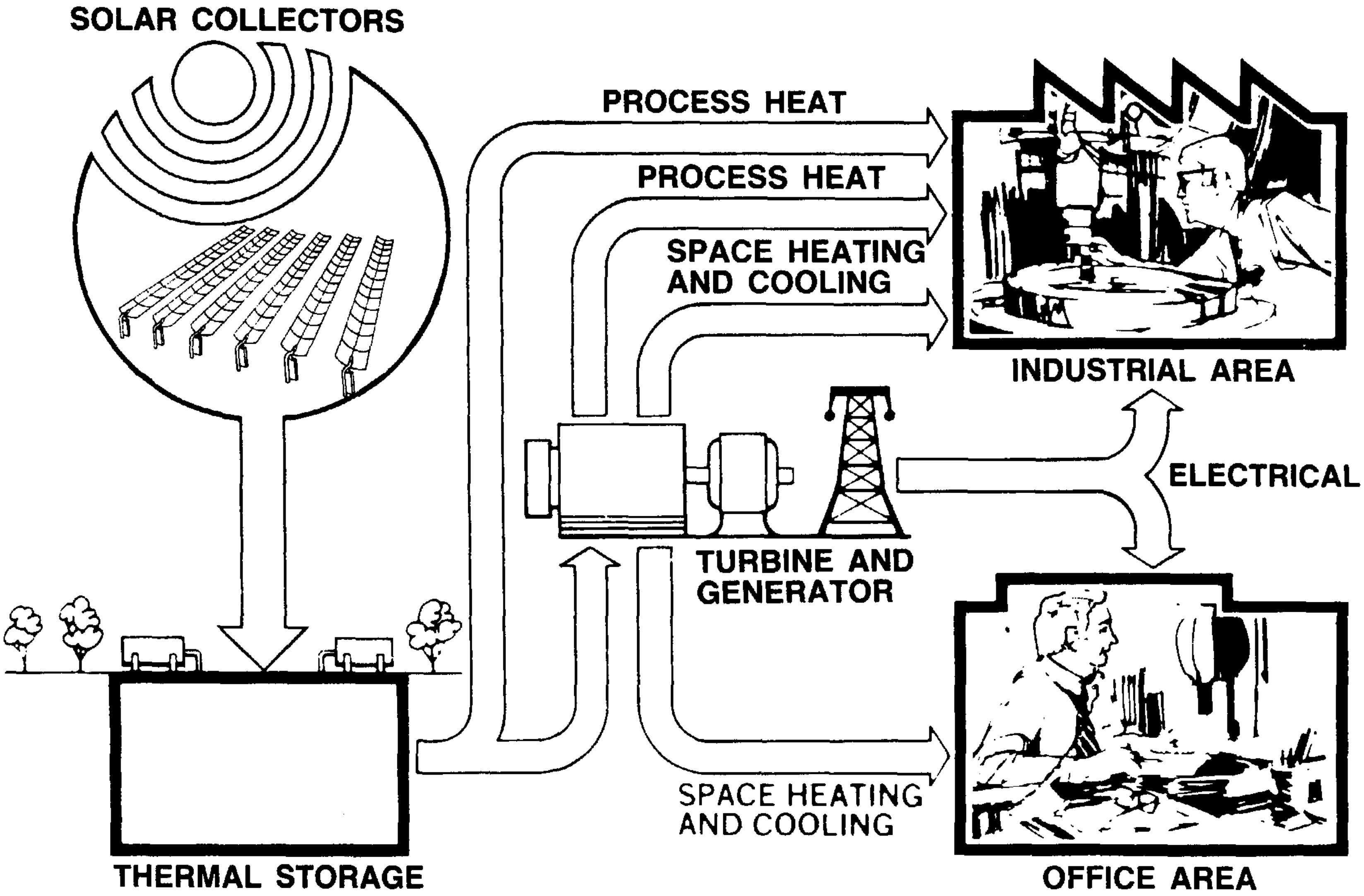
- PROCESS HEAT
- ELECTRICAL GENERATION
- TOTAL ENERGY

PROCESS HEAT



54972

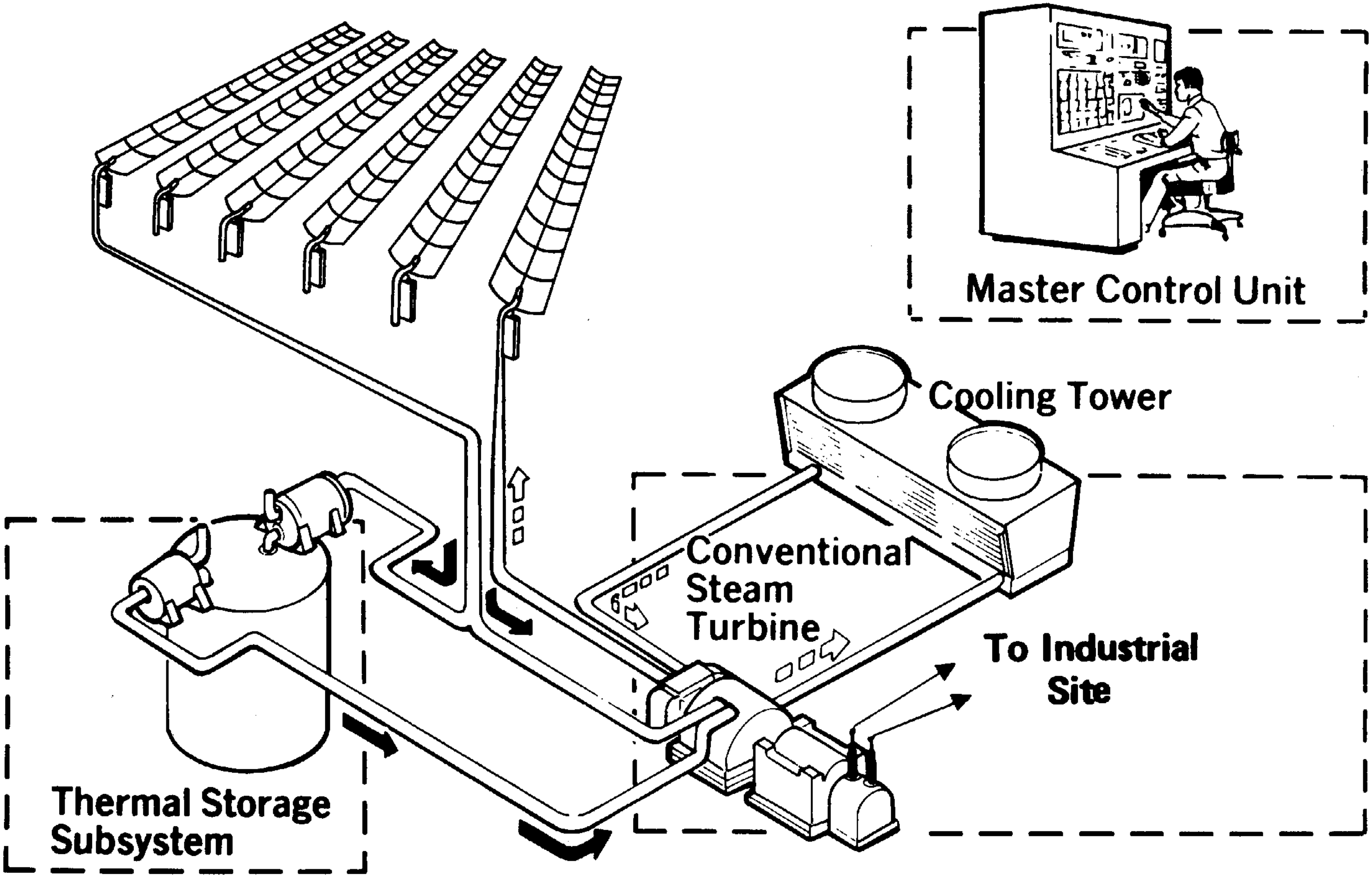
TYPICAL SOLAR TOTAL ENERGY SYSTEM



A7

ELECTRICAL GENERATION

54970



TYPICAL SOLAR TOTAL ENERGY SYSTEM DESIGN

ENERGY DEMAND SUMMARY MEAT PACKING - TEXAS

54975

Electrical

0.205 MW	16 hr/day	5 day/week (motors)
0.0976 MW	24 hr/day	7 day/week (refrigeration equipment)

Steam

5,000 lb/hr	125 psig	16 hr/day	5 day/week

Directed fired process heat

Environmental

Included in Electrical

Current energy source

Electricity - Local utility grid

Boiler - Intrastate natural gas with No. 2 fuel oil backup

SOLAR TOTAL ENERGY SYSTEM MEAT PACKING, TX

PARABOLIC TROUGH, GCR = 0.476

		η_T = 0.74		η_T = 0.80		η_T = 0.85		η_T = 0.90		
REFLECTIVITY	ABSORPTIVITY	A_{COLL} (FT^2)	FS (ACRES)	A_{COLL}	FS	A_{COLL}	FS	A_{COLL}	FS	
0.79	0.86	173,443	8.36	167,613	8.08	162,647	7.84	157,970	7.61	T_{SUPP} = 650°F
0.86	0.86	151,532	7.31	146,129	7.06	142,101	6.86	138,013	6.66	
0.91	0.86	138,880	6.70	134,212	6.47	130,236	6.28	126,490	6.10	
0.91	0.95	119,536	5.77	115,432	5.57	112,042	5.41	108,812	5.25	

SMALL CENTRAL RECEIVER, GCR = 0.23

						*	*	η_T = 0.82		
0.91		77,937	7.78	75,625	7.55	75,012	7.49	74,679	7.46	750°F
0.86		82,916	8.28	80,456	8.03	79,804	7.97	79,450	7.93	

DISH, GCR = 0.366

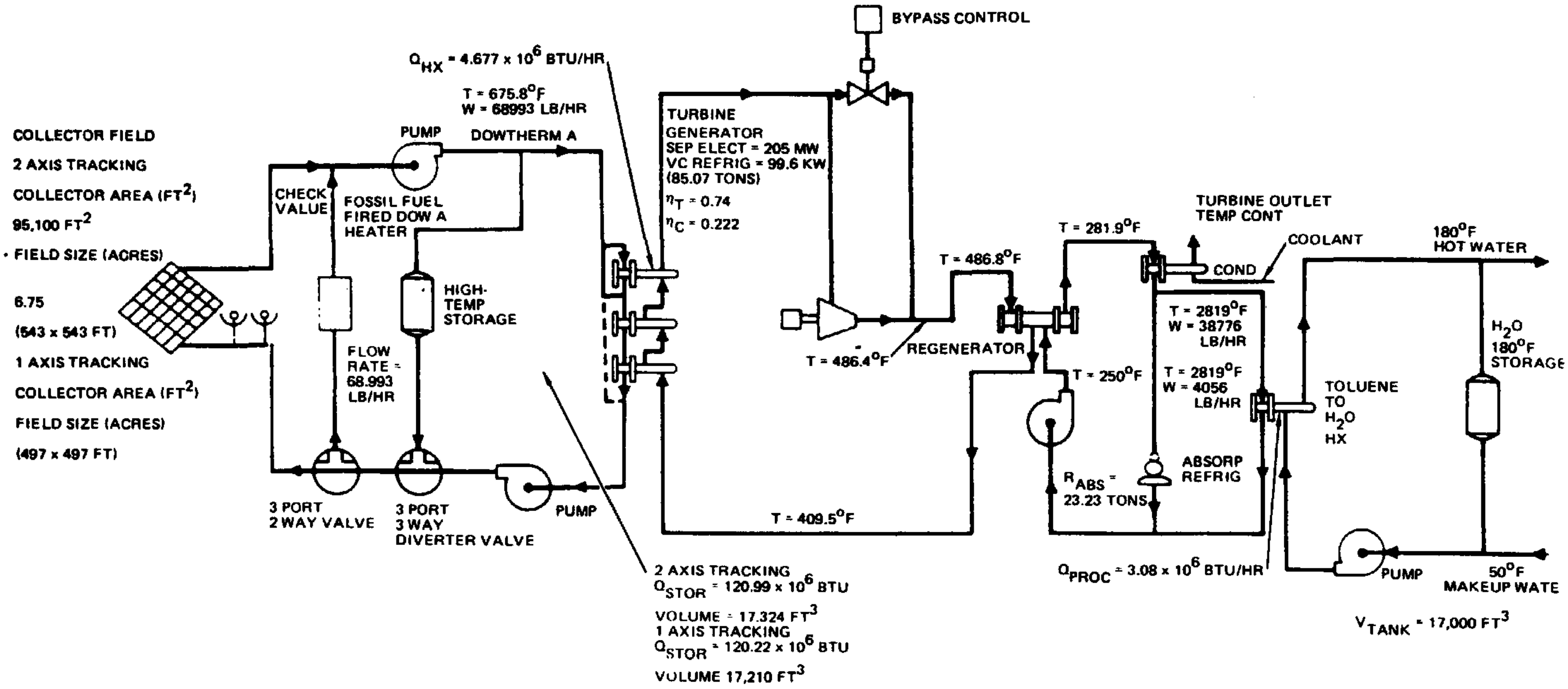
						*	*	η_T 0.82		
0.88		76,008	4.77	73,103	4.59	72,503	4.55	69,423	4.53	750°F

*GENERATES EXCESS ELECTRICITY

ANNUAL DISP: SCR = 0.90, PT = 0.89, DISH = 0.81

54976

CONCEPTUAL DESIGN: DISTRIBUTED COLLECTORS - MEAT PACKING PLANT - TEXAS - TOLUENE - DAYTIME OPERATIONS FROM 8 AM TO 12 MIDNIGHT



ECONOMICS

SOLAR TOTAL ENERGY SYSTEM CHARACTERISTICS

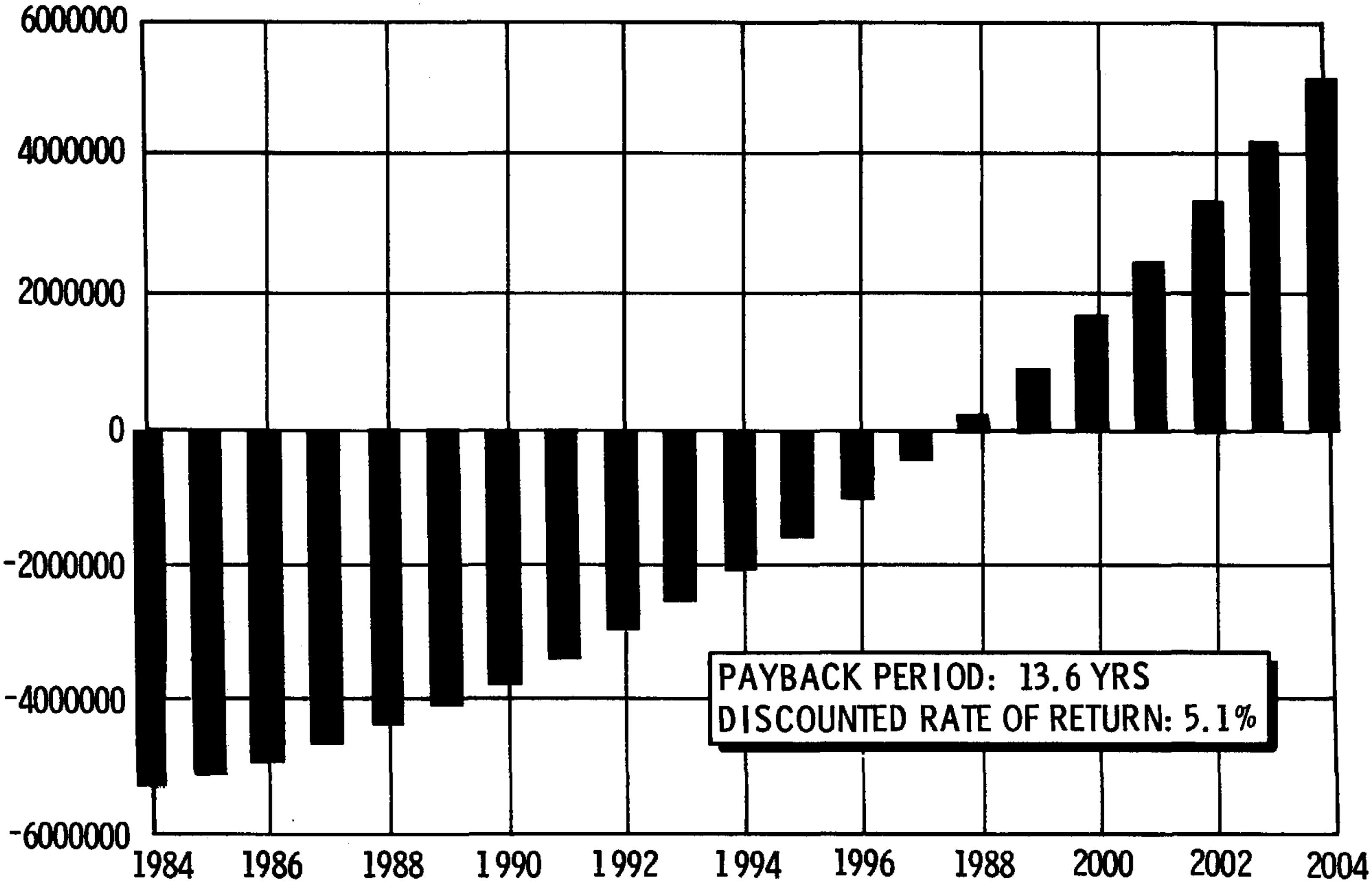
[MEAT PACKING PLANT "B"]

HELIOSTAT AREA	591,950 FT^2
NUMBER OF HELIOSTATS	1,770
SITE REQUIREMENTS	54.1 ACRES
WORKING FLUID	TOLUENE
ANNUAL ENERGY DISPLACEMENT	134,000 MBTU
● FOSSIL FUEL DISPLACEMENT	14,500 BBL FUEL OIL
● ELECTRICITY DISPLACEMENT	14.6 X 10^6 KWH

CASE DEFINITION
SOLAR TOTAL ENERGY
MEAT PACKING "B"

VARIABLE	UNIT	OPTIMISTIC	NOMINAL	PESSIMISTIC
HELIOSTAT COST	$/FT^2	5.13	8.3	11.5
CAPITAL COST	($/M, 1977)	$7.5M	$9.4M	$11.3M
INVESTMENT TAX CREDIT	RATIO	10%	10%	10%
ENERGY DISPLACEMENT, FUEL OIL	BBL/OIL	14,500	14,500	14,500
ENERGY DISPLACEMENT, ELECTRICITY	KWH	14.6×10^6	14.6×10^6	14.6×10^6
ANNUAL ENERGY DISPLACEMENT	MBTU	134,000	134,000	134,000
● PAYBACK PERIOD	YEARS	11.2 YRS.	13.6 YRS.	16 YRS.
● INTERNAL RATE OF RETURN	%	8.3%	5.1%	2.7%
● MAXIMUM	$M, ESC.	-$4.2M	-$5.3M	-$7.0M

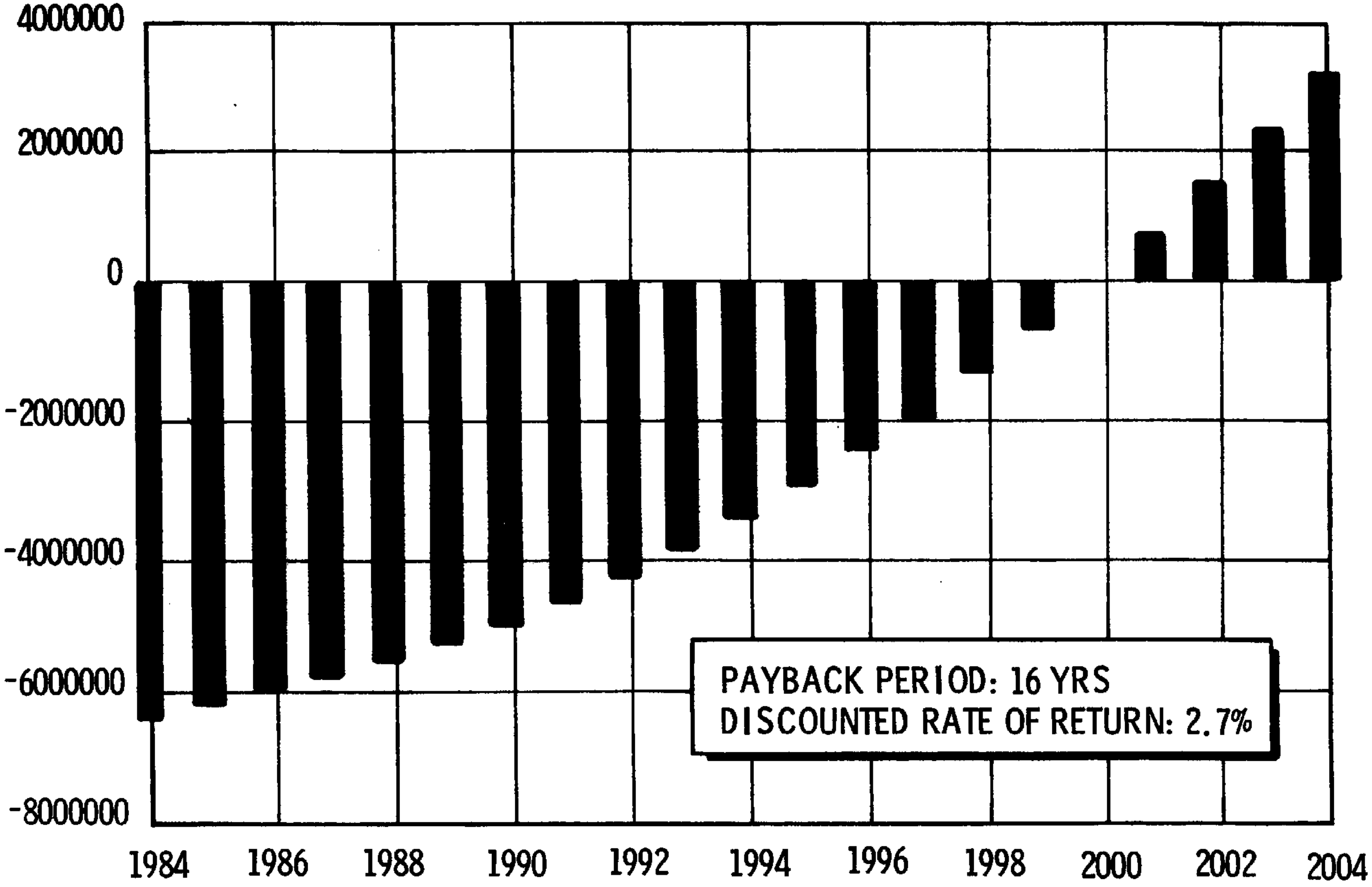
CUMULATIVE CASH FLOW-NOMINAL



PAYBACK PERIOD: 13.6 YRS
DISCOUNTED RATE OF RETURN: 5.1%

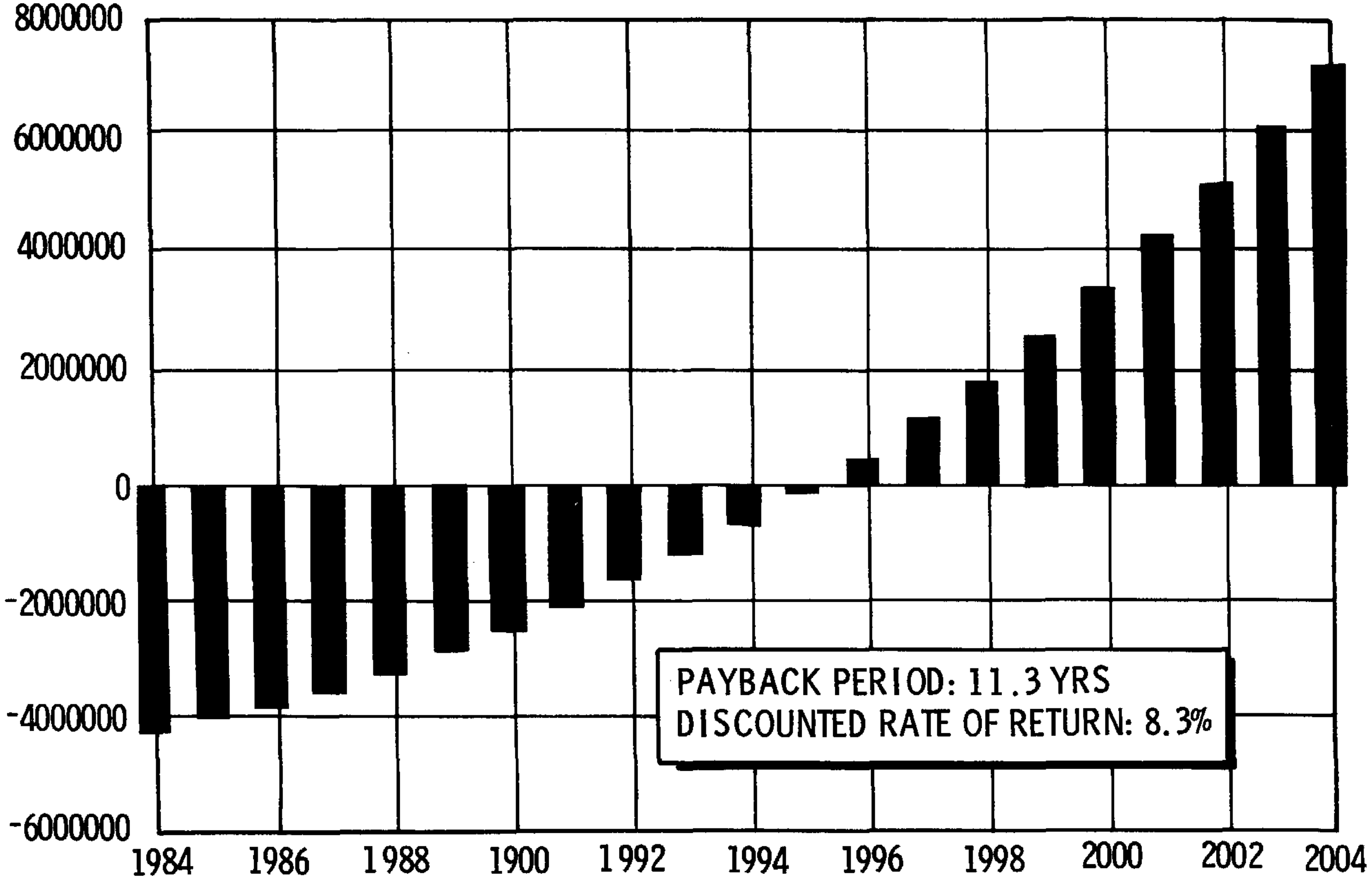
54981

CUMULATIVE CASH FLOW-PESSIMISTIC



PAYBACK PERIOD: 16 YRS
DISCOUNTED RATE OF RETURN: 2.7%

CUMULATIVE CASH FLOW-OPTIMISTIC



Survey Questionnaire

1.0 Plant Identifiers (if portions of this section are subject to proprietary restrictions, they need not be reported).

1.1. SIC Code 2011

1.2 City Dixon

1.3 State California

1.4 Zip Code 95620

1.5 Company Name Grayhound (Corp HQ Phoenix)

1.6 Plant Name Armour Food Co.

1.7 Plant Contact Ken Ries (Grayhound), Les Oesterreich

1.8 Phone Number (602) 248-5722, (916) 678-2363, Ext. 47

2.0 Land Availability for Solar Collectors

2.1 Quantity owned 48 acres

2.2 Shape and Terrain Flat see figure

2.3 Location relative to use South and East of Plant

2.4 Suitability for solar Excellent

2.5 Acquirable land (buy or lease) Some vacant land to South

2.6 Plant location (urban or rural) On edge of small town

3.0 Process Heat Requirements

Individual processes (up to 5):			Units
3.1	Name of process	Lamb and Beef Slaughter	
3.2	Supply temperature (Temperature at which heat transfer fluid is delivered to the process)	180 (water)	°F
3.3	Flow rate	5000	lb/hr
3.4	Pressure	150	psi
3.5	Heat transport medium (steam, air or other)		Steam
3.6	Steam quality	Saturated	%
3.7	Daily start hour	6 a.m. boiler startup, 8 a.m. plant	
3.8	Daily end hour	5 p.m. (second shift clean up)	
3.9	Days per week	5	
3.10	Scheduled downtime	None	weeks/year

The following sections of this questionnaire should be considered optional. If the information is available it would greatly aid in the economic feasibility systems studies which are being conducted.

			Units
4.0	Total Plant Energy Requirements		
	Fossil Fuel Requirements		
4.1	Fuel type		Natural Gas
4.2	Substitute Fuel, if any		#2
4.3	Annual fuel usage		MMBtu/yr
4.4	Current cost		$/MMBtu
4.5	Backup fuel		
	Electrical Requirements		
4.6	Utility company name		PG&E
4.7	Rate schedule (utility designated rate code, interruptibel or continuous)		
4.8	Peak power		550 KW
4.9	Peak/Average ratio		
4.10	Total annual purchased power	2.6×10^6	KWH
4.11	Total annual self-generated power	0	MWh
5.0	Economic factors		
5.1	After tax discount rate		%
5.2	Payback period		years
5.3	Number of employees		
5.4	Maintenance staff size		
5.5	Age of plant	50	years
6.0	Environmental		
6.1	Plant environment (dust, air pollutants, local mirco-climate, etc.)		Sacramento 20+ miles West
6.2	Environmental impact problems (EPA non-attainment area?) Plant does own sewage treatment		

Survey Questionnaire

1.0 Plant Identifiers (if portions of this section are subject to proprietary restrictions, they need not be reported).

1.1. SIC Code 2074

1.2 City

1.3 State Texas

1.4 Zip Code

1.5 Company Name Anonymous

1.6 Plant Name Cottonseed Oil

1.7 Plant Contact Plant Manager, Plant Engineer

1.8 Phone Number

2.0 Land Availability for Solar Collectors

2.1 Quantity owned 170 acres

2.2 Shape and Terrain Flat

2.3 Location relative to use Adjacent

2.4 Suitability for solar Excellent

2.5 Acquirable land (buy or lease) 2 Sections to South

2.6 Plant location (urban or rural) Rural

3.0 Process Heat Requirements

Individual processes (up to 5):		Units
3.1 Name of process Cottonseed Oil Extraction		
3.2 Supply temperature (Temperature at which heat transfer fluid is delivered to the process)	358	°F
3.3 Flow rate	18,000	lb/hr
3.4 Pressure	150	psia
3.5 Heat transport medium (steam, air or other)		Steam
3.6 Steam quality	100	%
3.7 Daily start hour		7:30
3.8 Daily end hour	3 shifts	
3.9 Days per week		7
3.10 Scheduled downtime	4 weeks/year Sept & Oct	

The following sections of this questionnaire should be considered optional. If the information is available it would greatly aid in the economic feasibility systems studies which are being conducted.

4.0	Total Plant Energy Requirements	Units
Fossil Fuel Requirements		
4.1	Fuel type	Natural Gas
4.2	Substitute Fuel, if any	#2
4.3	Annual fuel usage	≈ 200,000 MMBtu/yr
4.4	Current cost	1.70 $/MMBtu (1979)
4.5	Backup fuel	#2
Electrical Requirements		
4.6	Utility company name	Southwestern Public Service
4.7	Rate schedule (utility designated rate code, interruptibel or continuous)	
4.8	Peak power	40 MW
4.9	Peak/Average ratio	74% Load Factor
4.10	Total annual purchased power	≈ 24,000 MWH
4.11	Total annual self-generated power	MWh
5.0	Economic factors	
5.1	After tax discount rate	%
5.2	Payback period	years
5.3	Number of employees	
5.4	Maintenance staff size	
5.5	Age of plant	years
6.0	Environmental	
6.1	Plant environment (dust, air pollutants, local mirco-climate, etc.)	Dusty
6.2	Environmental impact problems (EPA non-attainment area?)	

Survey Questionnaire

1.0 Plant Identifiers (if portions of this section are subject to proprietary restrictions, they need not be reported).

1.1. SIC Code 2011

1.2 City Hereford

1.3 State Texas

1.4 Zip Code

1.5 Company Name Greyhound Inc.

1.6 Plant Name Armour Meat Packing

1.7 Plant Contact Mr. C. R. Taylor, Plant Manager

1.8 Phone Number

2.0 Land Availability for Solar Collectors

2.1 Quantity owned 400 acres

2.2 Shape and Terrain Flat

2.3 Location relative to use Adjacent to West

2.4 Suitability for solar Excellent

2.5 Acquirable land (buy or lease) Not needed

2.6 Plant location (urban or rural) Rural

3.0 Process Heat Requirements

Individual processes (up to 5):			Units
3.1	Name of process Beef Slaughter		
3.2	Supply temperature (Temperature at which heat transfer fluid is delivered to the process)	358	^{o}F
3.3	Flow rate	18,000	lb/hr
3.4	Pressure	150	psia
3.5	Heat transport medium (steam, air or other)		Steam
3.6	Steam quality	100	%
3.7	Daily start hour		8:00 a.m.
3.8	Daily end hour		2 shifts
3.9	Days per week		7
3.10	Scheduled downtime	zero	weeks/year

The following sections of this questionnaire should be considered optional. If the information is available it would greatly aid in the economic feasibility systems studies which are being conducted.

4.0	Total Plant Energy Requirements	Units
Fossil Fuel Requirements		
4.1	Fuel type	Natural Gas
4.2	Substitute Fuel, if any	None
4.3	Annual fuel usage	300,000 MMBtu/yr
4.4	Current cost	Unknown $/MMBtu
4.5	Backup fuel	None
Electrical Requirements		
4.6	Utility company name	
4.7	Rate schedule (utility designated rate code, interruptibel or continuous)	
4.8	Peak power	2.3 MW
4.9	Peak/Average ratio	
4.10	Total annual purchased power	11,000 MWH
4.11	Total annual self-generated power	0 MWh
5.0	Economic factors	
5.1	After tax discount rate	%
5.2	Payback period	years
5.3	Number of employees	
5.4	Maintenance staff size	
5.5	Age of plant	years
6.0	Environmental	
6.1	Plant environment (dust, air pollutants, local mirco-climate, etc.)	
6.2	Environmental impact problems (EPA non-attainment area?)	

1. Large amount of gas used to fuel internal combustion engines for refrigeration drive (1000 tons, 24 hr/day, 7 day week)

Survey Questionnaire

1.0 Plant Identifiers (if portions of this section are subject to proprietary restrictions, they need not be reported).

1.1. SIC Code 2022/2035/2079

1.2 City

1.3 State California

1.4 Zip Code

1.5 Company Name Anonymous

1.6 Plant Name Vegetable Oil Processing

1.7 Plant Contact Plant Manager

1.8 Phone Number

2.0 Land Availability for Solar Collectors

2.1 Quantity owned 50 acres

2.2 Shape and Terrain Flat

2.3 Location relative to use Adjacent to East

2.4 Suitability for solar Excellent

2.5 Acquirable land (buy or lease) 15

2.6 Plant location (urban or rural) Urban

3.0 Process Heat Requirements

Individual processes (up to 5):		Units
3.1 Name of process	Vegetable Oil Processing	
3.2 Supply temperature (Temperature at which heat transfer fluid is delivered to the process)	390	°F
3.3 Flow rate	12,000	lb/hr
3.4 Pressure	3000 $\frac{LB}{HR}$ @ 220, 9000 @ 150	psia
3.5 Heat transport medium (steam, air or other)		Steam
3.6 Steam quality	100	%
3.7 Daily start hour 3.8 Daily end hour 3.9 Days per week	24 hr/day, 7 day/week	
3.10 Scheduled downtime	zero	weeks/year

The following sections of this questionnaire should be considered optional. If the information is available it would greatly aid in the economic feasibility systems studies which are being conducted.

4.0	Total Plant Energy Requirements		Units
	Fossil Fuel Requirements		
4.1	Fuel type		Natural Gas
4.2	Substitute Fuel, if any		#6
4.3	Annual fuel usage	150,000	MMBtu/yr
4.4	Current cost	2.90 (1979), 3.40 (Feb 1980)	$/MMBtu
4.5	Backup fuel		#6
	Electrical Requirements		
4.6	Utility company name		PG&E
4.7	Rate schedule (utility designated rate code, interruptible or continuous)		Time-of-Day
4.8	Peak power		1.4 MW
4.9	Peak/Average ratio		
4.10	Total annual purchased power	5,500	MWH
4.11	Total annual self-generated power	0	MWh
5.0	Economic factors		
5.1	After tax discount rate		%
5.2	Payback period		years
5.3	Number of employees		
5.4	Maintenance staff size	8 mech., Super + 2 foremen	
5.5	Age of plant		years
6.0	Environmental		
6.1	Plant environment (dust, air pollutants, local mirco-climate, etc.)		oily
6.2	Environmental impact problems (EPA non-attainment area?)		

Survey Questionnaire

1.0 Plant Identifiers (if portions of this section are subject to proprietary restrictions, they need not be reported).

1.1. SIC Code 2047/2091

1.2 City

1.3 State California

1.4 Zip Code

1.5 Company Name Anonymous

1.6 Plant Name Seafood Processing

1.7 Plant Contact Plant Engineer

1.8 Phone Number

2.0 Land Availability for Solar Collectors

2.1 Quantity leased Approx. 5 acres all occupied with buildings

2.2 Shape and Terrain

2.3 Location relative to use Same

2.4 Suitability for solar Poor

2.5 Acquirable land (buy or lease) None

2.6 Plant location (urban or rural) Urban

3.0 Process Heat Requirements

Individual processes (up to 5):

			Units
3.1	Name of process	Seafood Processing	
3.2	Supply temperature (Temperature at which heat transfer fluid is delivered to the process)	500° → 350	°F
3.3	Flow rate	106,000	lb/hr
3.4	Pressure	260, 150	psia
3.5	Heat transport medium (steam, air or other)		Steam
3.6	Steam quality	100	%
3.7	Daily start hour		6:00 a.m.
3.8	Daily end hour		6:00 p.m.
3.9	Days per week		6
3.10	Scheduled downtime	zero	weeks/year

The following sections of this questionnaire should be considered optional. If the information is available it would greatly aid in the economic feasibility systems studies which are being conducted.

4.0 Total Plant Energy Requirements

			Units
Fossil Fuel Requirements	(Steam purchased from steam coop)		
4.1	Fuel type		Natural Gas
4.2	Substitute Fuel, if any		#2
4.3	Annual fuel usage	45,000	MMBtu/yr
4.4	Current cost	3.00 to 3.40 (1980)	$/MMBtu
4.5	Backup fuel		#2
Electrical Requirements			
4.6	Utility company name		So Cal Ed
4.7	Rate schedule (utility designated rate code, interruptible or continuous)		Time-of-Day
4.8	Peak power (includes refrigeration)		6 MW
4.9	Peak/Average ratio		
4.10	Total annual purchased power	24,000	MWH
4.11	Total annual self-generated power	0	MWh

5.0 Economic factors

5.1	After tax discount rate	%
5.2	Payback period	years
5.3	Number of employees	
5.4	Maintenance staff size	
5.5	Age of plant	years

6.0 Environmental

6.1	Plant environment (dust, air pollutants, local mirco-climate, etc.)	coastal
6.2	Environmental impact problems (EPA non-attainment area?)	

Survey Questionnaire

1.0 Plant Identifiers (if portions of this section are subject to proprietary restrictions, they need not be reported).

1.1. SIC Code

1.2 City San Mateo

1.3 State New Mexico

1.4 Zip Code

1.5 Company Name Gulf Mineral Resources

1.6 Plant Name Mount Taylor Mine and Mill

1.7 Plant Contact Dr. F. E. Kiviatt

1.8 Phone Number

2.0 Land Availability for Solar Collectors

2.1 Quantity owned - leased 1000 acres

2.2 Shape and Terrain Generally Flat

2.3 Location relative to use Adjacent to mill

2.4 Suitability for solar Excellent

2.5 Acquirable land (buy or lease) Forest Service land surrounds mill

2.6 Plant location (urban or rural) Rural

3.0 Process Heat Requirements

Individual processes (up to 5):			Units
3.1	Name of process	Uranium Mill	
3.2	Supply temperature (Temperature at which heat transfer fluid is delivered to the process)	358	^{o}F
3.3	Flow rate	51,200 to 116,900	lb/hr (seasonal)
3.4	Pressure	150	psia
3.5	Heat transport medium (steam, air or other)		Steam
3.6	Steam quality	100	%
3.7	Daily start hour	continuous	
3.8	Daily end hour		
3.9	Days per week		
3.10	Scheduled downtime	zero	weeks/year

The following sections of this questionnaire should be considered optional. If the information is available it would greatly aid in the economic feasibility systems studies which are being conducted.

4.0 Total Plant Energy Requirements   Units

Fossil Fuel Requirements

4.1 Fuel type #2

4.2 Substitute Fuel, if any None

4.3 Annual fuel usage (Plant to start operation in in 1982) assumed to be MMBtu/yr

4.4 Current cost $/MMBtu

4.5 Backup fuel

Electrical Requirements

4.6 Utility company name Will be serviced by 2 separate utilities

4.7 Rate schedule (utility designated rate code, interruptible or continuous)

4.8 Peak power Assumed to be 6 MW for mine pumps + mine air conditioning (seasonal)

4.9 Peak/Average ratio

4.10 Total annual purchased power TBD MWh

4.11 Total annual self-generated power 0 MWh

5.0 Economic factors

5.1 After tax discount rate %

5.2 Payback period years

5.3 Number of employees

5.4 Maintenance staff size

5.5 Age of plant years

6.0 Environmental

6.1 Plant environment (dust, air pollutants, local mirco-climate, etc.) High Desert

6.2 Environmental impact problems (EPA non-attainment area?)

Survey Questionnaire

1.0 Plant Identifiers (if portions of this section are subject to proprietary restrictions, they need not be reported).

1.1. SIC Code

1.2 City Boron

1.3 State California

1.4 Zip Code

1.5 Company Name U.S. Borax

1.6 Plant Name Boran

1.7 Plant Contact M. Hsoch - Pei Liu

1.8 Phone Number

2.0 Land Availability for Solar Collectors

2.1 Quantity owned 2000 acres

2.2 Shape and Terrain Flat

2.3 Location relative to use Adjacent to Plant

2.4 Suitability for solar Excellent

2.5 Acquirable land (buy or lease)

2.6 Plant location (urban or rural) Rural

3.0 Process Heat Requirements

Individual processes (up to 5): Units

3.1 Name of process Borax Production

3.2 Supply temperature 358 °F

(Temperature at which heat transfer fluid is delivered to the process)

3.3 Flow rate In excess of 400,000 lb/hr

3.4 Pressure 150 psia

3.5 Heat transport medium Steam

(steam, air or other)

3.6 Steam quality 100 %

3.7 Daily start hour

3.8 Daily end hour } 24 hr/day, 7 day/week

3.9 Days per week

3.10 Scheduled downtime 0 weeks/year

The following sections of this questionnaire should be considered optional. If the information is available it would greatly aid in the economic feasibility systems studies which are being conducted.

			Units
4.0	Total Plant Energy Requirements		
Fossil Fuel Requirements			
4.1	Fuel type		Natural Gas
4.2	Substitute Fuel, if any		#2
4.3	Annual fuel usage	2.7×10^6	MMBtu/yr
4.4	Current cost		$/MMBtu
4.5	Backup fuel		#2
Electrical Requirements			
4.6	Utility company name	So. Cal Ed Co.	
4.7	Rate schedule (utility designated rate code, interruptible or continuous)		Time-of-Day Billing
4.8	Peak power		21 MW
4.9	Peak/Average ratio		1.2
4.10	Total annual purchased power	Approx. 150,000	MWh
4.11	Total annual self-generated power	0	MWh
5.0	Economic factors		
5.1	After tax discount rate		%
5.2	Payback period		years
5.3	Number of employees		
5.4	Maintenance staff size		
5.5	Age of plant		years
6.0	Environmental		
6.1	Plant environment (dust, air pollutants, local mirco-climate, etc.)		Dusty
6.2	Environmental impact problems (EPA non-attainment area?)		

APPENDIX B

SOL-MET WEEK-PER-SEASONS

LOCATION -- ALBUQUERQUE

MONTH	DAYS	TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	2 3 7 11 19 21 24	5,54	6,99
JUNE	2 6 8 16 24 27 30	8,74	9,56
SEPTEMBER	1 2 5 7 13 17 29	6,40	7,13
DECEMBER	1 2 4 6 9 17 30	2,98	5,97

LOCATION -- APALACHICOLA

MONTH	DAYS	TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	4 9 10 16 21 26 30	4,65	4,06
JUNE	7 8 10 17 23 27 28	6,35	5,19
SEPTEMBER	9 12 13 14 15 27 29	4,70	4,37
DECEMBER	9 14 15 16 20 22 26	2,64	3,48

LOCATION -- BISMARK

MONTH	DAYS	TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	3 5 8 15 16 23 30	3,68	4,38
JUNE	4 8 14 16 19 24 26	6,42	5,90
SEPTEMBER	9 14 16 18 21 25 28	4,38	5,88
DECEMBER	5 6 7 21 23 25 28	1,16	2,15

LOCATION -- BOSTON

MONTH	DAYS	TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	5 10 13 18 26 28 31	3,36	3,19
JUNE	11 17 18 23 24 27 30	5,41	4,23
SEPTEMBER	1 6 8 14 19 27 30	3,87	3,95
DECEMBER	6 9 11 14 16 23 24	1,16	1,82

LOCATION -- BROWNSVILLE

MONTH	DAYS	TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	4 7 10 15 24 27 29	4,60	3,75
JUNE	1 3 7 15 17 22 23	6,61	5,06
SEPTEMBER	3 6 11 12 20 22 25	5,75	5,31
DECEMBER	6 8 10 18 22 28 31	2,68	2,96

LOCATION -- CAPE HATTERAS

MONTH	DAYS	TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	2 10 13 16 24 25 31	4,45	4,11
JUNE	6 7 10 12 21 23 25	6,50	5,55
SEPTEMBER	3 4 6 10 12 23 24	4,90	4,41
DECEMBER	2 10 14 16 23 24 27	2,31	3,50

LOCATION -- CARIBOU

MONTH	DAYS	TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	1 5 7 9 17 19 21	3,97	5,24
JUNE	1 5 11 26 27 28 30	5,62	4,55
SEPTEMBER	12 13 15 17 18 19 23	3,53	3,54
DECEMBER	6 12 17 18 24 26 31	1,08	1,76

LOCATION -- CHARLESTON

MONTH	DAYS	TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	2 5 7 14 19 24 30	4,07	3,61
JUNE	10 15 16 18 23 26 29	6,06	4,35
SEPTEMBER	2 12 15 16 22 27 28	4,28	3,60
DECEMBER	1 8 16 17 20 24 29	2,25	3,21

LOCATION -- COLUMBIA

MONTH	DAYS	TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	1 7 9 13 14 21 22	3,52	3,65
JUNE	3 4 15 22 23 26 27	6,55	5,85
SEPTEMBER	2 5 6 13 20 28 30	4,73	4,61
DECEMBER	4 9 17 18 20 23 26	1,69	2,64

LOCATION -- DODGE CITY

MONTH	DAYS	TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	7 8 11 13 17 28 29	4,79	5,11
JUNE	5 7 17 20 25 28 30	7,48	6,87
SEPTEMBER	5 8 10 11 12 15 18	5,69	6,56
DECEMBER	4 5 9 13 19 27 28	2,57	5,03

LOCATION -- EL PASO

MONTH	DAYS	TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	5 6 8 17 18 27 31	5,89	6,88
JUNE	2 3 7 11 12 16 23	8,74	8,93
SEPTEMBER	10 11 13 15 18 25 29	6,29	6,85
DECEMBER	3 4 6 8 12 15 29	3,26	5,96

LOCATION -- ELY

MONTH	DAYS	TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	4 8 10 17 20 26 31	5,06	6,07
JUNE	2 5 11 16 20 26 27	7,87	8,42
SEPTEMBER	4 8 13 17 18 24 29	6,22	7,73
DECEMBER	2 7 8 9 18 28 29	2,43	5,17

LOCATION -- FORT WORTH

MONTH	DAYS							TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	4	7	9	11	13	18	26	4,40	4,43
JUNE	1	2	19	20	22	26	27	6,65	5,85
SEPTEMBER	3	4	14	17	22	23	29	5,41	5,10
DECEMBER	2	11	13	14	19	26	30	2,61	3,94

LOCATION -- FRESNO

MONTH	DAYS							TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	6	11	12	21	26	29	31	5,66	6,04
JUNE	8	9	11	13	16	17	27	8,73	9,65
SEPTEMBER	18	19	25	26	27	28	30	5,92	8,03
DECEMBER	4	6	11	13	15	16	26	1,89	2,62

LOCATION -- GREAT FALLS

MONTH	DAYS							TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	2	9	10	16	22	29	30	3,77	3,87
JUNE	5	6	7	9	13	20	30	6,84	7,01
SEPTEMBER	5	8	10	12	16	18	28	4,60	5,14
DECEMBER	1	16	19	21	22	23	31	1,18	2,17

LOCATION -- LAKE CHARLES

MONTH	DAYS	TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	2 4 9 13 22 25 26	4,39	3,95
JUNE	6 10 11 16 17 23 27	6,15	4,36
SEPTEMBER	4 8 9 10 16 18 23	5,17	4,29
DECEMBER	6 7 10 12 23 28 29	2,39	2,85

LOCATION -- MADISON

MONTH	DAYS	TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	2 5 7 11 27 29 30	3,44	3,47
JUNE	11 15 17 19 22 28 30	6,06	5,27
SEPTEMBER	5 13 14 15 25 26 28	3,87	3,41
DECEMBER	3 9 12 15 22 23 31	1,41	2,66

LOCATION -- MEDFORD

MONTH	DAYS	TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	4 9 11 14 15 27 29	3,48	3,04
JUNE	2 9 13 18 22 26 28	7,33	7,45
SEPTEMBER	2 5 14 17 19 22 27	5,03	5,49
DECEMBER	1 4 12 13 19 25 31	1,04	1,40

LOCATION -- MIAMI

MONTH	DAYS	TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	4 8 13 19 20 29 30	4,96	3,85
JUNE	6 18 19 21 26 27 30	5,59	3,69
SEPTEMBER	4 10 11 15 19 23 24	4,76	3,71
DECEMBER	1 7 12 16 18 20 27	3,19	3,51

LOCATION -- NASHVILLE

MONTH	DAYS	TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	8 11 12 15 18 22 23	3,66	3,47
JUNE	3 6 10 14 15 18 19	6,33	5,01
SEPTEMBER	1 6 7 11 21 27 30	4,82	3,95
DECEMBER	2 3 11 16 18 20 22	1,98	2,64

LOCATION -- NEW YORK

MONTH	DAYS	TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	5 7 10 13 21 25 27	3,46	3,18
JUNE	8 11 12 15 16 19 28	5,77	4,27
SEPTEMBER	1 6 9 11 16 23 28	4,11	3,07
DECEMBER	4 6 12 13 14 16 22	1,41	1,82

LOCATION -- OMAHA

MONTH	DAYS	TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
JANUARY	9 12 16 18 23 26 30	2.12	3.41
APRIL	3 5 6 10 19 24 27	4.83	4.63
JULY	2 4 8 12 16 19 28	6.59	5.72
OCTOBER	3 7 12 17 23 27 28	3.06	3.88

LOCATION -- PHOENIX

MONTH	DAYS	TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	1 3 10 13 23 28 29	5.84	6.78
JUNE	14 15 18 22 25 27 30	8.98	8.88
SEPTEMBER	2 4 7 16 17 27 29	6.62	8.01
DECEMBER	2 5 7 8 18 27 30	3.06	4.90

LOCATION -- SANTA MARIA

MONTH	DAYS	TOTAL HORIZONTAL (KWH/M2)	DIRECT NORMAL (KWH/M2)
MARCH	4 10 12 14 16 17 20	4.74	4.62
JUNE	2 3 7 12 19 20 22	7.11	6.86
SEPTEMBER	10 14 15 19 22 29 30	5.45	6.27
DECEMBER	1 3 9 11 21 22 31	2.61	4.19

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LOCATION -- SEATTLE

                                                    TOTAL        DIRECT
                                                  HORIZONTAL     NORMAL
MONTH                       DAYS                  (KWH/M2)      (KWH/M2)

MARCH           10 11 17 19 21 27 30                2,60          2,03

JUNE             5 10 13 16 20 22 30                5,65          4,41

SEPTEMBER        7 11 13 14 18 21 24                3,30          2,79

DECEMBER         1 13 16 18 23 27 29                 ,54           ,45


LOCATION -- STERLING/WASH, DC

                                                    TOTAL        DIRECT
                                                  HORIZONTAL     NORMAL
MONTH                       DAYS                  (KWH/M2)      (KWH/M2)

MARCH            4  5  8 10 11 19 23                3,42          3,41

JUNE             2  5  6 15 22 28 30                5,98          4,39

SEPTEMBER        2  9 10 12 15 20 29                4,18          3,75

DECEMBER         2  6  9 14 17 22 27                1,56          2,17
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APPENDIX C

REGIONAL COLLECTOR REQUIREMENTS FOR SOLAR TOTAL ENERGY SYSTEMS

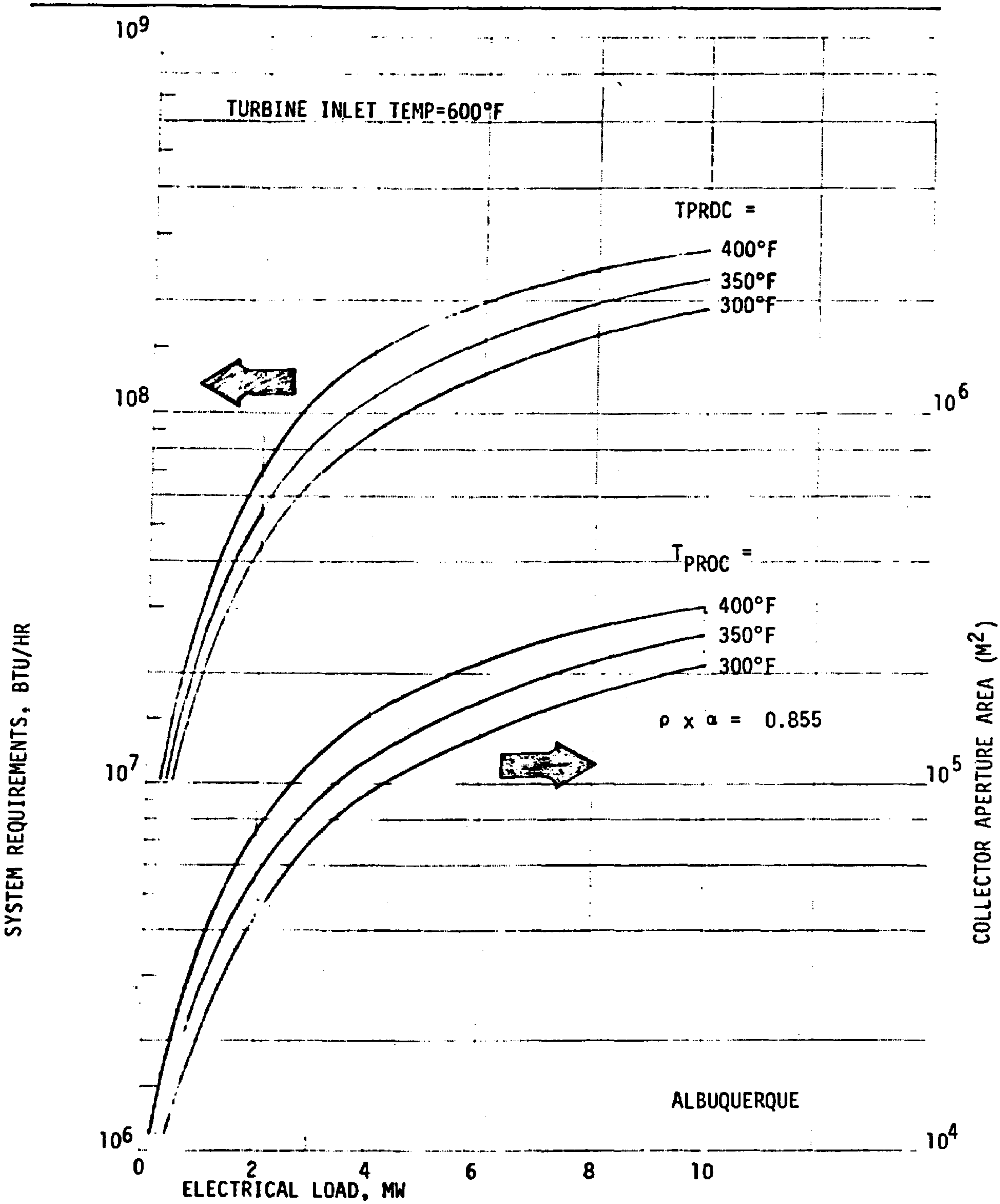


FIGURE - VARIATION OF SYSTEM REQUIREMENTS WITH ELECTRICAL LOAD

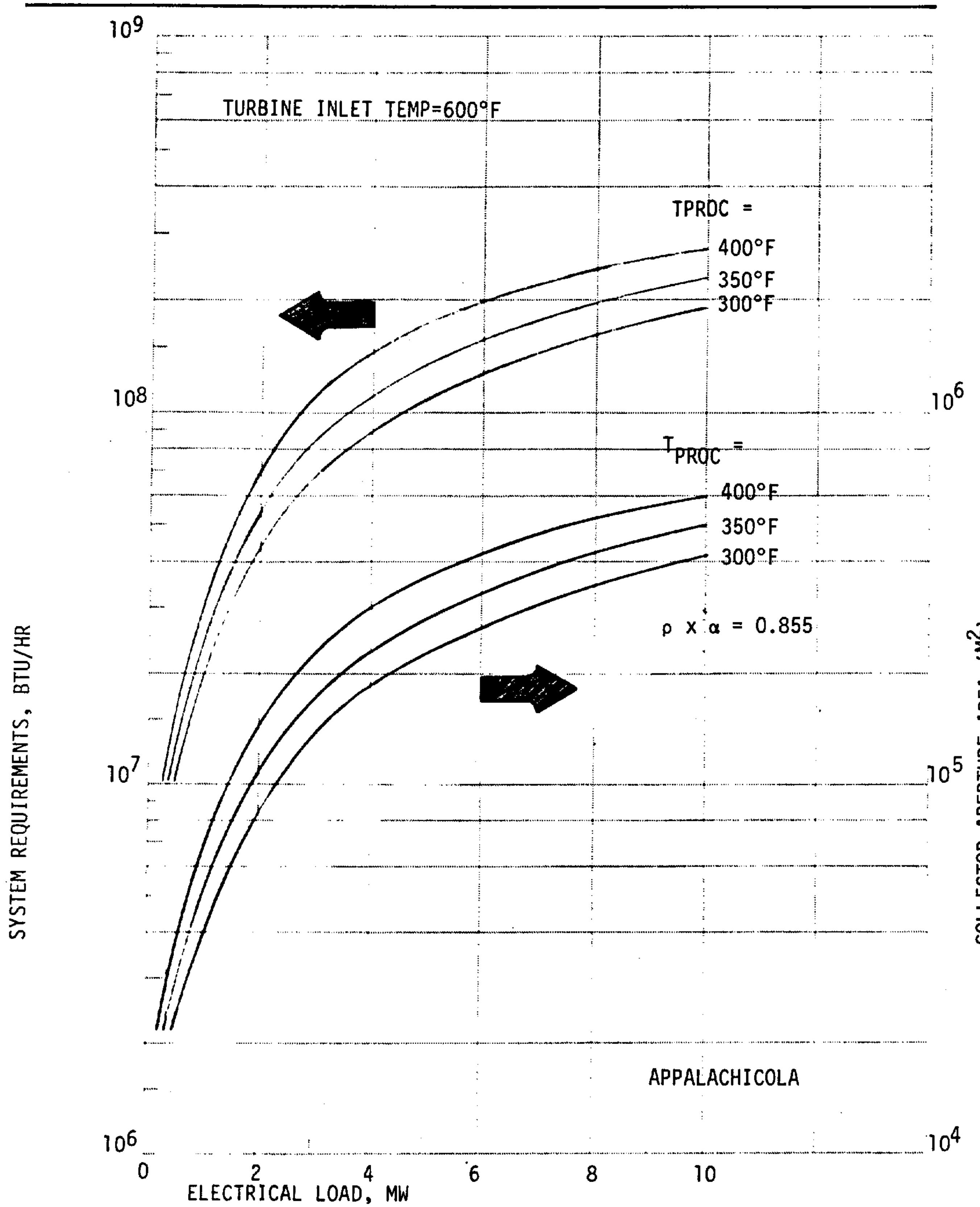


FIGURE - VARIATION OF SYSTEM REQUIREMENTS WITH ELECTRICAL LOAD

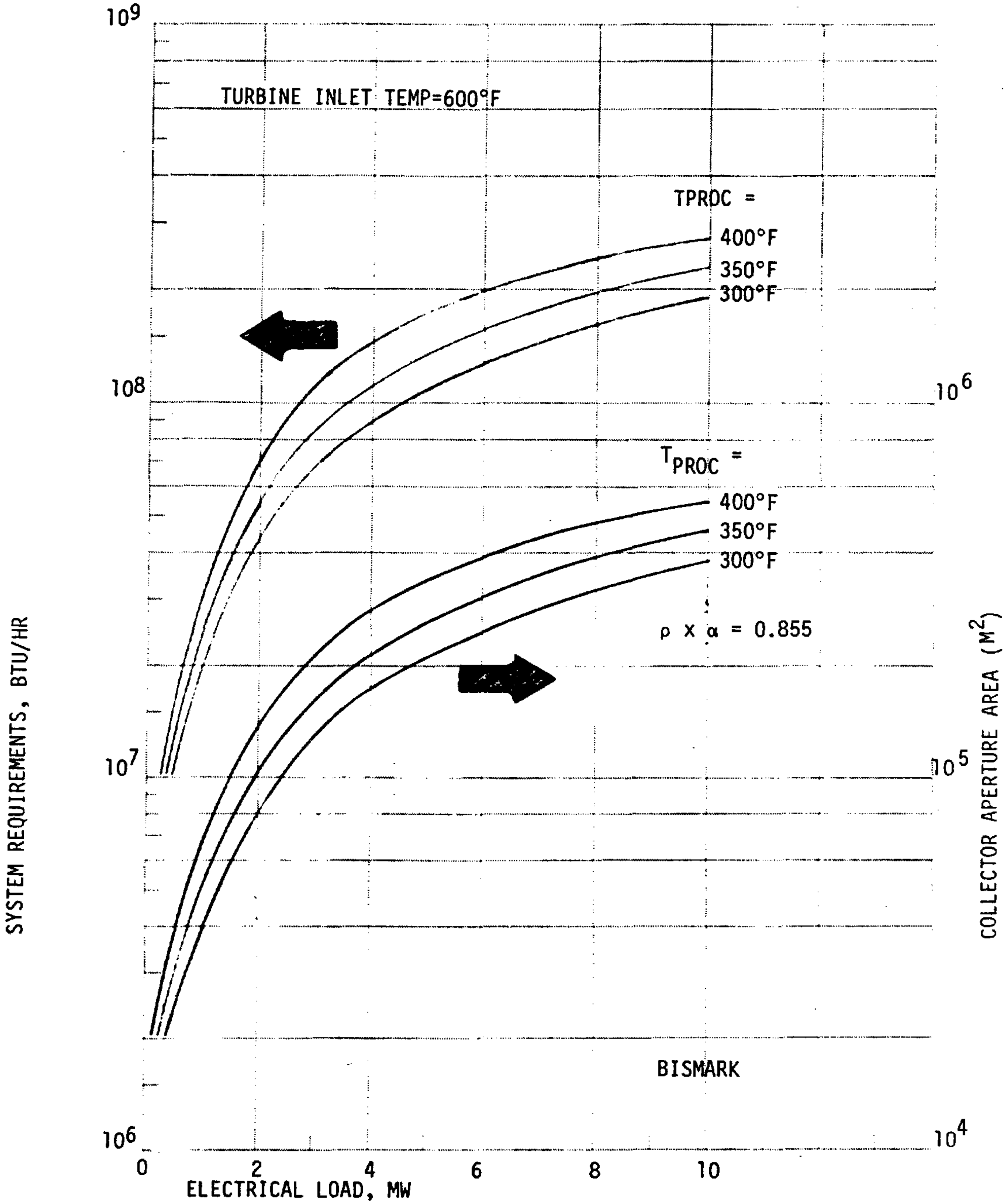


FIGURE - VARIATION OF SYSTEM REQUIREMENTS WITH ELECTRICAL LOAD

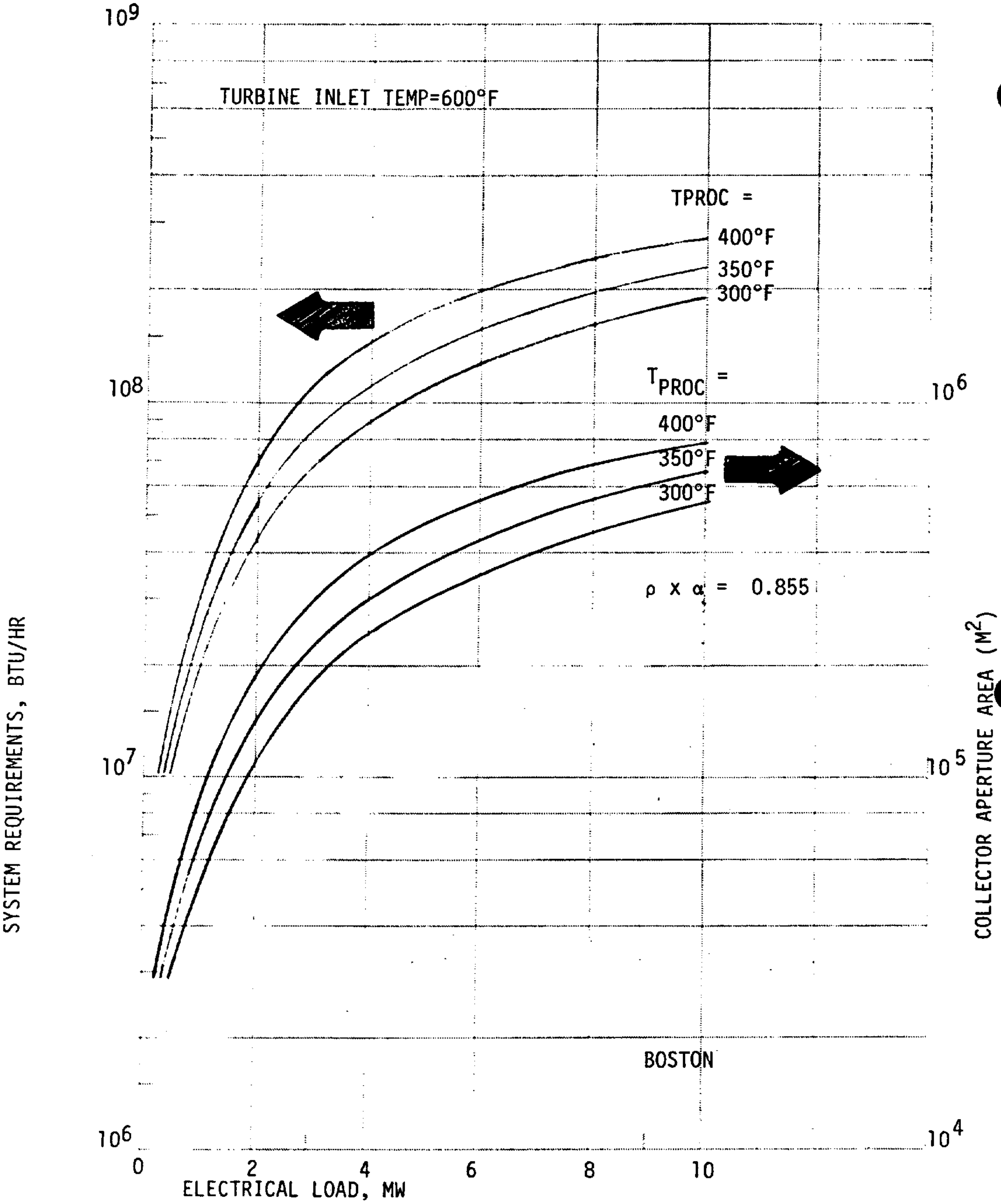


FIGURE - VARIATION OF SYSTEM REQUIREMENTS WITH ELECTRICAL LOAD

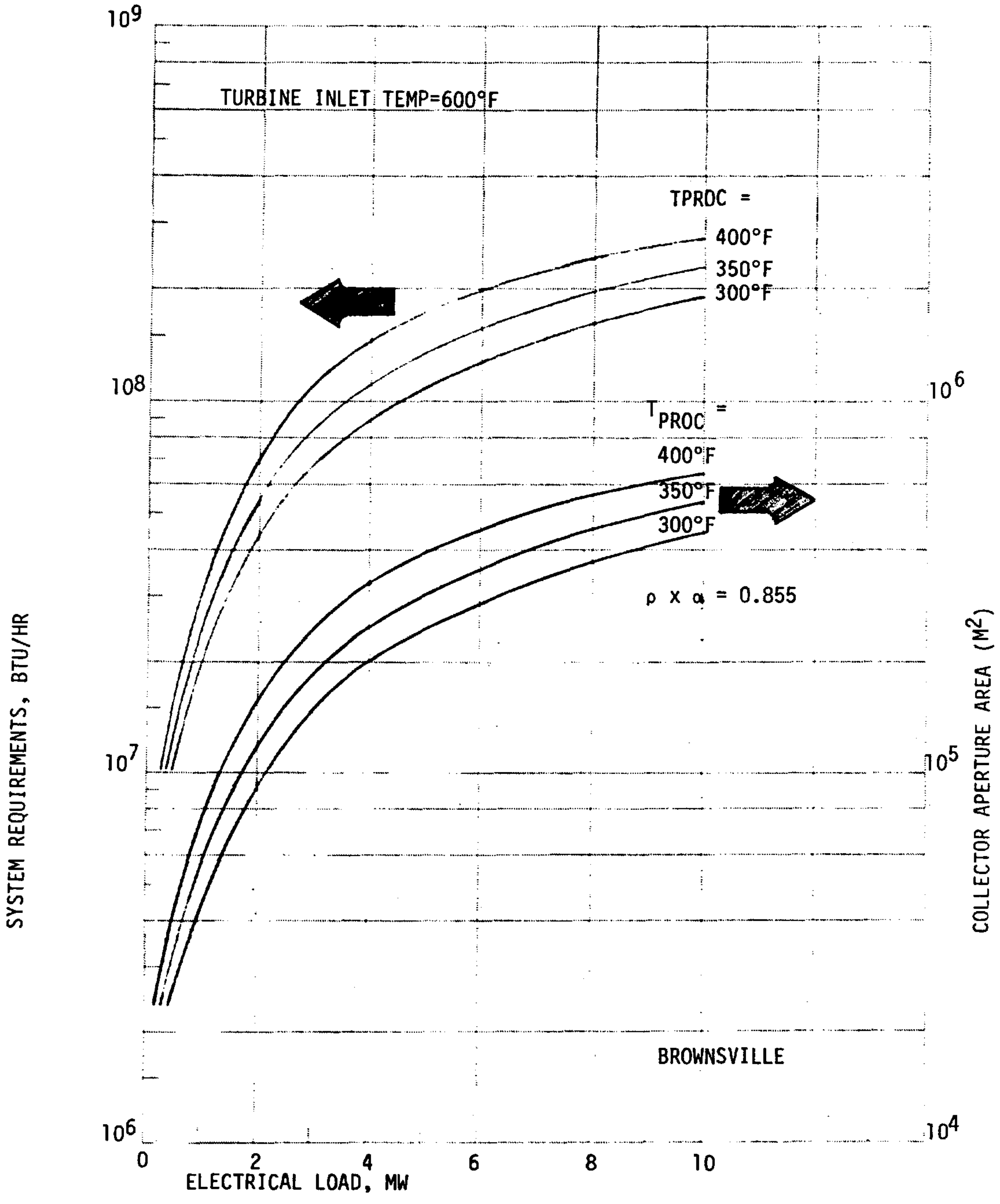


FIGURE - VARIATION OF SYSTEM REQUIREMENTS WITH ELECTRICAL LOAD

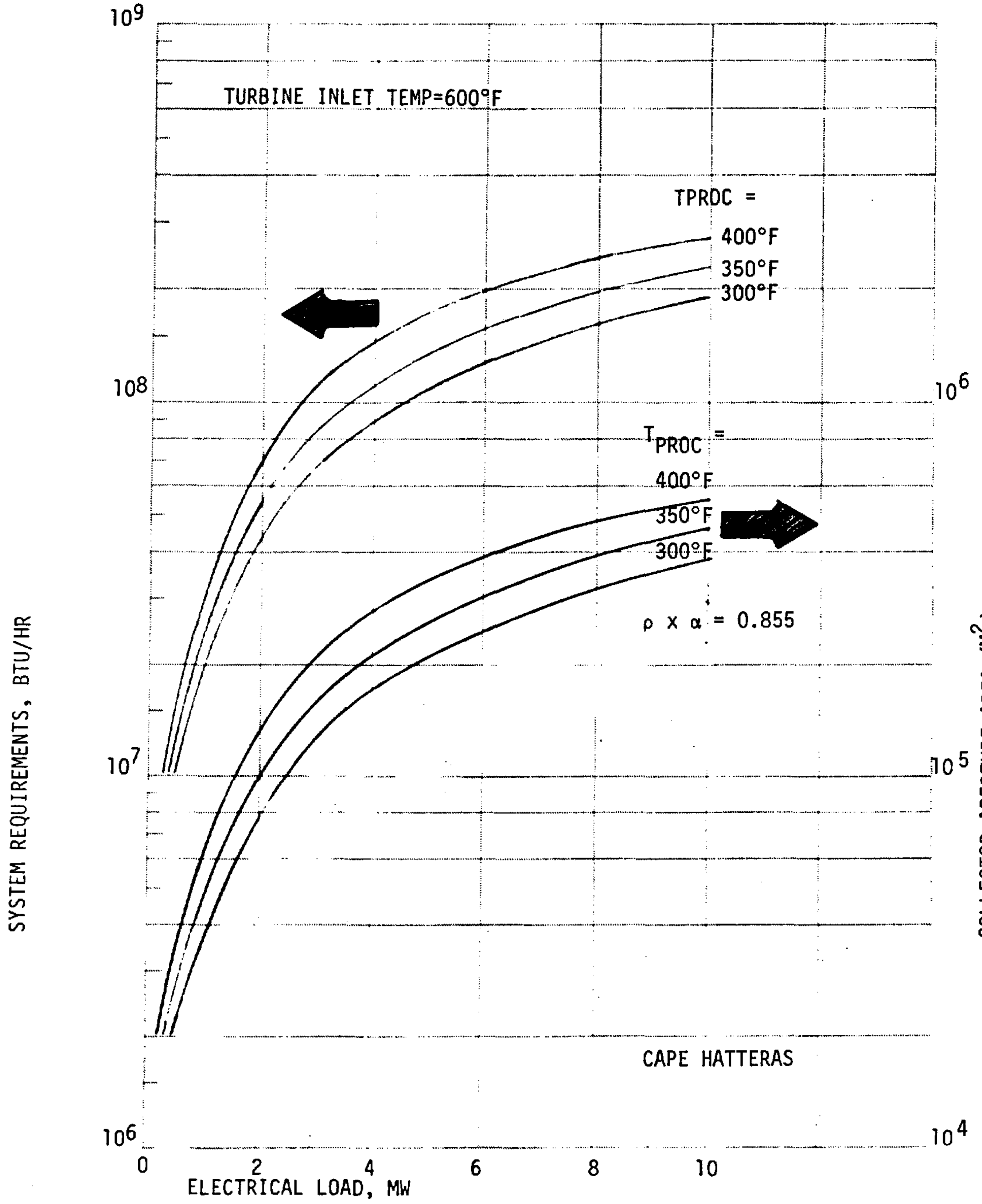


FIGURE - VARIATION OF SYSTEM REQUIREMENTS WITH ELECTRICAL LOAD

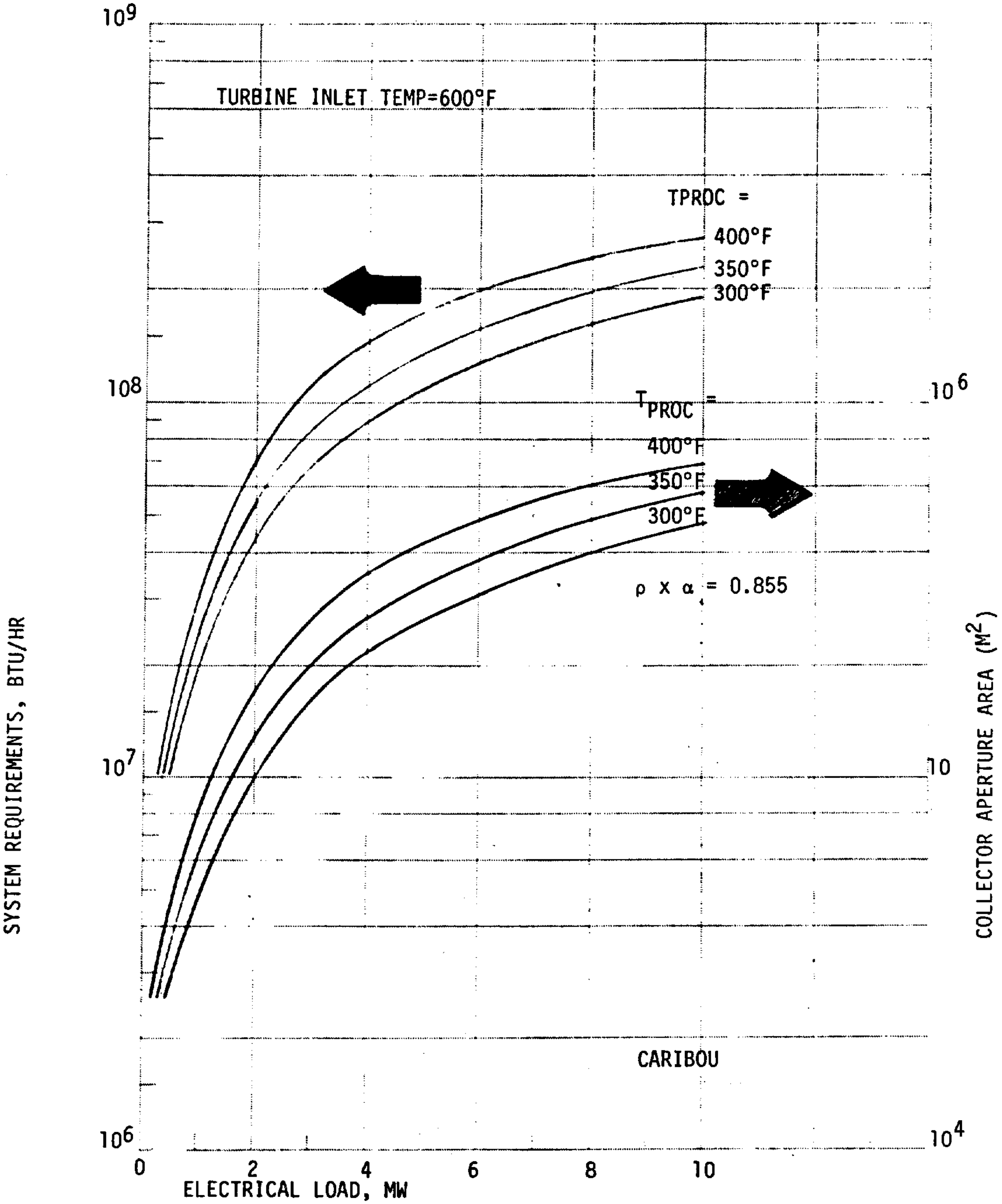


FIGURE - VARIATION OF SYSTEM REQUIREMENTS WITH ELECTRICAL LOAD

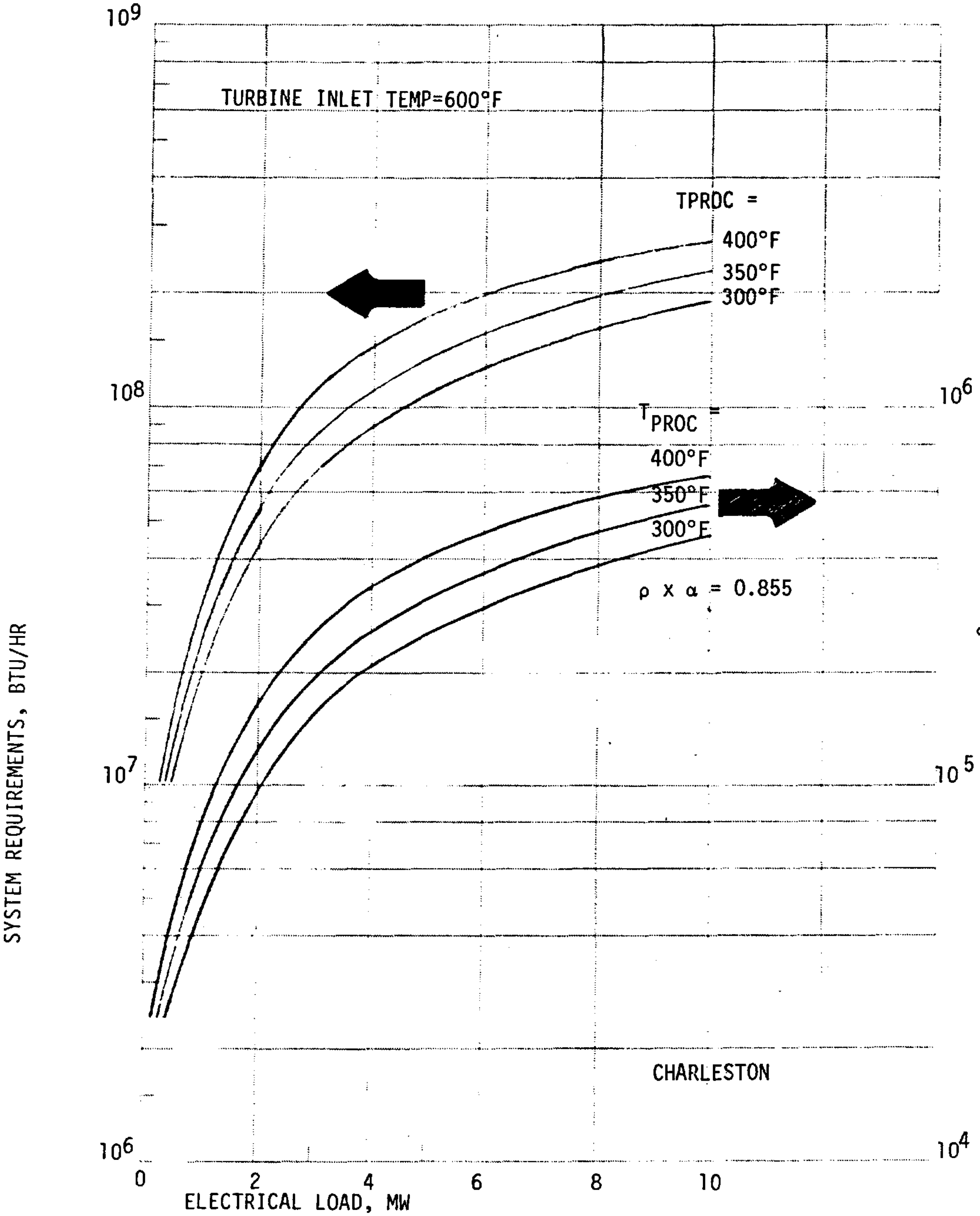


FIGURE - VARIATION OF SYSTEM REQUIREMENTS WITH ELECTRICAL LOAD

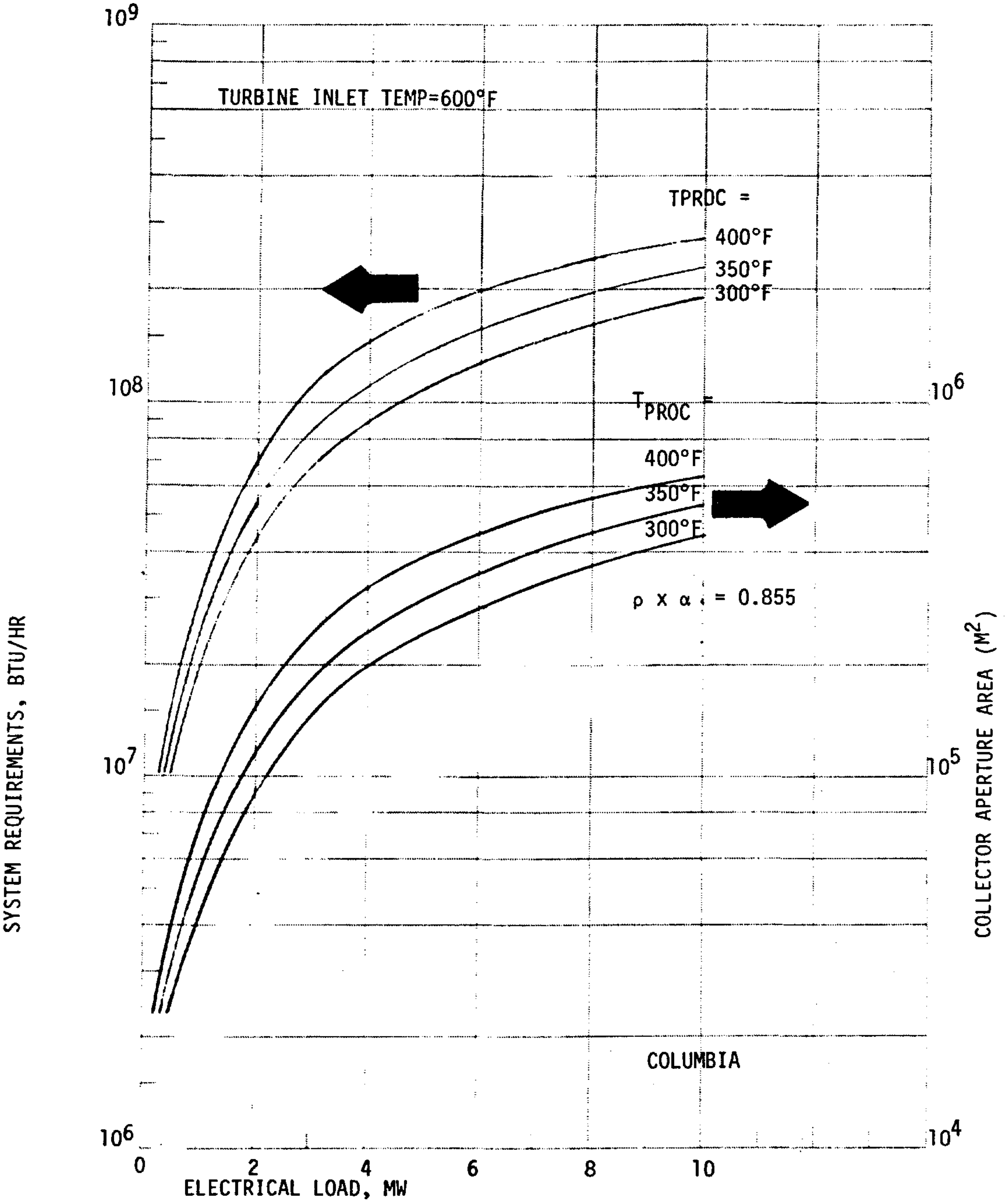
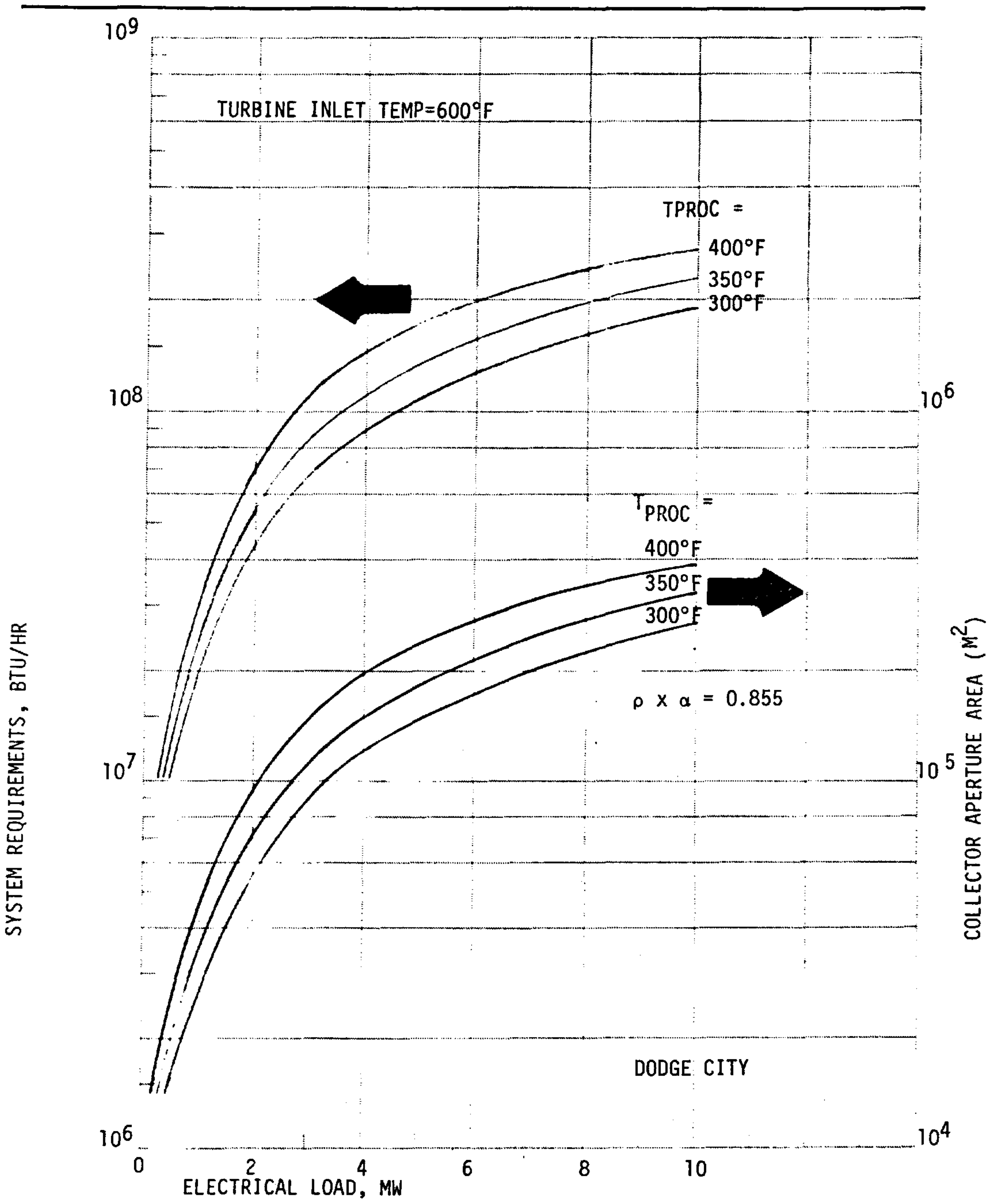


FIGURE - VARIATION OF SYSTEM REQUIREMENTS WITH ELECTRICAL LOAD



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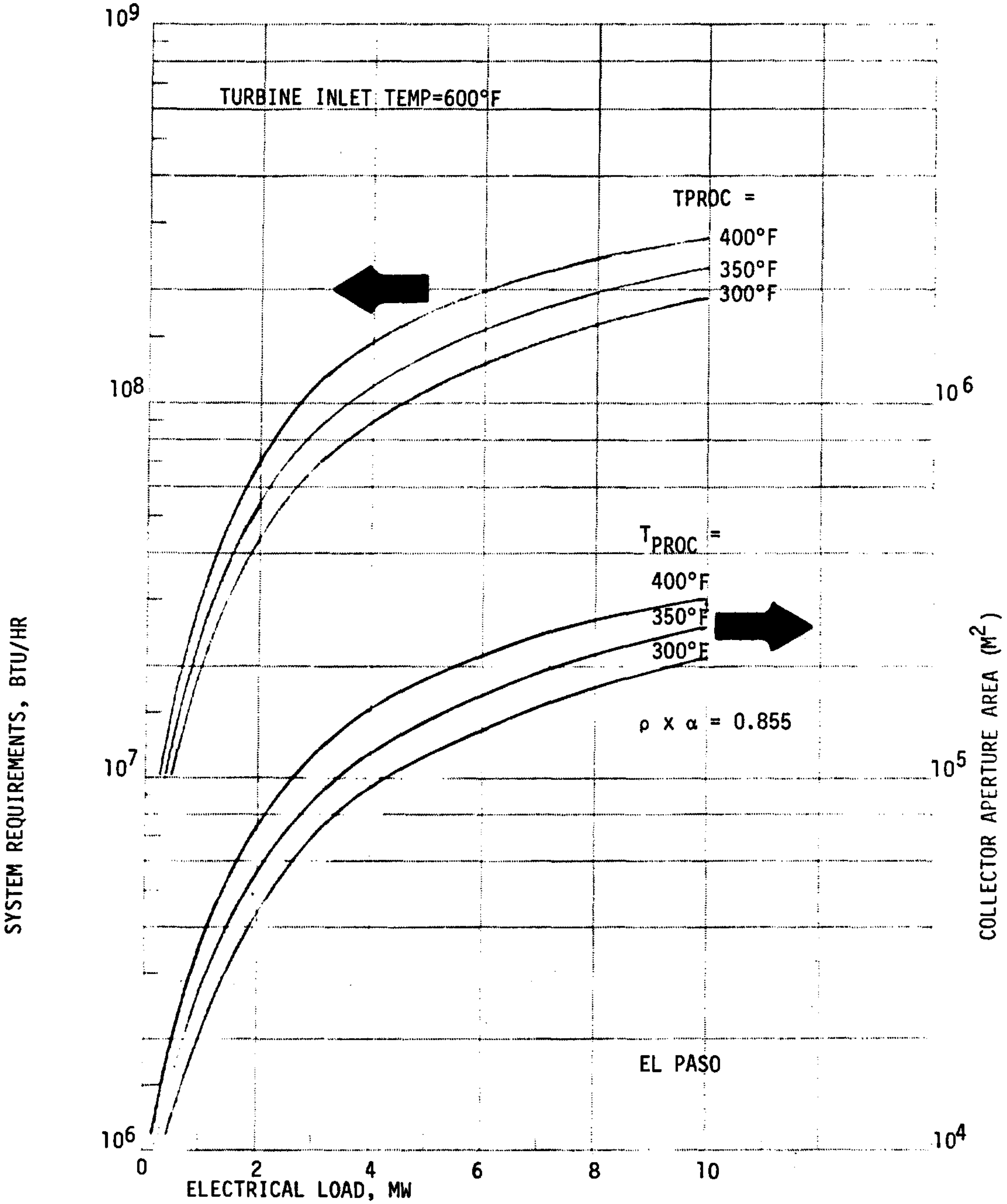

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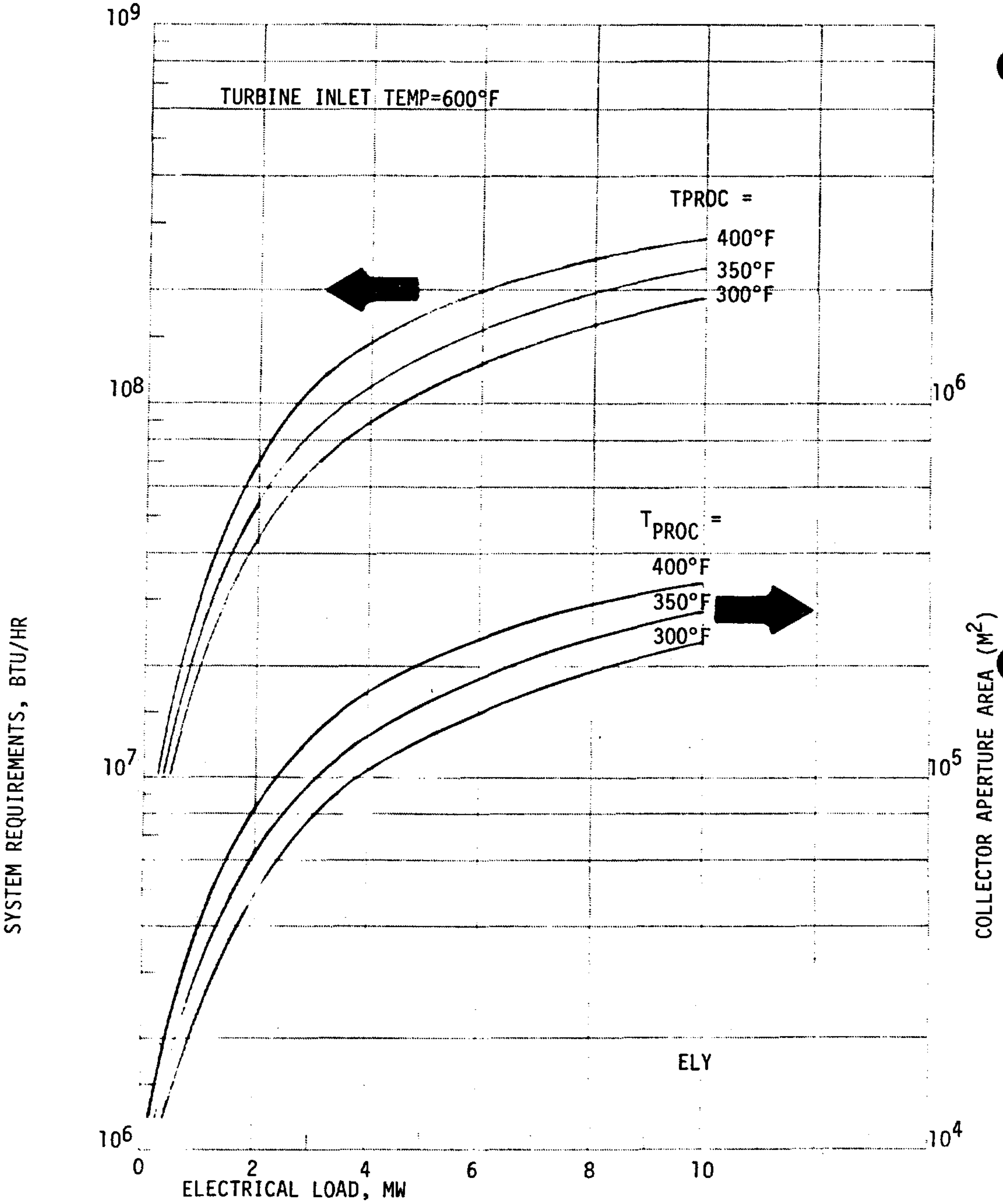

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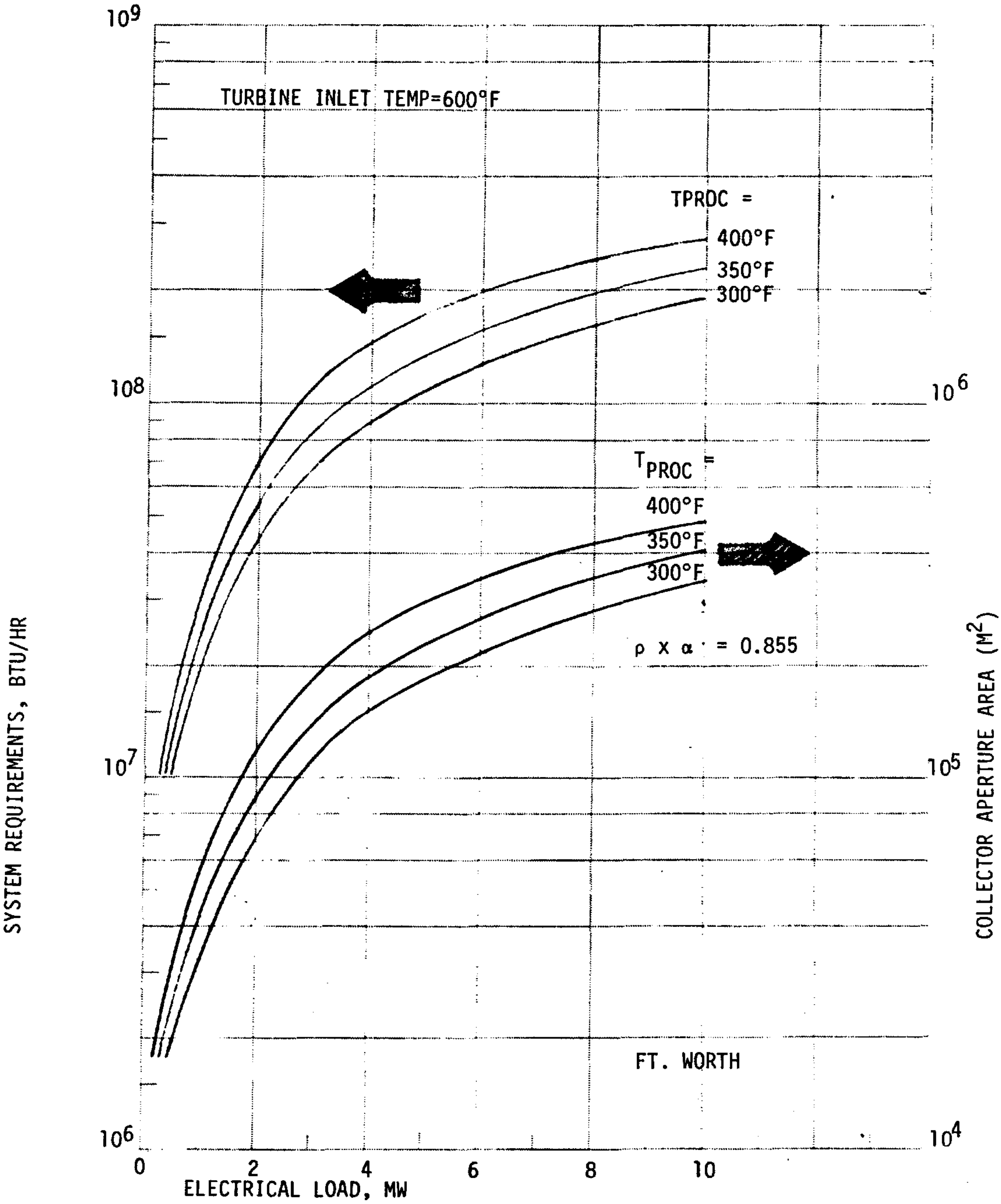

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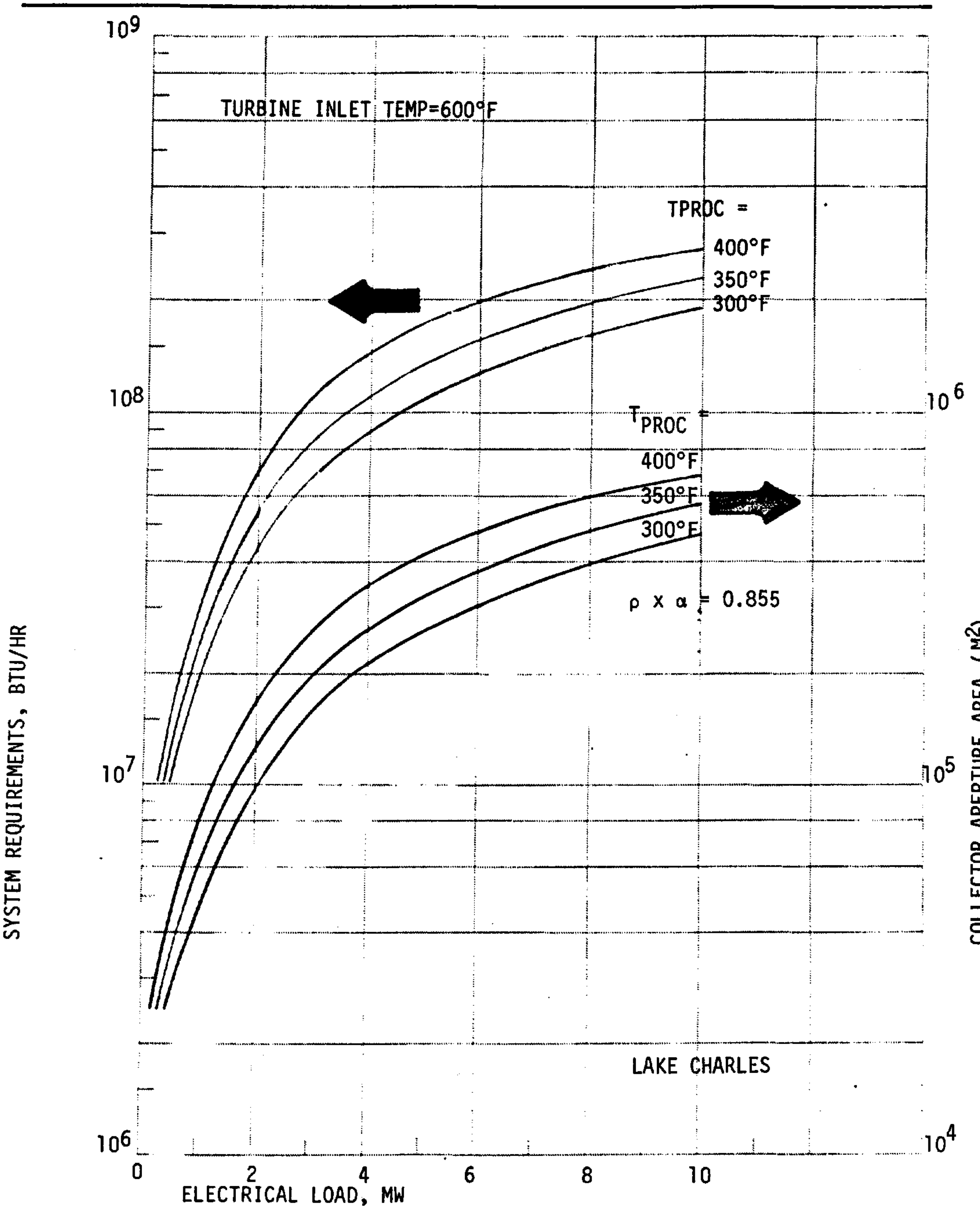

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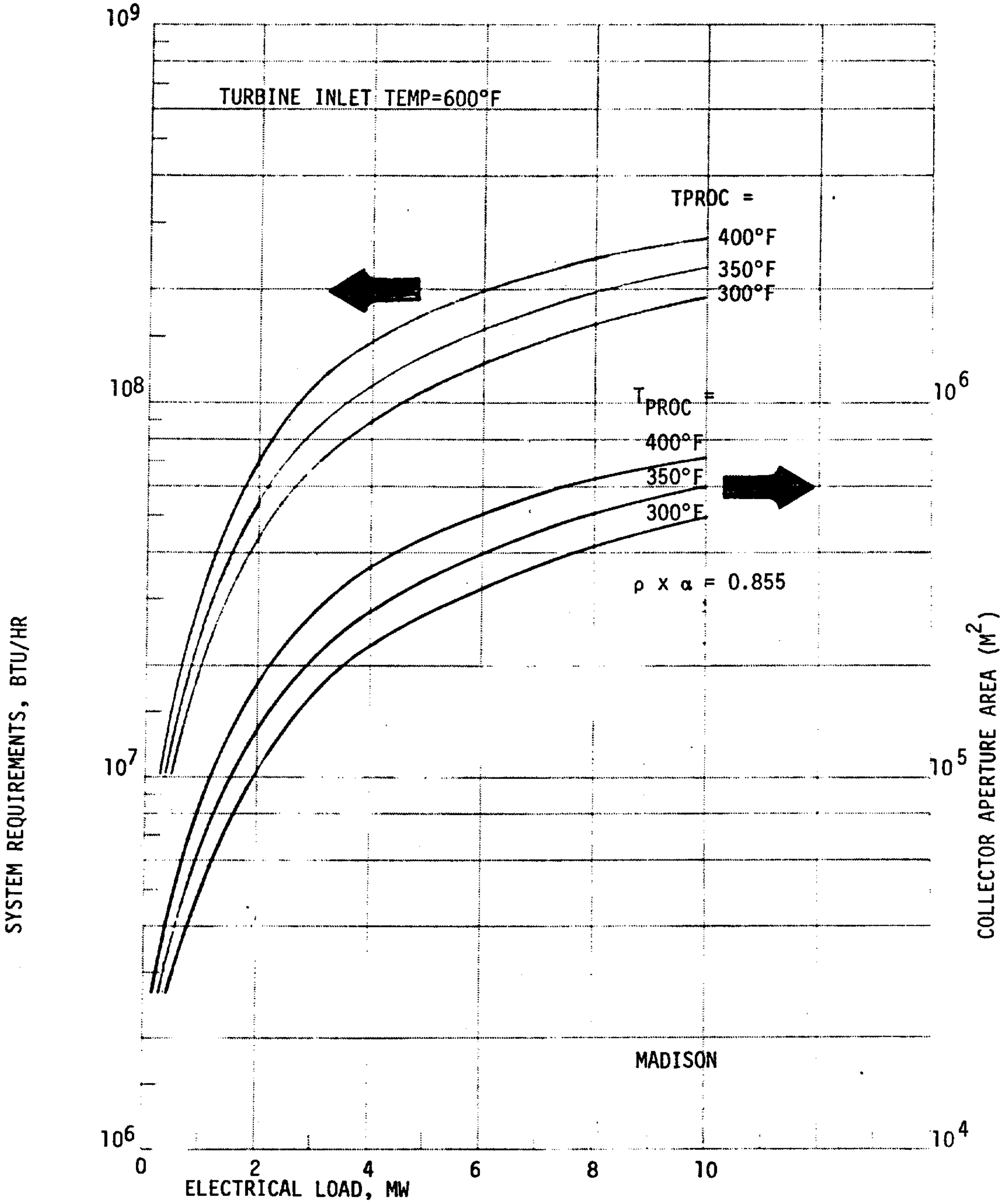

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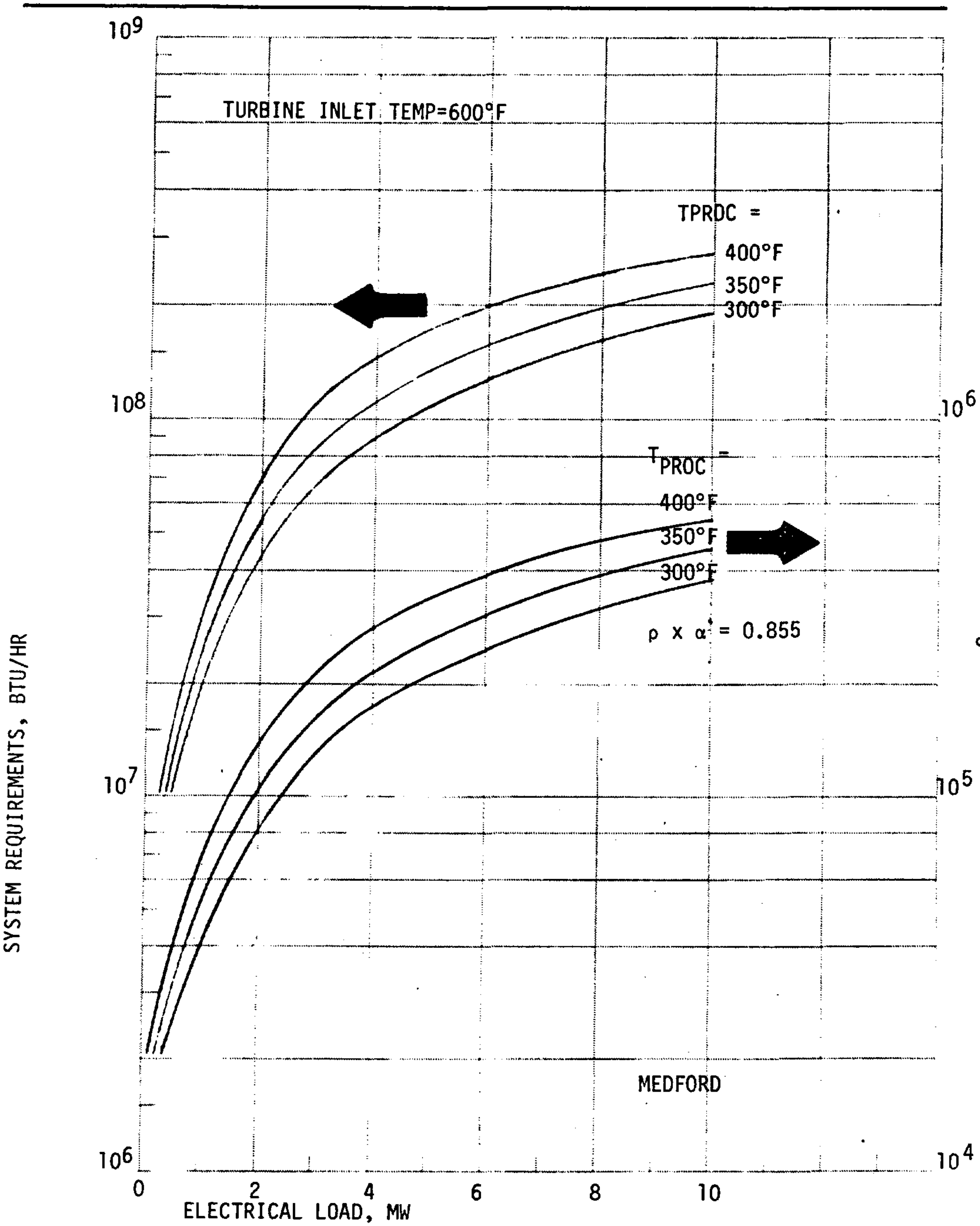

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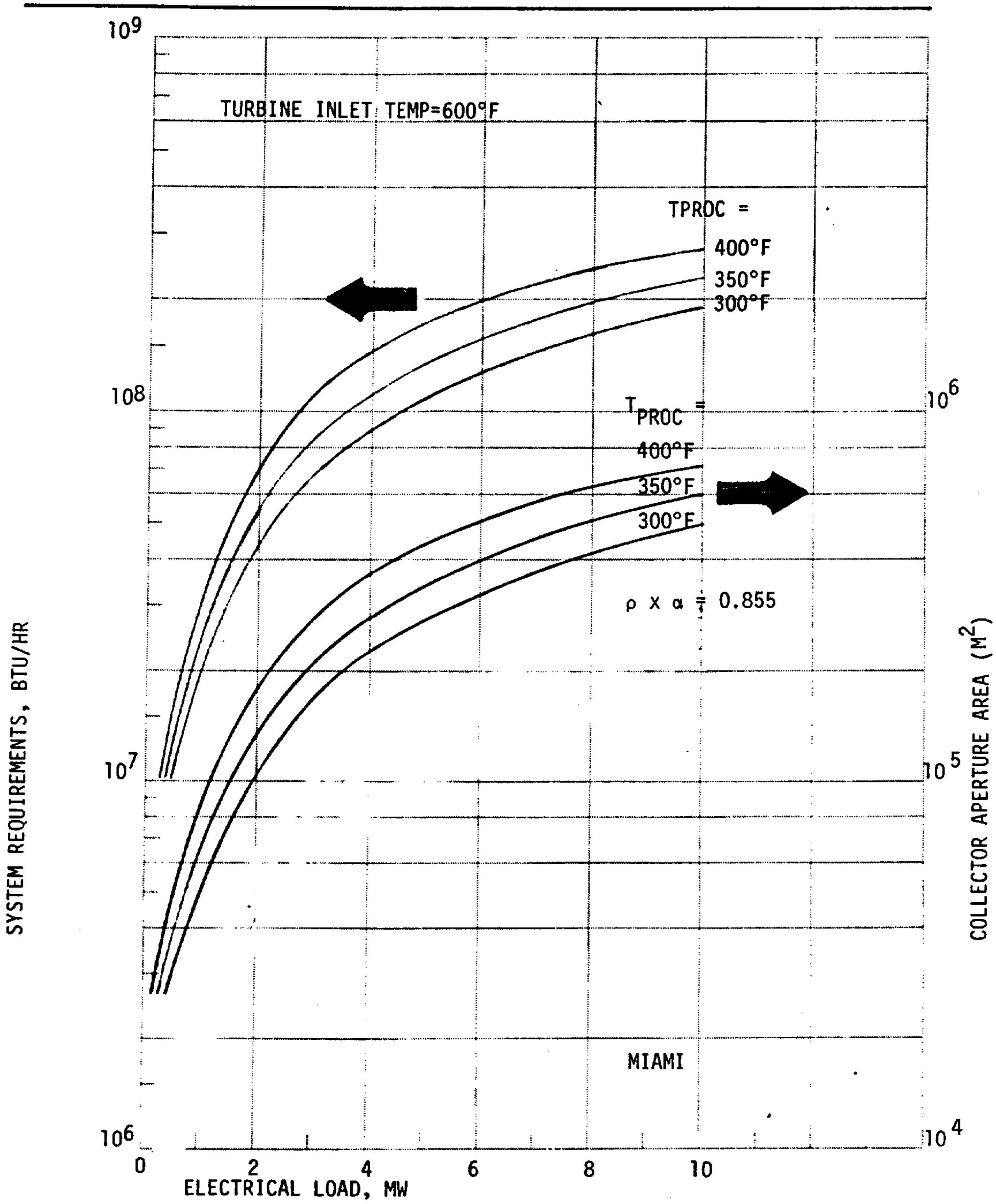

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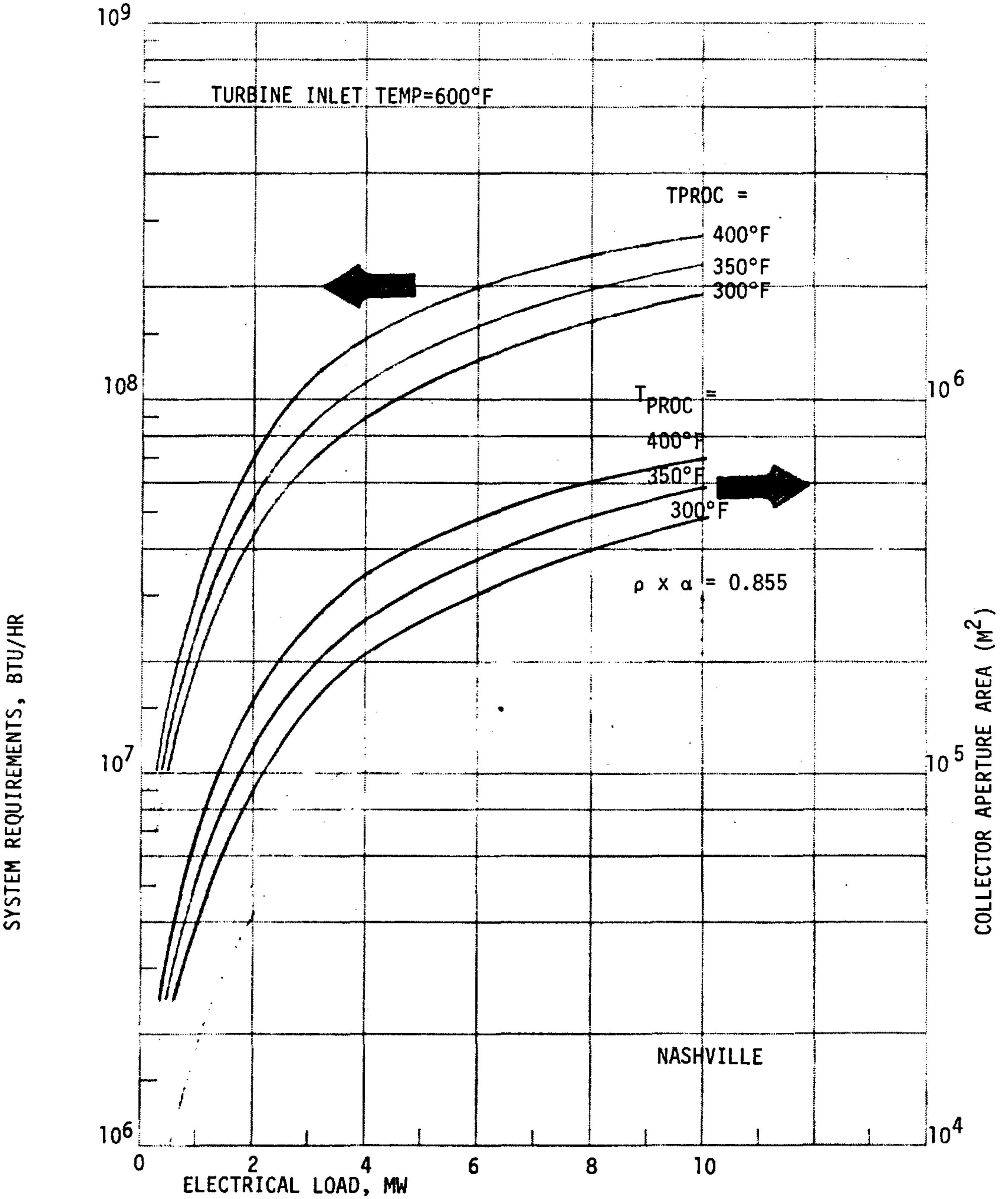

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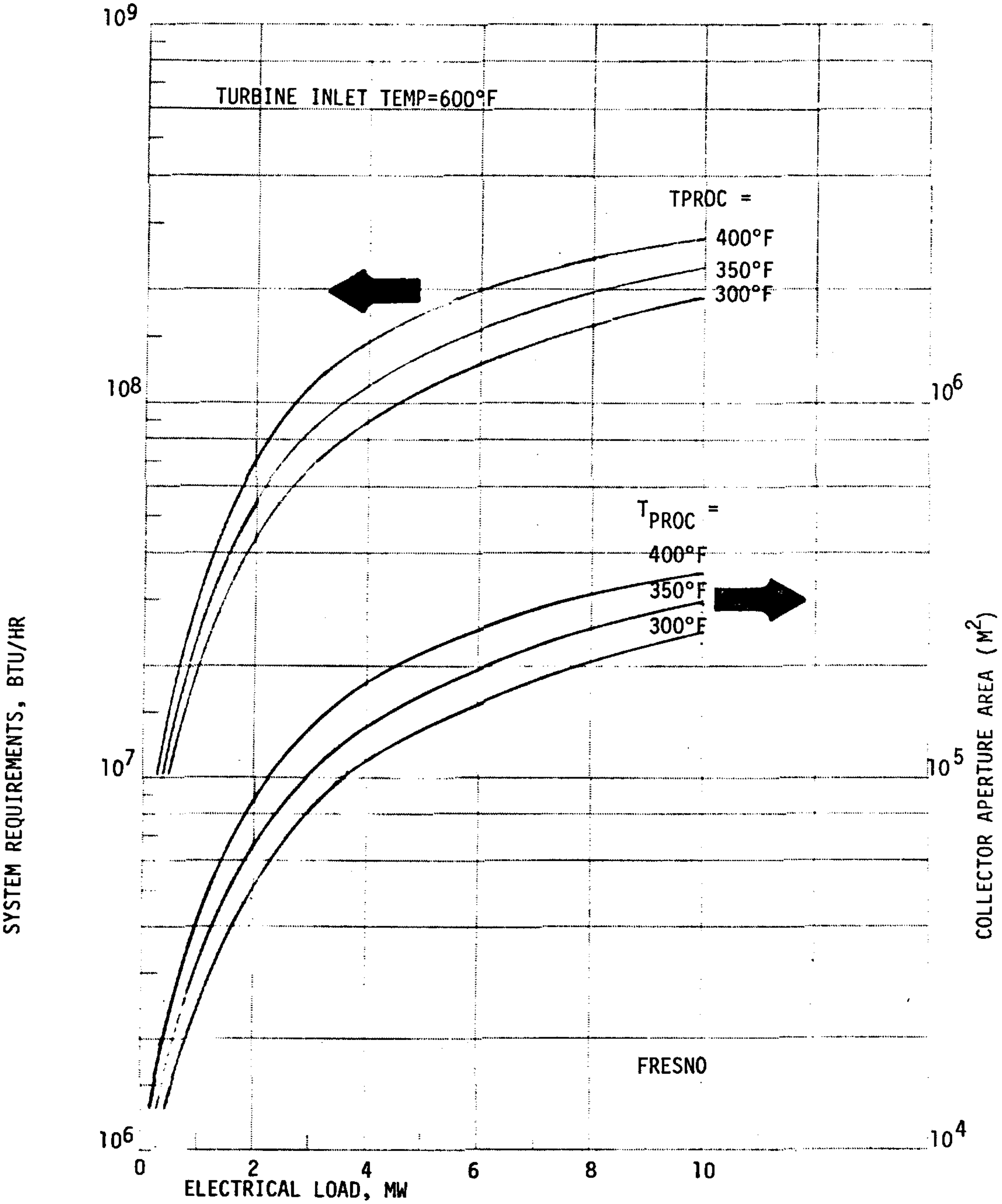

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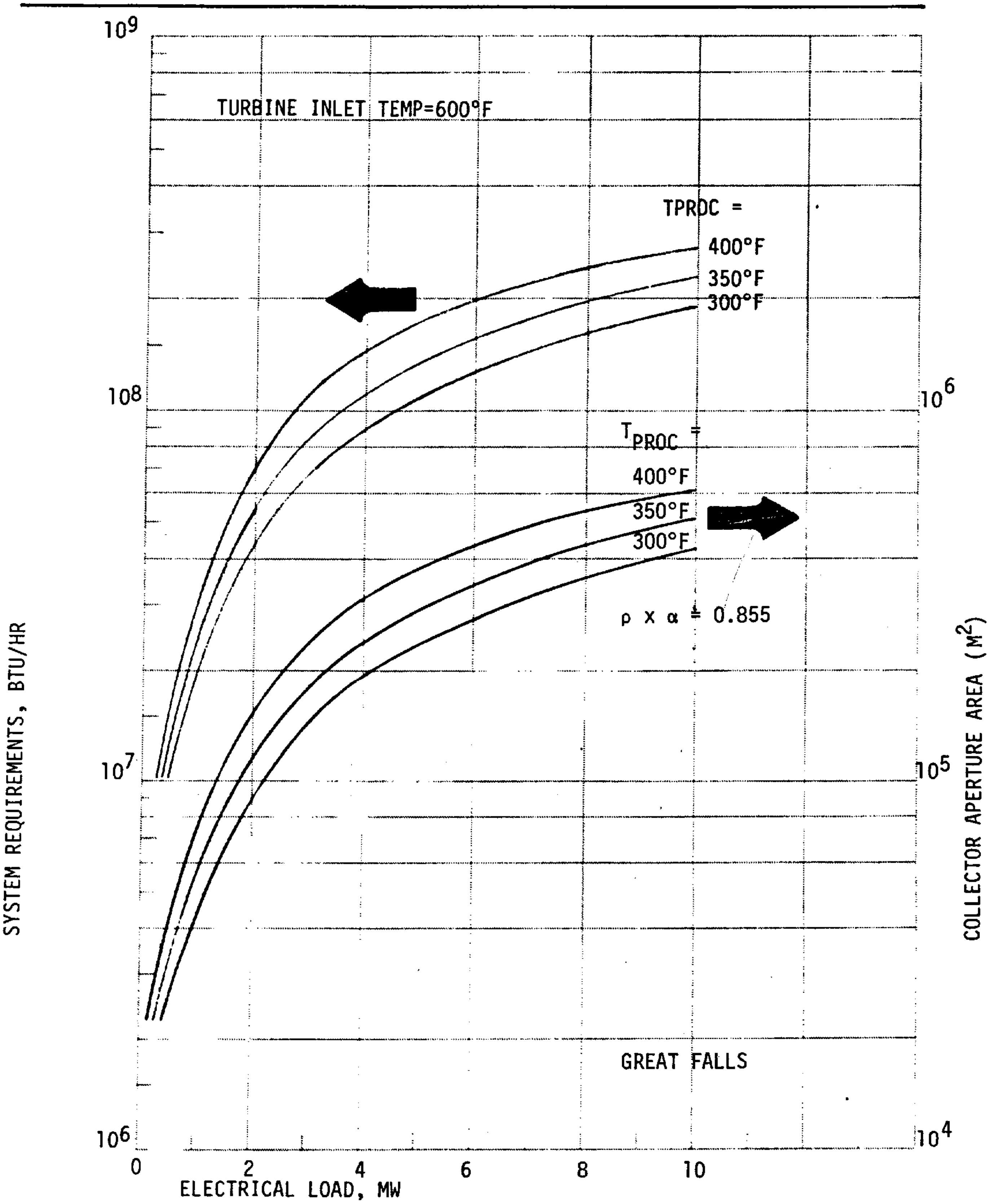

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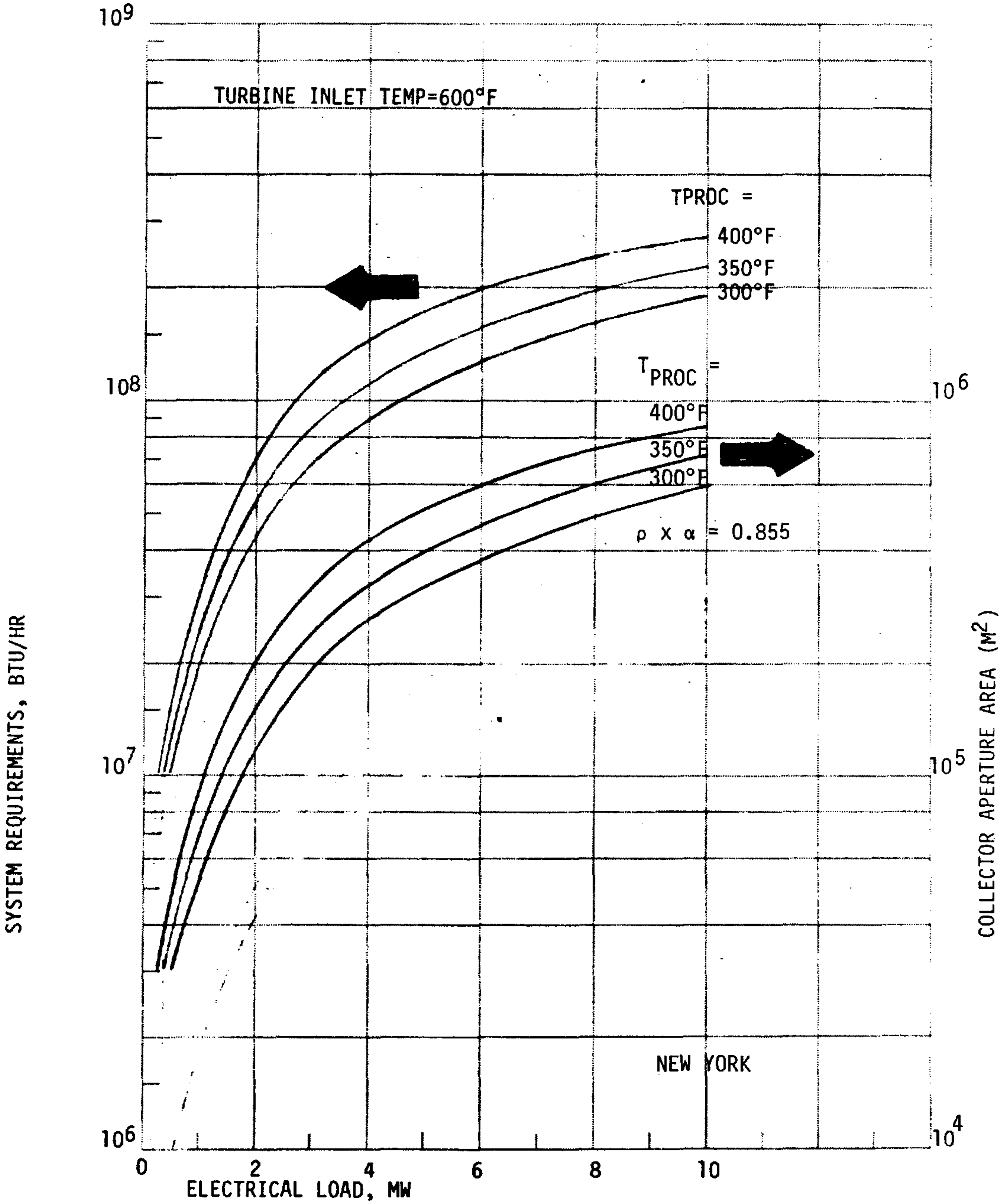

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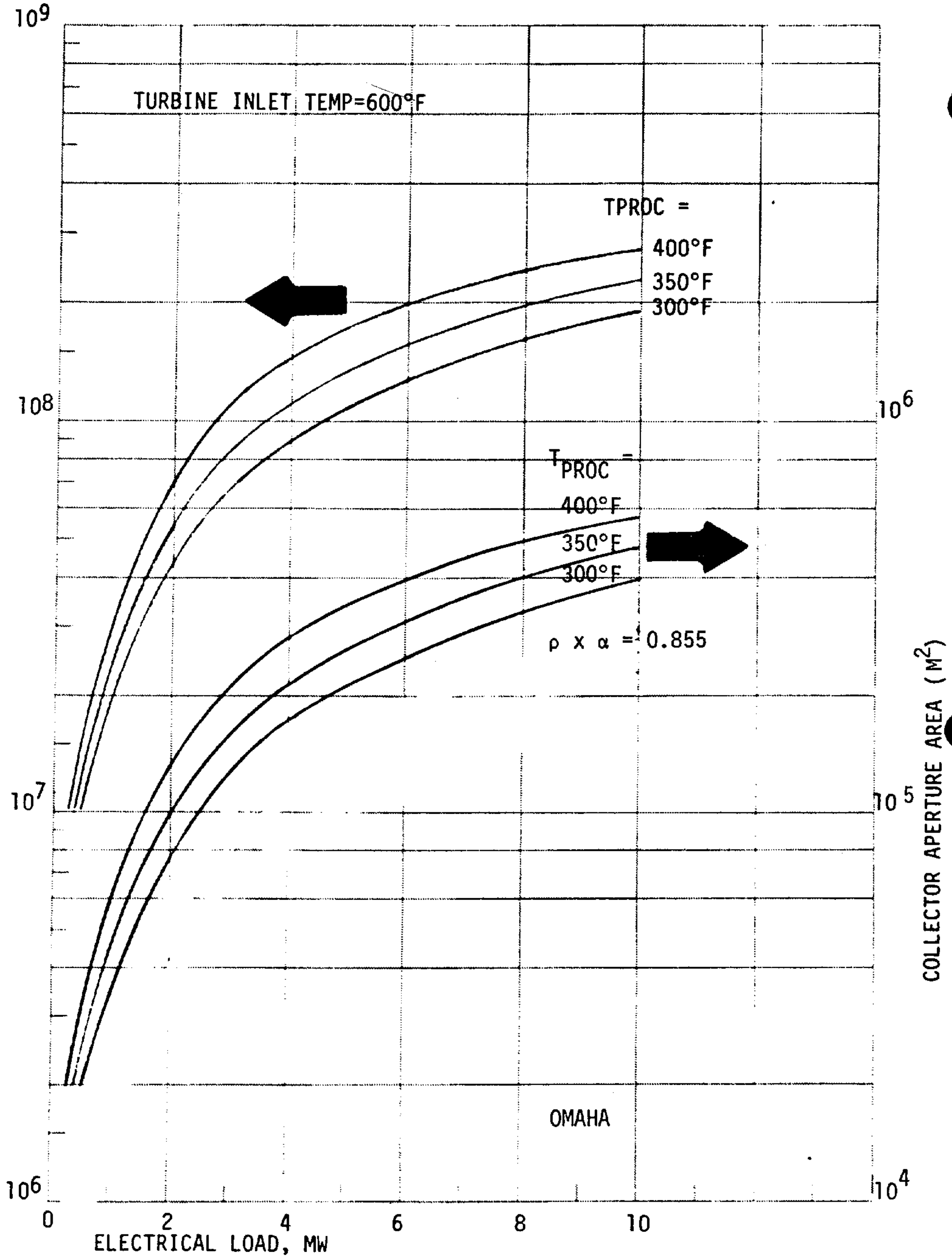

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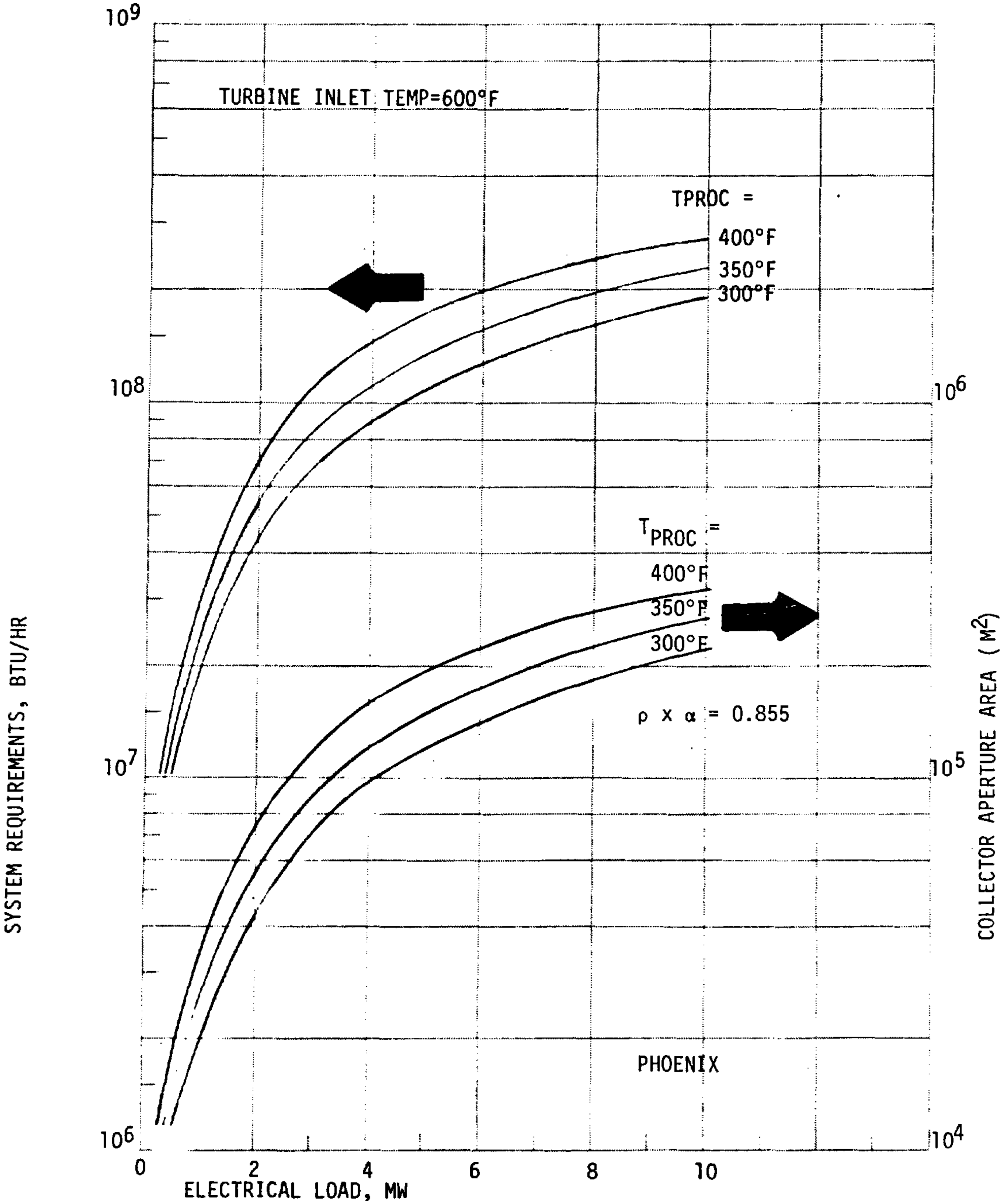

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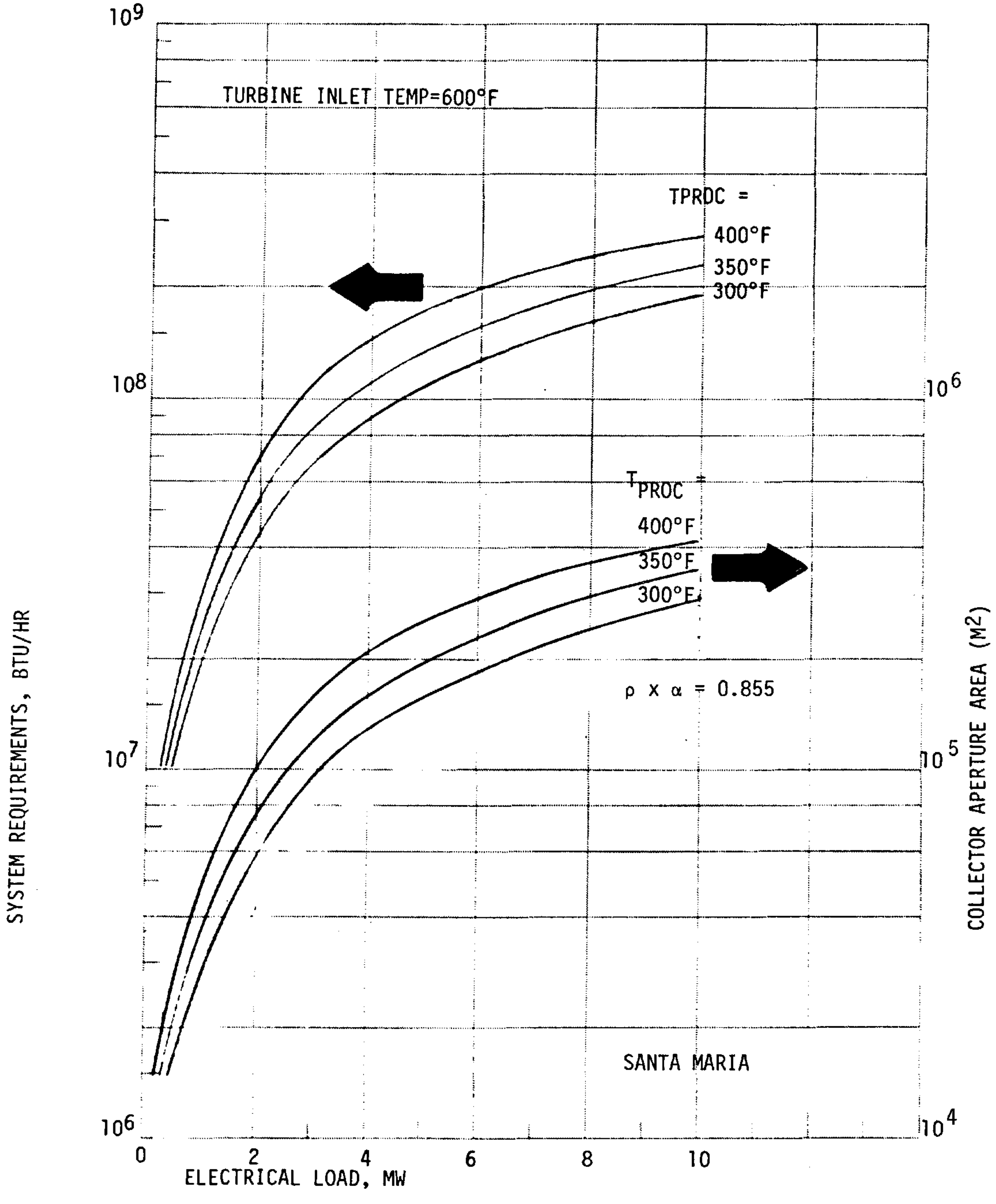

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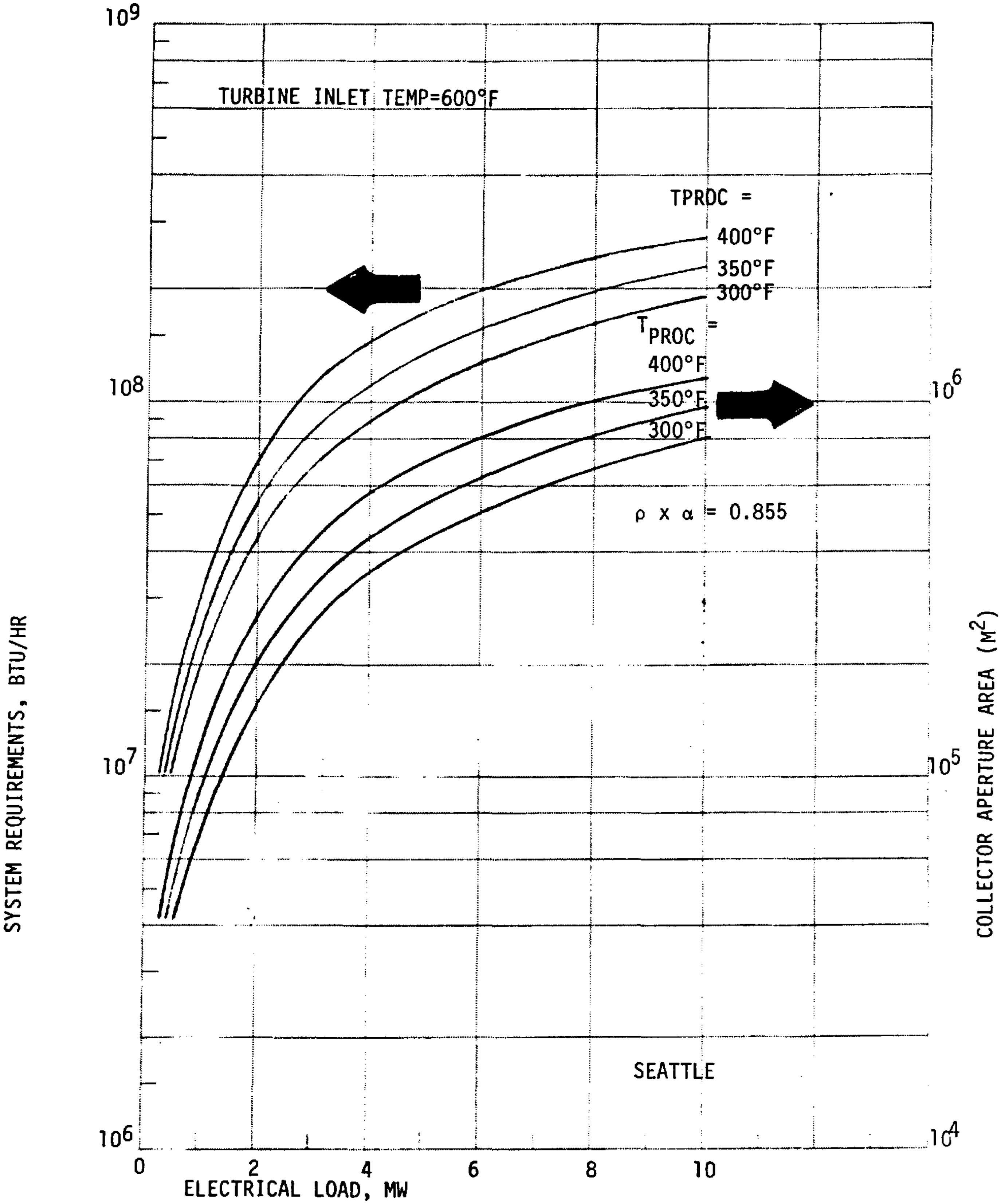

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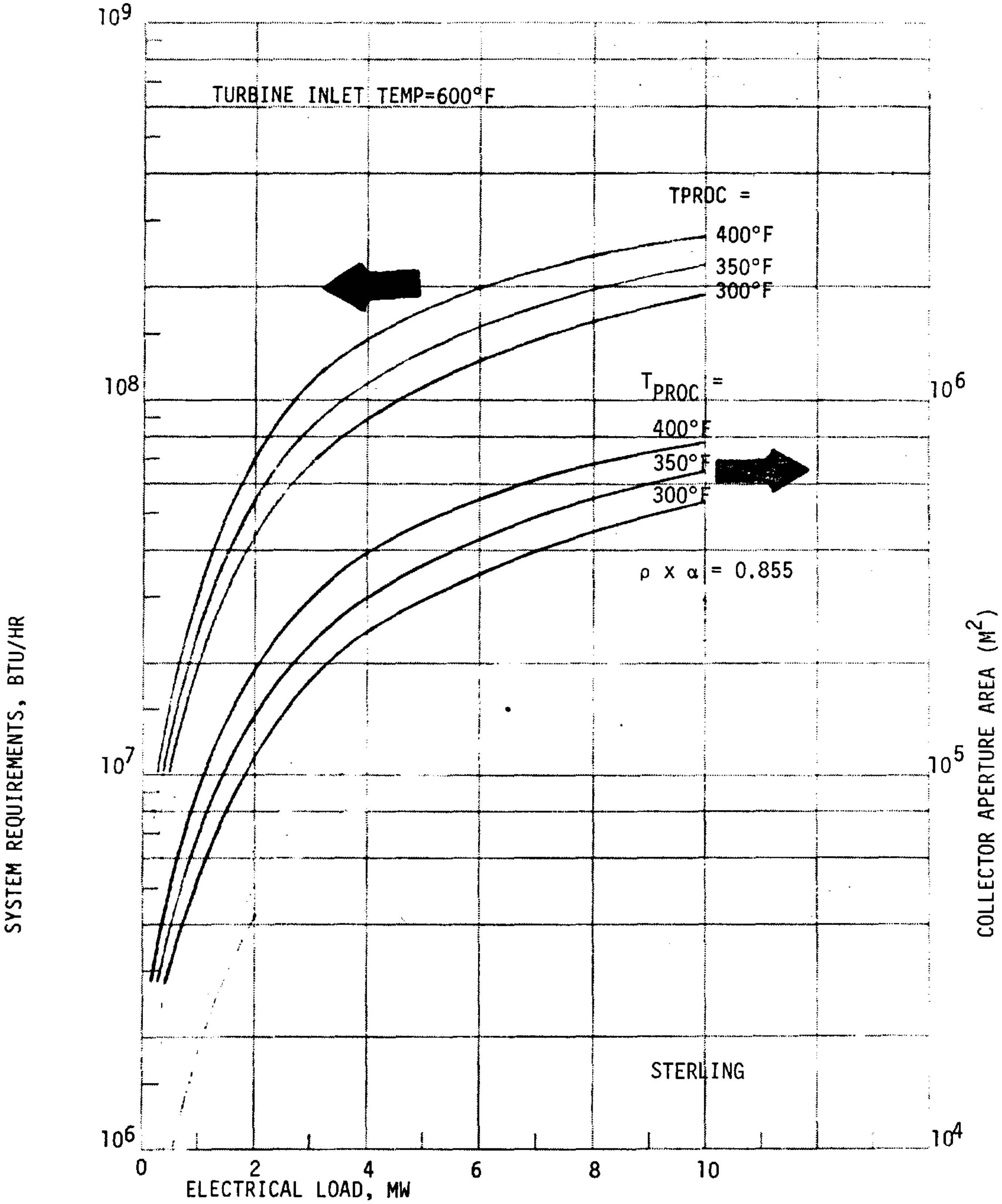

FIGURE - VARIATION OF SYSTEM REQUIREMENTS WITH ELECTRICAL LOAD

APPENDIX D

INDUSTRIAL SURVEY SUMMARIES

LAURA SCUDDER'S
Snack Foods Division, PET Incorporated
Anaheim, California

Mr. Richard Almada
Manager of Engineering
Anaheim, California

GENERAL

Laura Scudder's produces snack foods such as potato chips, corn chips and other fried vegetable-based snack foods at their Anaheim facility. Our contact at the facility was the plant engineer, Mr. Richard Almada.

ENERGY USE

Current energy use includes a natural gas fired boiler producing approximately 3400 pounds/Hr of 100 psig steam and large (compared to the boiler use) amounts of natural gas to heat process cooking oil. The oil is heated directly at each cooker as opposed to batch heating in a central oil heater. No information has been obtained as to electrical use. However, assumed usage includes air conditioning of the plant, process conveyors and plant lighting, automatic packaging machines, and food mixers. The steam usage is for cleaning and sterilizing the food handling and cooking equipment.

Electricity is assumed to be purchased from the city of Anaheim power company with natural gas purchased from Southern California Gas Company.

FINANCIAL

The only financial criteria discussed was payback period. They said their normal requirement on capital investment was less than 5 years and generally 3 to 4 years. However, the actual decision criteria would be made using the more rigorous approach of discounted cash flow internal rate of return although they were hesitant to discuss details.

SOLAR OPPORTUNITY

Insulation at the facility location in Anaheim can be considered good but not excellent. They have typical southern California coastal weather with early morning and late afternoon cloud cover with smog, hazy sunshine during the day. The plant is situated in urban industrial/commercial area on approximately 13 acres. About 50% of that could be used for collector installation plus about one acre of roof on their two-story building. Any involvement by PET Foods in solar projects at this time was unknown to Mr. Almada.

ARMOUR FOOD COMPANY
Dixon, California
Division of Greyhound Corporation

Mr. Ken Ries
Manager, Energy Programs
Greyhound Corporation
Phoenix, Arizona

Mr. A. J. Bernhardt
Plant Manager

Mr. Les Oesterreich
Operations Manager

Armour Food Company
Dixon, California

GENERAL

Armour Food Company, a division of the Greyhound Corporation, is one of the country's largest meat packing concerns. We initially spoke to Mr. K. M. Ries, Manager of Energy Programs at Greyhound corporate headquarters in Phoenix. It was through him that the plant specific energy and economic information was obtained. We later visited a slaughter house owned by Armour in Dixon, California. The Dixon plant is engaged primarily in lamb slaughter and packing. They also process a lessor amount of beef. About 10% of the nation's lamb slaughtering is done in the Dixon plant.

ENERGY USE

The peak electrical demand for the Dixon plant is approximately 550 KWe. About one-third of the electrical demand is for powering vapor compression refrigeration 24 hours a day. The rest is used during the one-shift, five-day/week plant operation to provide power for the conveyor system in the plant and driving a high pressure air supply used to drive pneumatic knives. This plant generates 5,000 lbs per hour of steam which is used primarily for plant cleanup during the last half of the first shift and for the duration of the second shift. In addition the steam is used for knife sterilization during the slaughtering operation.

All of the electricity is purchased from a local utility while the steam is generated on site using natural gas with number 2 deisel as backup. The overall thermal-to-electric ratio is approximately 2.6 to 3.0. The steam is generated at 330^{o}F and utilized as 180^{o}F hot water in the clean up operation.

FINANCIAL

Financial criteria has been discussed only in general terms at this time. However, we hope to obtain more definitive information from them in the near future. In general they would like a sooner pay back than is typical of solar installations.

SOLAR OPPORTUNITY

Greyhound has had some activity in solar. They have responded to at least four P.O.N.'s from DOE in the past as industrial partners in solar studies. They have also participated in fossil total energy system studies and are actively engaged in energy conservation activities for their facilities. The Dixon plant is located in a good insulation area and is situated on approximately 50 acres of land, close to half of which could be available for collectors. The majority of the buildings at the site are not structurally suitable for collector installation. The thermal-to-electrical ratio is marginally favorable for total energy as currently used. However, switching some of this electric power refrigeration to absorbtion chilling would greatly improve the ratio. Economics would be the driving criteria for solar utilization as opposed to technological considerations.

COTTONSEED OIL MILL
TEXAS

Manager, Corporate Energy Control
Plant Engineer
Plant Operations Manager

GENERAL

This company, which preferred to remain anonymous, is a large producer of cottonseed and other vegetable oils. The particular facility visited produces cottonseed oil.

ENERGY USE

The peak electrical demand at this plant is 4.0MWe. The majority of the electrical power is used to power machinery used to prepare the cottonseed, obtained from local cotton gins, for the oil extraction process. This involves, in older plants like this one, first delinting the seed and then hulling the seed. In newer plants the delinting is eliminated, thereby reducing the electrical demand by a considerable amount. The plant generates on the order of 18,000 LB/Hr of 150 psig saturated steam which is used in the oil extraction process. The seed is essentially pressure cooked with the steam to remove the oil.

Electricity is purchased from a local utility. Natural gas to fire the boilers is purchased from a local gas company on a long term, but interruptable, contract which includes allowances for price escalation.

FINANCIAL

Their current requirement on capitol investment is a minimum of 20% return on investment which equates approximately to a 5-year payback for a 15-year project life. The company attitude regarding solar is that "With the present state-of-the-art, the use of solar energy in industry is a few years off."... and that they "should follow developments closely but unless a solar project can be subsidized, this energy will have very little impact on our energy program."

SOLAR OPPORTUNITY

The company is very energy conscious and recently completed a very detailed energy audit of this facility. They have performed a detailed analysis of cogeneration (fossil fueled) at this facility. Their conclusion was that a natural-gas-fueled total energy system was economically viable. However, because of uncertainties in natural gas supplies either because of a shortage or because of political dictates to alternate fuels, they are extremely hesitant to invest in a total energy system. They are enthusiastic about the possibility of a solar powered total energy system and have somewhat mellowed their pessimistic view of solar economics based on data we have provided them.

The thermal to electric power ratio at this facility is low (1.3 to 2.0) and would not lend itself to an optimum total energy system. However, modification of the process to the more modern (no delint) process would improve the ratio by reducing the electrical demand. They have no plans to do this at this time, but they do have other newer facilities which have more favorable (higher) ratios. Out of 170 acres approximately 60 acres is available for collectors. There is a large parcel of agricultural land to the south of the plant (at least two sections.) Recent land sales in the area for land of this type was for about $10,000/acre. The insolation in this area is judged to be reasonably high; however, they are subject to frequent dust and occasional severe hail storms.

Armour Food Company
Hereford, Texas
Division of Greyhound Corporation

Mr. Ken Ries
Manager, Energy Programs
Greyhound Corporation
Phoenix, Arizona

Mr. C. R. Taylor
Plant Operations Manager
Armour Food Company
Hereford, Texas

GENERAL

Armour Food Company, a division of the Greyhound corporation, is one of the country's largest meat packing concerns. We initially spoke to Mr. Ken Ries, Manager of Energy Programs at Greyhound Corporate headquarters in Phoenix. Plant specific energy and economic data were obtained from Mr. Ries. A subsequent visit to the Hereford, Texas, facility was made to obtain more detailed information about the plant and to assess the site in terms of solar adaptability. The Hereford plant is the largest beef slaughtering facility in the U.S. in terms of total beef processed. Their operation is exclusively beef, as opposed to the Dixon plant, which slaughters both lambs and beef. Another major difference in the Hereford operation as opposed to Dixon is the operation of on-site rendering of animal fat at Hereford which increases the plant's steam requirements as steam cookers are used in the rendering process.

ENERGY USE

The peak electrical demand at the Hereford plant is 2.3 MWe. The electricity is used primarily to provide power for the various conveyor systems used throughout the plant along with plant lights and environmental air circulation. Electrical power is also used to generate high pressure air for pneumatic knives. Also included in the peak is power to drive a 100-ton backup refrigeration unit. Primary refrigeration is provided by four natural gas spark ignition engines providing compressor power for 1000 tons of refrigeration. Thirty seven thousand pounds per hour of steam is generated on site with natural-gas-fired boilers at 150 psig (358°F saturated). The bulk of the steam is used for cooking energy in the rendering process with the remainder used for clean-up and cutting equipment sterilization. All of the electricity is purchased from a local utility while the steam is generated on site with natural gas with number 2 deisel as backup. The over all thermal (steam only) to electric ratio is approximately 4.5 to 5.

FINANCIAL

Financial criteria has been discussed only in general terms at this time. However, we hope to obtain more definitive information from them in the near future. In general they would like a sooner payback than is typical of solar installations.

SOLAR OPPORTUNITY

Greyhound has had some activity in solar. They have responded to at least four P.O.N.'s from DOE in the past as industrial partners in solar studies. They have also participated in fossil total energy system studies and are actively engaged in energy conservation activities for their facilities. Their Hereford plant is located in a good insulation area and is situated on approximately 400 acres of land, over half of which could be available for collectors. The majority of the buildings at the site are not structurally suitable or large enough for collector installation. The thermal-to-electrical ratio is favorable for total energy as currently used. There is also the potential for additional large displacement of natural gas by converting the gas-fueled engines used for driving refrigeration compressors with solar electronic vapor compression or waste heat fired absorption chillers. A prudent selection of a mix of these replacement systems could be made so as not to adversely affect the current total energy-favorable thermal to electric power ratio.

VEGETABLE OIL PROCESSOR

CALIFORNIA

Division Energy Manager
Plant Manager
Maintenance Foreman

GENERAL

This Company, which preferred to remain anonymous , is a large producer and processor of edible oils. The particular facility visited processes oils into shortening, cooking oils, margarine, salad dressings and process cheeses.

ENERGY USE

The peak electrical demand at this plant is approximately 1.4 MWe. This occurs during most of the first shift (8-5) which is when product packaging is accomplished. This demand drops to around 0.6 MWe for the remainder of the day and throughout the weekend. This provides the necessary power to run the processes which are on an around the clock duty cycle. The majority of this non-peak process demand is for vapor cycle process cooling. The plant generates an average of 12,000 lb/hr of saturate steam. The steam is generated at 220 psia. However, only a small portion of the process requires steam at that pressure and the bulk of the steam is used at 150 psia and below.

Electricity and natural gas are purchased from a local utility. They have recently gone to time of day billing for electricity and have been advised that their gas charges are increasing by 60% as of the first of the year (January 1980).

FINANCIAL

Their current requirement on capital investment is a minimum of 20% return on investment which equates approximately to a five year payback for a 15 year project life. With their recent dramatic increase in energy costs they are more closely following the development of alternate energy sources and appear willing to relax these requirements if they are convinced of the technological as well as the economical viability of the project even at a reduced return or more lengthly payback periods.

SOLAR OPPORTUNITY

This facility's parent company is very energy conscious and recently completed detailed energy audits of several facilities and is in the process of an audit of this facility. Several of their facilities have been analyzed with respect to converting to fossil fired cogeneration. They are enthusiastic about the possibility of a solar powered total energy system and appear willing to relax their current economic criteria to assure a better energy supply picture and reduce operating expense.

The thermal to electric ratio at this facility is approximately 2.5 at peak and would be marginal for total energy. However, shifting a portion of the electrical vapor compression demand to absorption cooling would improve the ratio. They own approximately 20 acres of land, the bulk of which is leased to a farmer, adjacent to the facility which could be used for collectors. Insolation in the area of the plant is judged to be reasonably high. However, the amount available during the winter season is only about 1/3 that available during the summer season.

SEAFOOD PROCESSOR AND CANNERY

CALIFORNIA

Plant Engineer
Plant Engineering Staff Member
Marketing Manager Advance Products

GENERAL

This Company, which is a subsidiary of a major U.S. Food Company, is engaged in the processing and canning of seafood and seafood by products. This company has several plants located worldwide. The particular facility visted is located on the West Coast of the U.S.

ENERGY USE

The facility visited operates two plants at this location. The energy demand although separated for accounting purposes was considered in total for the facility. The electrical demand is approximately 6 MWe. A large portion of this demand is used to provide rerigeration for cold storage. The average steam flow is approximately 106,000 lb/pr with less than 5% condensate return. The steam is produced at 220 psia however, only a small portion is used at that pressure to drive 3 150 hp steam turbines exhausting at 10 psia. The bulk of the steam is used at 150 to 140 psia for steam cooking. A protion of the steam is used to provide hot water (180°) for cleanup. The peak demand occurs 12 hr/day 6 days/wk.

Electricity is purchased from a local utility. Billing is divided into several accounts some of which are subject to time of day demand charges. The boilers are fired with natural gas purchased from the local gas utility at agricultural rates. The boiler backup fuel is number 2 diesel but at this time accounts for less than 5% of their fuel usage. As with other California users they are facing a substantial rate increase the first of this year (1980).

FINANCIAL

Their current requirement on capital investment is based on providing a 2 to 3 year payback period. However, faced with the realization of dramatically increased utility bills they appear willing to relax this requirement when considering energy conservation or alternate energy systems.

SOLAR OPPORTUNITY

The company is becoming increasingly energy conscious, but appear to have a wait and see attitude towards solar. They appear to be more concerned with energy availability than cost per se, especially in their plants located outside the continental U.S.A., many of which currently operate in co-generation modes. They also expressed an interest in the potential for solar desalinization in these somewhat remote locations.

The thermal to electric ratio at this facility is about 5 during peak demand periods and would lend itself to operating in a total energy mode. Land availability at this particular facility would be a problem as it is located in a highly industrialized area with little vacant land. The demand however is diversified and identifiably separate enough that smaller systms could be designed to handle one or more of these separately identifiable demands with collectors located on roof tops. The availability of insolation in this area is subject to coastal climate limitation of early morning and late afternoon low clouds and fog.

GULF MINERAL RESOURCES COMPANY

Dr. F. E. Kiviat
Gulf Research and Development Corp. (GR&DC)
Pittsburgh, Pa.

General

We have been working with Dr. Kiviat in conjunction with solar applications. He is our contact for all data on the Gulf Mineral Resources Company (GMRC) mining and milling operations at Mt. Taylor near San Mateo, New Mexico.

Gulf Mineral Resources Company, a division of Gulf Oil Corporation, proposes the construction of a uranium mill located 3.5 miles northeast of San Mateo, New Mexico (60 miles west of Albuquerque) at an altitude of 7200 feet above mean sea level. It is scheduled for completion and operation by the end of 1982. The mill site is in a relatively level valley where ample land is available north of the mill for a heliostat field. The mine supplying ore to the mill is three miles south of the mill. The mine has two 3400-foot shafts in place. The mill is designed to process 4200 tons of blended ore per day to yield 25,000 lb/day of U_3O_8 as finished yellow cake product, when operating 24 hours/day.

Energy Use

The mine requires electrical power to pump 6250 gpm of water from the shafts (approximately 6 MWe) and to air condition the mine working environment. The electricity is supplied by redundant sources to assure continuous water removal from the mine.

The uranium milling process will include grinding, leaching, countercurrent decantation,solvent extraction, and yellow cake precipitation and drying. Steam is used at several points in the process to provide hot ore slurry for more efficient chemical reactivity, and to preheat boiler feedwater. The steam requirements range from 51,200 lbs/hr in the summer to 116,900 lbs/hr in the winter. Steam will be generated in two fuel-oil fired water tube boilers at 150 psig, saturated (366 deg F).

Financial

Financial criteria will be released as part of the Solar Retrofit Study currently in progress on the mill.

Solar Opportunity

GR&DC has shown strong interest in the Solar Retrofit Program and has had support from GMRC on the project. The Mt. Taylor installations are in an area of excellent insolation with an annual average of 6.8 kWh/m^2/day. There is ample level land adjacent to the mill site for a collector field in the 40 MWt size, or greater.

This would permit a solar thermal system that would provide all the process steam and a portion of the electrical load for water pumping.

U.S. Borax and Chemical Corp.

Boron, California

Mr. T. Cromwell
Vice President-General Manager
Boron Plant

Mr. Hsueh-Pei Liu
Senior Engineer
Boron Plant

GENERAL

The U.S. Borax and Chemical Corp, a member of the RTZ Group, is one of the largest producers of borax products in the world. Our original contact was with Mr. R. W. Sprague of U.S. Borax Research, who introduced us to the Boron plant personnel and arranged for a visit to the Boron plant. The Boron plant provides over 80% of the free world's borax from a huge open-pit mine.

ENERGY USE

The peak electrical demand for the Boron plant is 21,000 KWe, and the plant uses over 150 million KWHr per year, which is purchased from Southern California Edison. The demand is essentially constant, 24 hours/day, 365 days/year.

Process steam is generated at the plant primarily for use in dissolving the borate product from the mined ore. The plant has seven gas-fired (with diesel oil backup) steam generators, ranging from 60,000 LB/HR to 150,000 LB/HR, which produce steam at 150 psig. The peak steam demand is 466,000 LB/HR with 2.675 billion pounds of steam produced annually. The natural gas is purchased from Pacific Gas and Electric on an interruptible supply basis. Approximately one million gallons of backup diesel fuel are stored at the plant. The steam demand is also essentially constant, 24 hrs/day, 365 days/year. The overall thermal-to-electric ratio is about 6.0 cm annual average and 7.3 at peak.

FINANCIAL

Preliminary financial analyses have indicated excellent potential return on investment for both a pilot solar plant and for a full-scale plant. Additional work is in progress.

SOLAR OPPORTUNITY

The Boron plant is located in the Mojave desert, in one of the sunniest areas in the U.S. (about 40 miles from Barstow, the site of the 10 MWe Solar-1 Plant). U.S. Borax is very interested in Solar Energy and has responded to two previous DOE RFP's. They have also done studies on using coal as an alternate energy source to gas/oil. The Boron plant is located on several square miles of company-owned level land with enough room for the largest required collector field. This plant is an excellent prospect for a large solar energy system.

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