JIM FISH 8452

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SOLAR INDUSTRIAL RETROFIT SYSTEM, NORTH COLES LEVEE NATURAL GAS PROCESSING PLANT, FINAL REPORT

Executive Summary

July 1980

Work Performed Under Contract No. AC03-79SF10736

Northrup, Incorporated
Hutchins, Texas

and

ARCO Oil and Gas Company
Bakersfield, California

U.S. Department of Energy

Solar Energy

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Prepared for the

U. S. DEPARTMENT OF ENERGY

As part of

Contract No. DE-AC03-79SF10736

by

Northrup, Incorporated

and

ARCO Oil and Gas Co.

FOREWORD

This report was prepared for the Department of Energy under Contract No. DE-AC03-79SF10736. It presents the results of a ten (10) month study to develop a site specific conceptual design of a solar retrofit system for the ARCO Oil and Gas Company North Coles Levee Natural Gas Processing Plant near Bakersfield, California.

The guidance and support of the Department of Energy Program Manager, Fred Corona, and the technical assistance and support of Jim Gibson of Sandia National Laboratories were of great benefit in the performance of this study and their contributions are hereby acknowledged.

The authors of the report are the persons responsible for performing the design and analysis work and include; F. A. Blake, A. J. Anderson, R. J. Thomas and R. L. Henry of Northrup, Inc. and H. E. Wold, W. S. Deinlein and Louis Hartmangruber of ARCO Oil and Gas Co.

The report is bound in two books. One is the technical report of the conceptual design effort and the other is an appendicies which contains quantities of supporting data and methods too voluminous for inclusion in the technical report. Section 1 of the technical report, "Executive Summary" is also published under separate cover.

The technical report is organized into seven major sections.

Section 1	Executive Summary
Section 2	Introduction
Section 3	Selection of Perferred System
Section 4	Conceptual Design
Section 5	Subsystem Characteristics
Section 6	Economic Analysis
Section 7	Development Plan

The appendicies book contains seven subjects that directly relate to the design work.

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SECTION 1.0

EXECUTIVE SUMMARY

This volume summarizes project work performed by Northrup, Inc., a subsidiary of the Atlantic Richfield Company, for the U. S. Department of Energy (DOE) under DOE Contract No. DE-AC03-79SF10736 during the period September 15, 1979 - July 15, 1980. The purpose of the project was to develop a site-specific conceptual design for a practical and cost-effective solar retrofit system to supply process heat for a representative petroleum industry application.

The application selected for the project is the processing of natural gas to:

- Extract natural gas liquids and produce propane, butane and gasoline from them.
- Condition the residue natural gas for marketing.

The process requires heat in the 193 to 304°C (380-580°F) range which is readily achievable with concentrating solar thermal systems. The application is also ideal for solar retrofit because many natural gas processing plants utilize a heat transfer oil which permits an extremely simple interface with the fired oil heaters normally used.

The solar retrofit conceptual design was developed for the ARCO Oil and Gas Company's North Coles Levee Natural Gas Processing Plant No. 8 located near Bakersfield, California. This plant uses gas-fired heaters and gas turbine exhaust heat to heat oil which is then cascaded through a series of reboilers thus supplying process heat at several required temperatures.

1.1 BACKGROUND

This project is part of the U. S. Department of Energy Solar Repowering/Industrial Retrofit Program.

1.1.1 Objective

The objective of the project was to develop a site-specific conceptual design for a practical and cost-effective solar retrofit system to supply process heat for a representative petroleum industry application. The particular application selected for the project is the ARCO Oil and Gas Company's North Coles Levee Natural Gas Processing Plant No. 8 located near Bakersfield, California.

1.1.2 Technical Approach

The technical approach employed by the design team in developing the conceptual design of the solar retrofit system for the North Coles Levee Plant started with establishing preliminary Systems Requirements Specification (SRS) based upon general technical requirements set forth in the contract statement of work, the plant requirements, and the heliostat-central receiver concepts originally proposed. Tradeoff analyses were then performed to determine the system configuration. These tradeoff analyses included collector field size and arrangement, receiver type and configuration, piping arrangement, solar-fossil interface, augmentation temperatures, control approaches and related issues affecting subsystem configurations and major component selection.

Once the subsystem configurations, major components, operating conditions and control approaches were selected, the overall conceptual design was completed in sufficient detail to develop reliable performance estimates and to estimate detailed design and construction costs. An economic evaluation based on a 20-year life-cycle-cost analyses was performed, and environmental and safety assessments were prepared. Finally, a development plan for a phased program leading to system operation in 1984 was prepared.

1.1.3 Design Team

In addition to Northrup, Inc., the design team included the industrial partner, ARCO Oil and Gas Company, also a subsidiary of the Atlantic Richfield Company. Northrup, Inc. served as prime contractor with overall project management responsibility, and was also responsible for the solar system design (collector field, receiver and controls), the performance and economic analyses, and preparation of the development plan. ARCO Oil and Gas Company, in addition to providing general technical assistance and design concurrence, had specific responsibility for the receiver loop design, the solar-fossil interface design, and the environmental and safety assessments.

1.1.4 Design Concept

Figure 1-1 presents an artist's rendering depicting the solar retrofit system installed at the North Coles Levee Plant. An array of 320 Northrup II heliostats (being developed under separate DOE funding) occupies a 120^{o} circular sector with a radius of 304.8 m (1000 ft) requiring a total enclosed land area of 97,288 m^{2} (24 acres). Each heliostat has a mirror surface area of 52.6 m^{2} (566 ft^{2}) and is computer controlled (open loop) to maintain focus on a single cavity type central receiver mounted atop a 61m (200 ft) steel tower due south of the heliostat field. The receiver incorporates standard heat exchanger panels to absorb the concentrated solar radiation.

Heat transfer oil used by the natural gas processing plant (located behind the tower in Figure 1-1) is directed through the receiver panels where it is heated to 293^{o}C (560^{o}F) when the solar system is in operation. At design conditions (noon, summer solstice) the solar system will supply 9518 KW_t (32.5 x 10^{6} Btu/hr.), or approximately 90 percent of the heat normally supplied by the plant's existing gas-fired heaters. The gas-fired heaters, which are throttled and kept on line to compensate for solar interruptions, supply the balance of heat and maintain a uniform outlet temperature of 301^{o}C (575^{o}F).

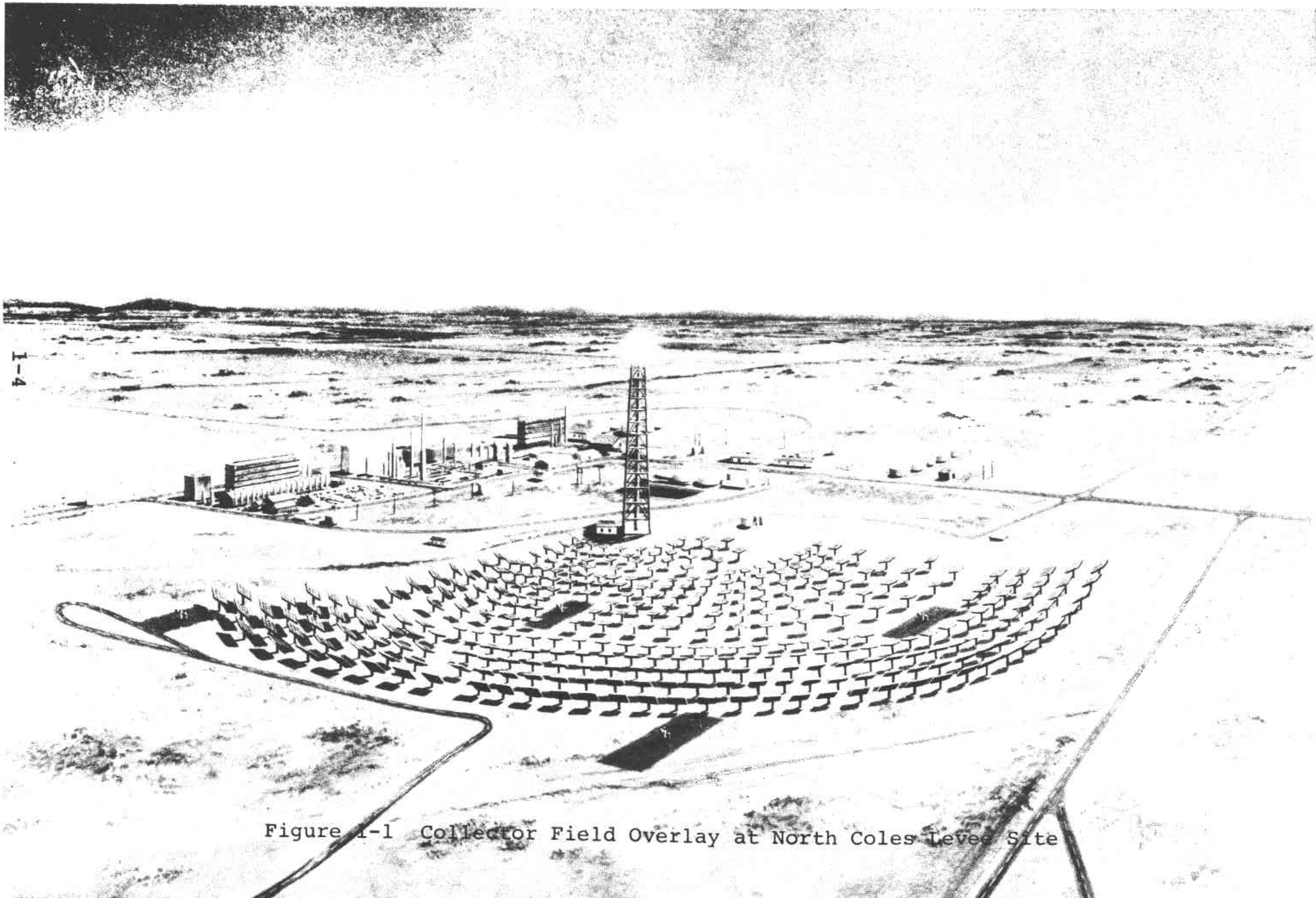


Figure 1-1 Collector Field Overlay at North Coles Levee Site

On an annualized basis, the solar retrofit system will supply 24.4 percent of the total process heat requirements that otherwise would be supplied by the gas-fired heaters. Based upon an assumed cost of $\$100/m^2$ for production heliostats and taking maximum advantage of applicable tax credits, the energy supplied by the solar system over a 20-year life cycle would cost 47 percent less than the same amount of energy supplied by natural gas.

1.2 SITE DESCRIPTION

1.2.1 Location

The site for the installation of the solar collector/receiver system is adjacent to the North Coles Levee Natural Gas Processing Plant No. 8 which is located approximately 35.4 km (22 mi.) west of Bakersfield, Kern County, California. This places it near the southern end of the San Joaquin Valley. The floor of the valley at this location is flat and relatively level and the soils are loose well-drained loam containing rock fragements.

1.2.2 Climate

The general climate of the plant area is warm and semiarid. The normal rainfall is around .15 m (6 in.), 90% of which falls from October through April. Winters are mild and tend to be fairly humid with intermittant foggy conditions. Summer skies are clear and conditions are usually hot and dry. Annual average direct normal solar insolation is between 6 and 7 kwh/m^2 daily.

The seasonal average clear day conditions obtained from the U.S. Weather Service in Bakersfield are as follows:

Clear	202 days
Partly Cloudy	78 days
Cloudy	85 days (includes 22 days of heavy fog)
Precipitation	.254 mm (0.01 in) 36 days
Thunder showers	3 days

1.2.3 Plant Process

The plant is a refrigerated absorption oil plant that recovers propane, butane, and gasoline from raw natural gas. A simplified flow diagram of the process is presented in Figure 1.2. The process consists of the raw gas from the field being dehydrated and bubbled through an oil that absorbs the hydrocarbons with molecular chains longer than methane. The absorption oil is then flowed sequentially through the deethanizer where the ethane fraction is removed; the strippers where the natural gas liquids are separated from the absorption oil; the depropanizer where the propane fraction is removed; and finally to the debutanizer where the butane is removed leaving raw natural gasoline. The separation process at each station is powered by the selective application of heat energy. For safety reasons the entire process avoids the direct use of flame and is powered instead by a heat medium oil (HMO) that is heated remotely and circulated to the stripper deethanizers, depropanizer and debutanizer reboilers (See Figure 1.2). The system operates between 193°C (380°F) and 301°C (575°F). The process heat is supplied by a combination of two fired heaters and one heat recovery unit that operates on waste heat from a continuously operated gas turbine. Nominally, $8.00 \times 10^3 m^3$ (2.1×10^6 gal) of HMO are circulated through the system daily; 73% of which is heated by the fired heaters. These heaters consume .33 m^3/s (1.0×10^6 scfd) of natural Gas. The solar system is designed to displace a significent portion of this natural gas consumption.

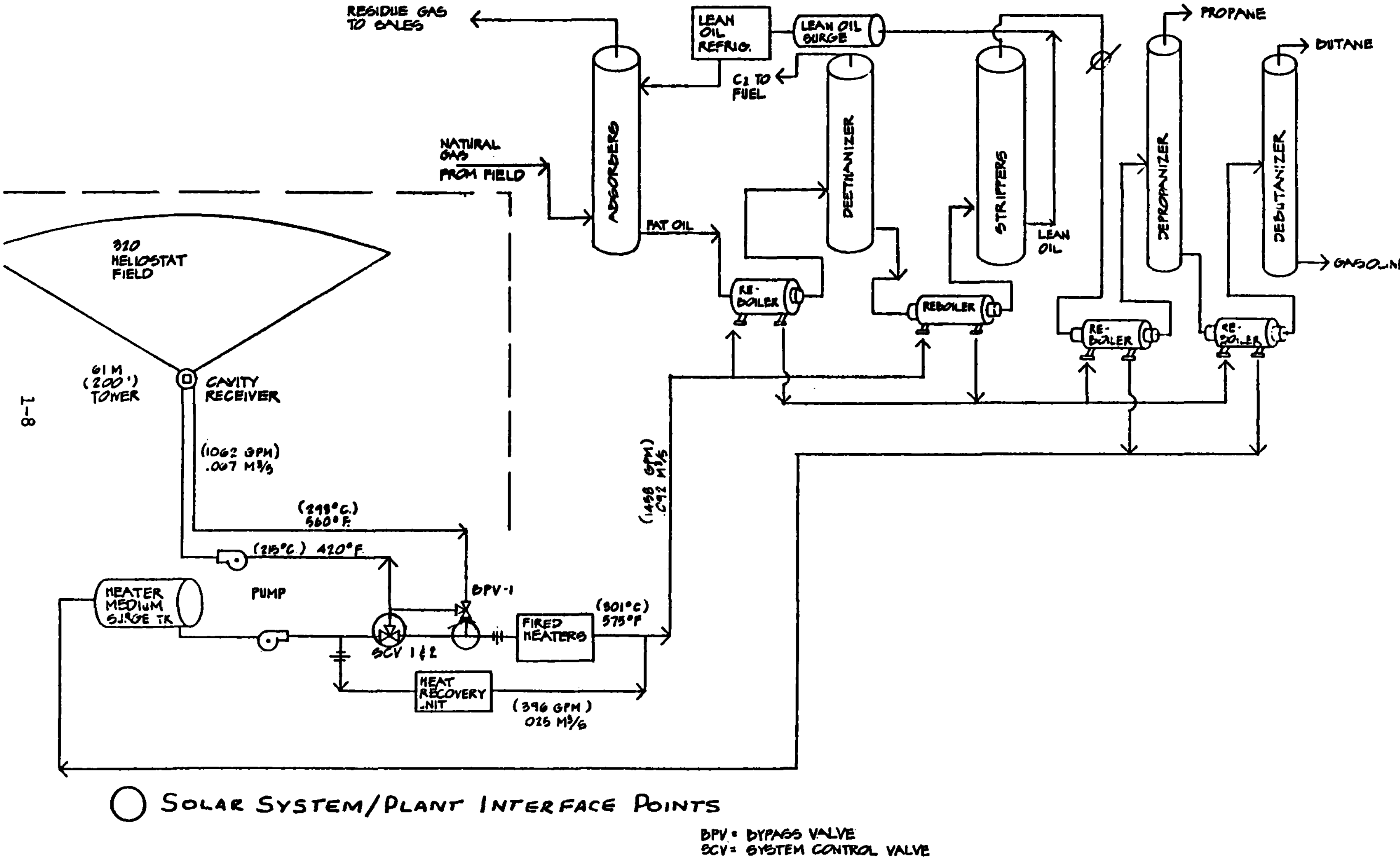


Fig 1-2 North Coles·Levee Industrial Retrofit

Flow Diagram

1.3 PROJECT SUMMARY

Programmatic

The project began on September 15, 1979 and was scheduled for completion on June 15, 1980. There has been a subsequent modification (A) that extended the period of performance until July 15, 1980.

The funding level was established at $310,526 which includes all direct, overhead and G&A costs and fee. This sum provided for 9,935 manhours along with relatively small amounts for computer usage and travel.

During the course of the design and analysis, all major milestones were accomplished on schedule and the contract completed well within the budgeted funds.

Technical

The central purpose guiding the design effort during the course of the project has been to develop the most efficient process heat system for minimum cost, within land use and other site specific constraints. This has been accomplished through the judicious selection of parametric and tradeoff analyses involving the collector field configurations, receiver types, system interface, augmentation temperatures, and control strategies. Critical evaluation and utilization of the results of these analyses have produced a system that has significant value not only for the North Coles Levee site, but for many other sites that utilize similar process heat applications.

The more important performance and operational characteristics of the system that contribute to the unique design are as follows.

. All solar energy collected is utilized, except for small transfer losses.

. The control system is simple, straight forward and minimizes the use of control valves, pumps, and other active components.

- The fired heaters are maintained at operating temperatures providing the system with excellent response to solar startup, shutdown and cloud transient conditions.

- The range of operating temperatures (215-296°C) and pressures 6.9×10^2 kPa (100 psi) permits the use of low cost carbon steel for the embossed receiver panels, pipes, valves and fittings.

- The same fluid serves as both receiver and heat transfer fluid.

- Minimum impact on normal plant operation and procedures.

- The collector field configuration permits continued use of the land for its primary purpose-production of oil and natural gas.

- Easily adaptable to power additional processes or enhanced and secondary oil recovery if this should be desirable or necessary.

1.4 CONCEPTUAL DESIGN

The flow relationship between the solar process heat system and the existing plant is shown in Figure 1-2. In order to facilitate the design and analysis process, the solar plant has been divided into three interdependent systems. These are: the collector system, composed of the heliostats and associated field and unit control system; the receiver system, which contains the receiver and tower; and the receiver loop, that includes the riser and downcomer, interconnect piping, and the control valves and associated instrumentation.

The collector field is composed of 320 heliostats arranged in a radial stagger configuration and located north of a single cavity receiver with the aperture centerline 61 m (200 ft.) above ground level, Figure 1-3. The receiver is positioned atop a 3-legged steel tower. The tower mounted riser and downcomer are connected to the existing heat medium oil system near the inlet to the fired heaters by a 381 m (1250 ft.) above grade piping run.

Collector System

The heliostat selected for the design of the North Coles Levee process heat system is the Northrup II, Figure 1-4. It is a dual axis tracking heliostat with a pedestal mount. The normal stow position is vertical but under anticipated extreme high wind conditions, it is driven to a horizontal orientation with the reflective surfaces facing up. The gross face area of the heliostat is approximately 7.62 m (25 ft. x 25 ft.) with mirror module spacing and edge treatment the net reflective area is 52.6 m^2 (566 ft^2). Each mirror is nominally 4 feet by 12 feet with a 3 inch depth. 12 modules comprise the mirror array for each heliostat. The mirror support rack consists of open roof-type trusses which are combined with tubular members which connect to the drive unit. The drive unit is gear-driven with separate motors

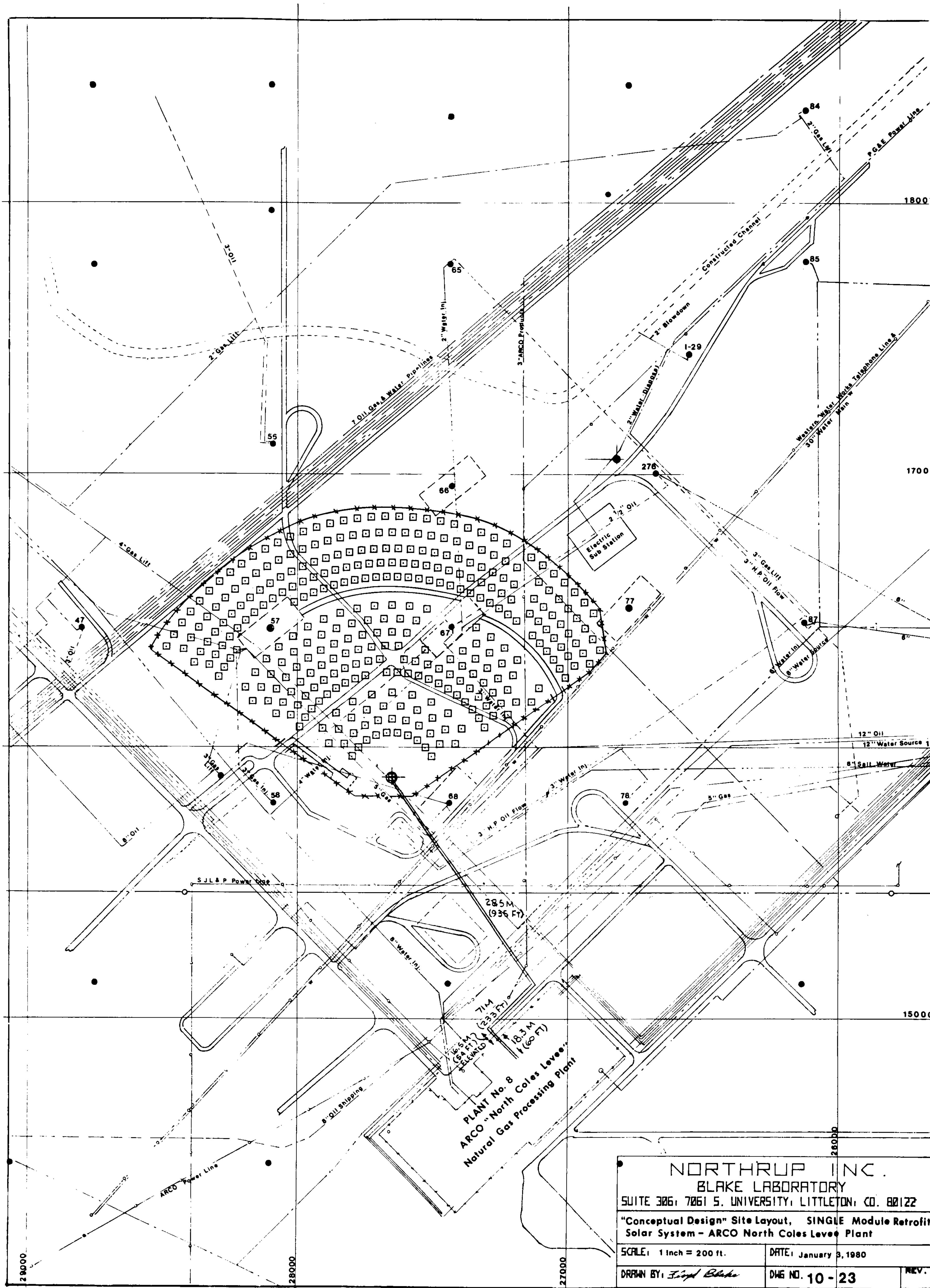

NORTHRUP INC.
BLAKE LABORATORY
SUITE 306, 7061 S. UNIVERSITY, LITTLETON, CO. 80122
"Conceptual Design" Site Layout, SINGLE Module Retrofit Solar System - ARCO North Coles Levee Plant
SCALE: 1 inch = 200 ft.
DATE: January 3, 1980
DRAWN BY:
DWG NO. 10-23
REV.
PLANT No. 8
ARCO "North Coles Levee"
Natural Gas Processing Plant
285M
(936 Ft)
71M
(233 Ft)
18.3M
(60 Ft)
Electric Sub Station
Constructed Channel
PG&E Power Line
Western Water Works Telephone Line &
30" Water Main
7 Oil, Gas & Water Pipelines
S J L & P Power Line
ARCO Power Line
12" Oil
12" Water Source
8" Salt Water
8" Oil Shipping
8" Water Inj.
3" H.P. Oil Flow
3" Gas Lift
2" Blowdown
2" Water Disposal
4" Gas Lift
1800
1700
1500
28000
27000
26000

Fig 1-3

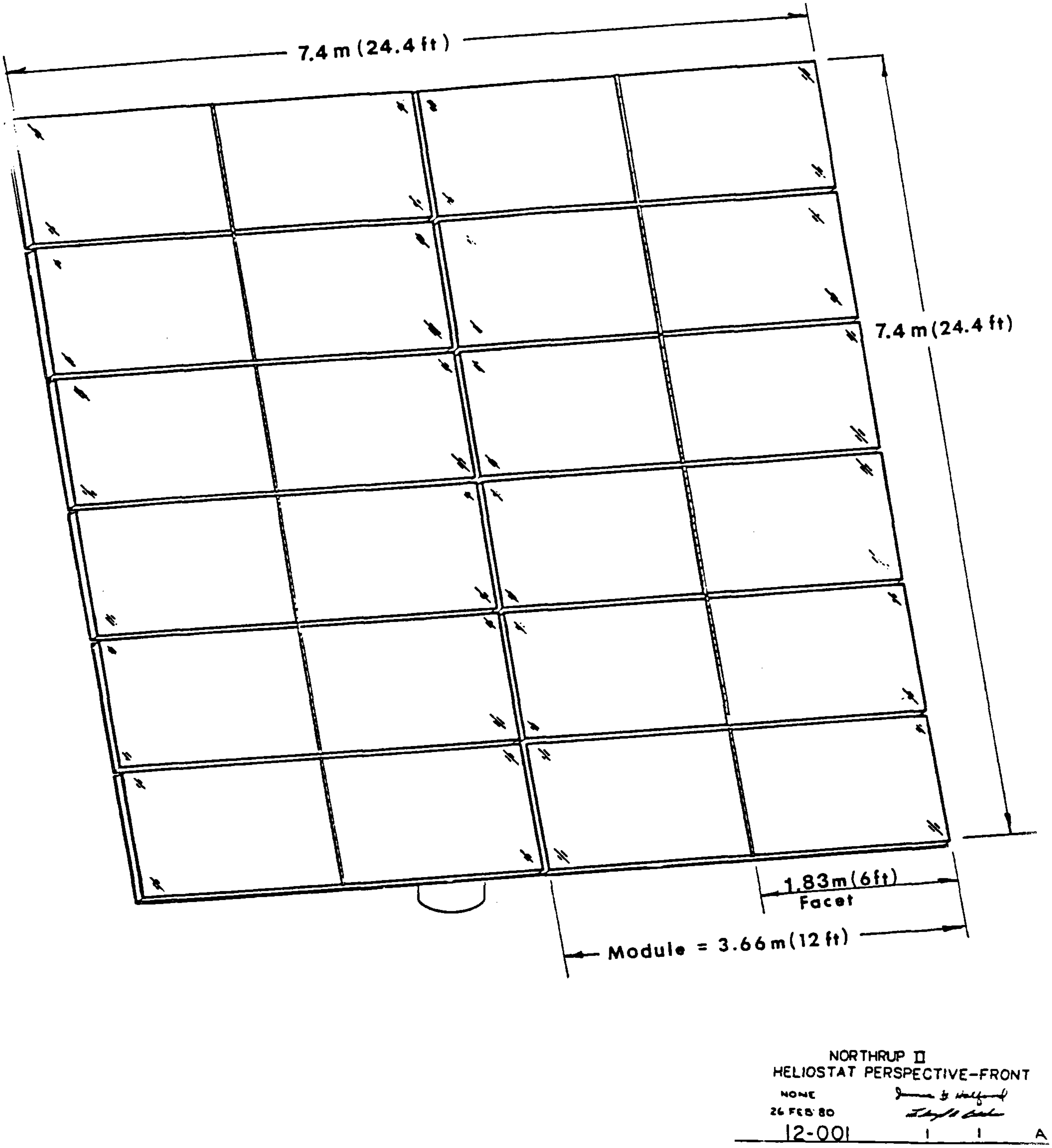


Figure 1-4a

Northrup II Heliostat Front View

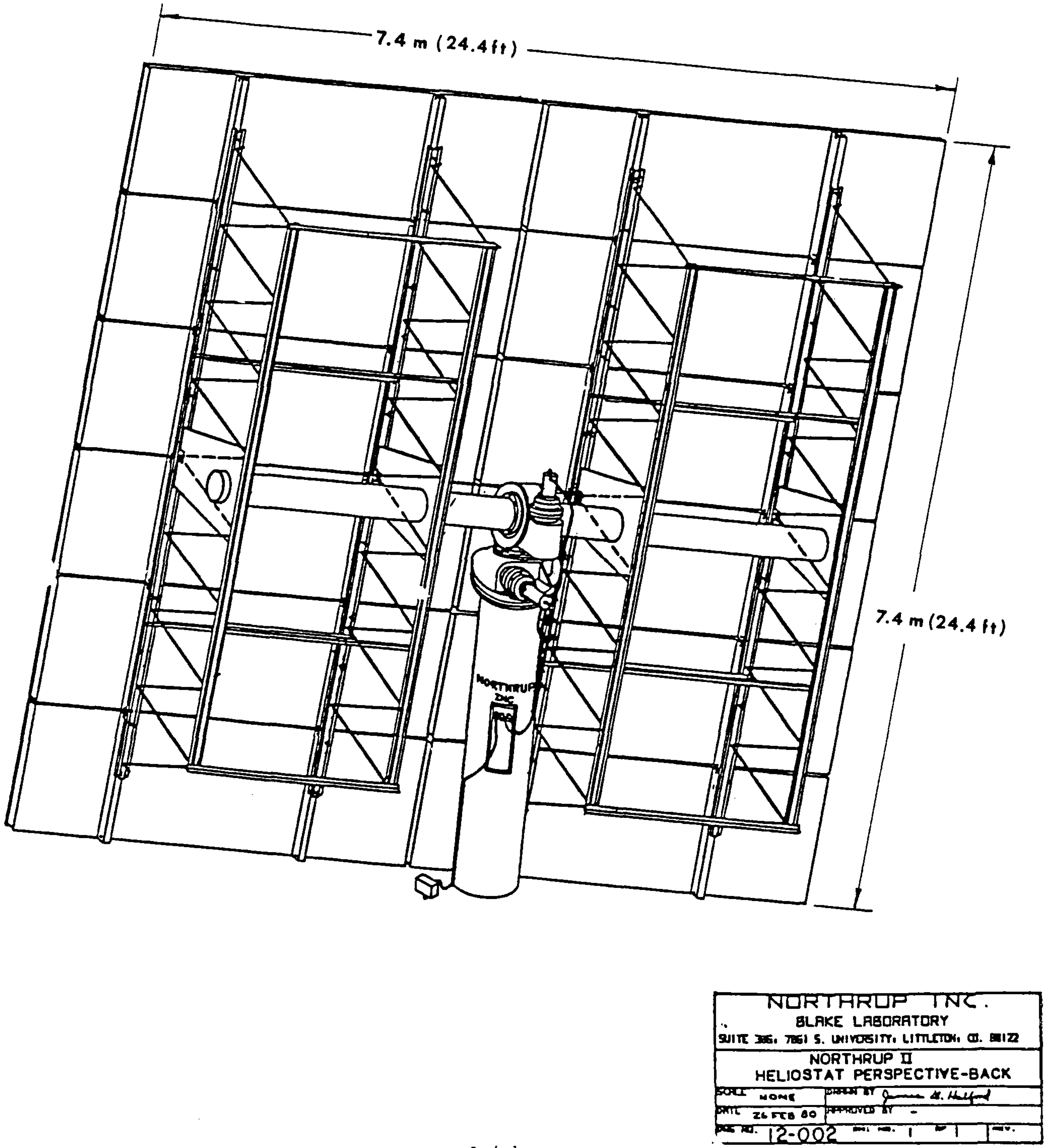


Figure 1-4 b

Northrup II Heliostat - Back View

and gear systems for azimuth and elevation. The foundation for the drive consists of a one-piece cylindrical pipe which is driven into the soil at the site by conventional pile-driving techniques.

The Northrup drive unit incorporates independent azimuth and elevation sections into a unified housing. Both of these drive elements are identical in terms of motor, input-stage, and output stage gearing. The basic drive concept is keyed to the use of D-C stepper motors which provide both motive power (torque) and position control (precise incremental rotation); i.e., no encoders or other continuous position sensors are required. Stepper motors interface well with digital minicomputers and microprocessors, and are able to deliver an accurate rotational increment of 1.8 angular degrees per motor step. An intermediate, printed circuit board device known as a translator provides the sequencing and switching logic which converts pulses from a minicomputer or microprocessor into motor steps, therefore allowing step rate, direction, and number of steps to be controlled by external logic. With proper translator selection, stepping rates as high as 2000 steps/second can be accurately achieved.

The control software for the Northrup II heliostats consists of two packages; one in the control room handling the external data processing, communication, and control and one at the heliostat, handling the internal data processing, communication and direct motor control.

Receiver System

Both a flat plate external receiver and a cavity receiver were analyzed during the project. The selection of the unit field configuration (320 heliostats) dictates that the receiver will be a north-facing cavity type. The flow rate through the receiver has been established at 6.7×10^{-2} m^3/sec (63,750 gal/hr) of heat medium oil (HMO). The normal operation range for the HMO will be 215.5^{o}

to 293° C (420°F to 560°F). The receiver is being sized to deliver 9.518 MW_t at the point of interface with the existing plant system.

In general, the receiver geometry is a circular arc segment; 120° included angle on a 7.3 m (24 ft) radius; approximately 9.1 m (30 ft) in height; with the aperture centerline 61 m (200 ft) above ground level. An isometric view of the receiver is shown in Figure 1-5.

The design incorporates standard sized heat exchanger panels with reduced and protected fin areas for high flux uses. The panels are available in a wide variety of metals, sizes, flow patterns, manifold connections, pass sizes and embossing patterns.

The Arcoles Analyzer was used to evaluate the system parameters for a number of panel sizes, physical arrangements, and flow patterns to establish an optimum balance and efficiency within the design criteria. A summary of the analyses results are presented below.

Max. Fin Temp.	659° F
Max. Tube Temp.	628° F
Max. Oil Temp.	600° F
Max. Thermal Stress	21,484 psi

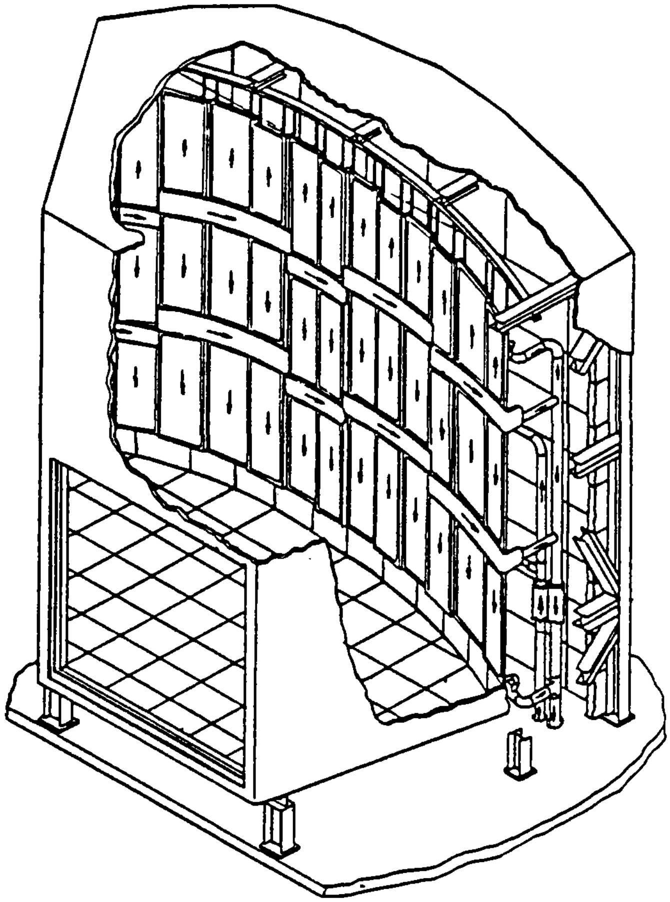
HEAT TRANSFER DATA

TIME/DAY	355	80	173
8:00	88.69	89.54	88.4
10:00	90.33	90.08	88.95
12:00	90.26	90.41	89.36

RECEIVER EFFICIENCY (%)

The number and arrangement of the heliostats dictated an optimum tower height that would place the receiver aperture centerline 61 m (200 ft.) above grade. Steel towers are more cost effective in this height range. The initial tower analysis was performed using the SNLL cost algorithms. A four-legged tower designed to survive in UBC earthquake Zone 4 (0.5g average ground acceleration) and 40.2 m/s (90 mph) wind conditions (Bakersfield area from 100 yr. recurrence interval chart in ANSI-A58.1-1972) was selected for this analysis.

A quote for a three legged tower that would survive under the same conditions was received from Unarco-Rohn. While the actual cost of the



9.518 MW_t Receiver

Fig 1-5

tower structure was significantly higher than that predicted by the SLL equations, the tower costs quoted for the foundation, accessories, engineering and fee resulted in a much lower overall installed cost for the UNarco-Rohn Standard RS-222-C tower ($563,922 vs. $749,560). As a result this tower was selected for the North Coles Levee conceptual design. Figure 1-6 presents a sketch of the RS-222-C tower and shows the service platform and receiver location.

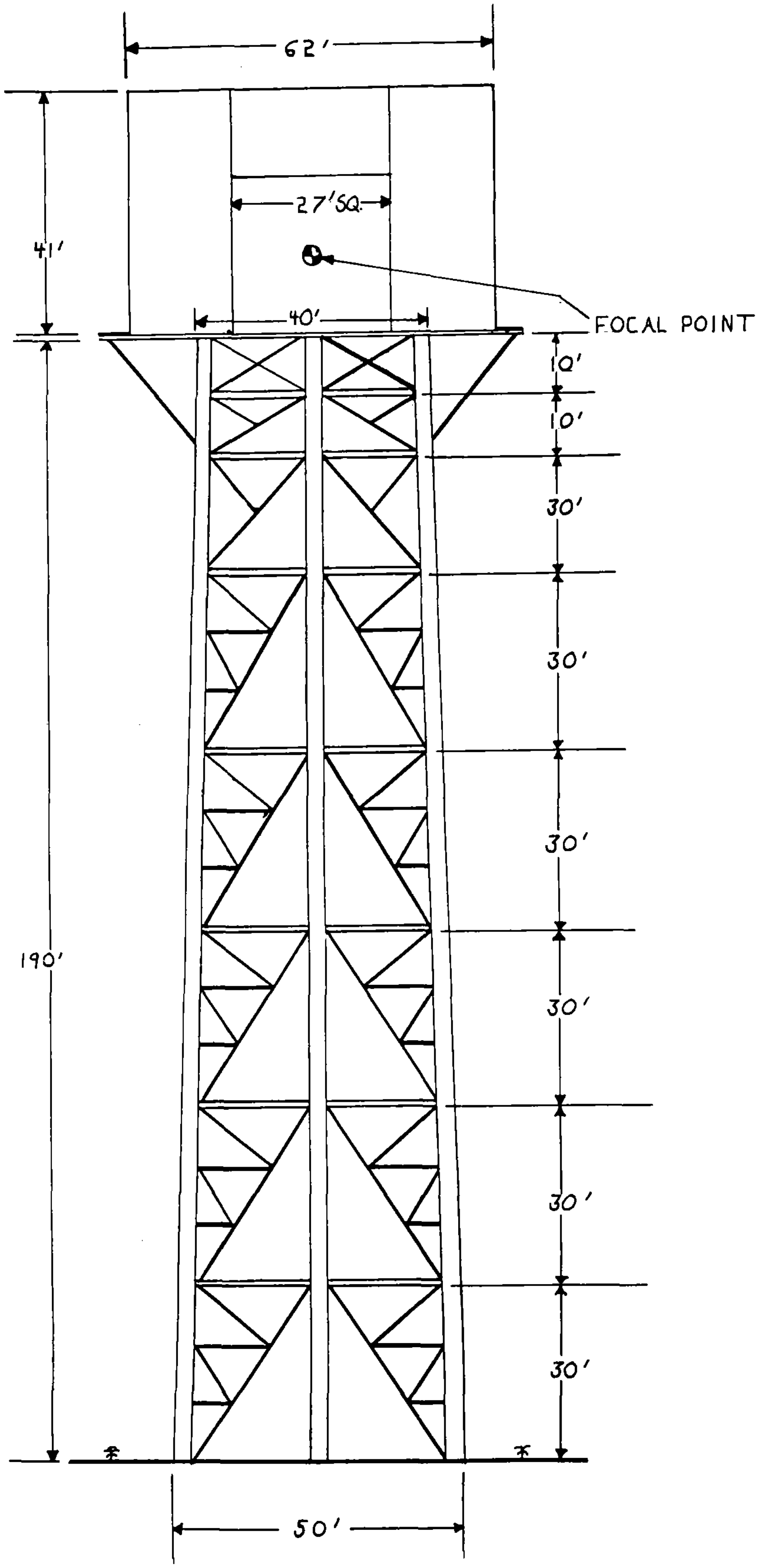
Receiver Loop

The receiver loop contains the riser and downcomer, the piping run between the tower and the existing plant interface, and the interface and bypass control valves. The length of each leg of the piping run 457.2 m (1500 ft.) including the 60.96 m (200 ft.) vertical section. The riser, which carries the HMO from ground level up to the receiver and the downcomer, which returns the HMO to ground level are simply uniform extensions of the linear interconnect piping run.

The relatively low temperatures and pressures to which the system is subjected permits the use of inexpensive Schedule 40 Carbon Steel pipe for the receiver loop piping. A nominal .201 m (8 in.) pipe was selected.

A piping layout showing the piping between the plant and the tower is presented in Figure 1-7. Figure 1-8 shows the actual plant hook up. Both expansion joints and loops were considered. While the loop configuration requires less maintenance, the additional cost of the piping and insulation and the pressure drop penalty (which in turn effects pump costs) eliminated this configuration from further consideration. The pressure drop vs. cost trade off was also the factor that determined the selection of pipe size. Temperatures and pressures were the key consideration in the selection of pipe type and code requirement.

System control is very simple and straightforward. Except for emergencies or major malfunctions, the HMO system is in continuous operation and the temperature of the oil to the process is controlled by automatic control valves located at the inlet to the fired heaters. These valves control the fuel supply to the heaters.



9.5 MW_T RECEIVER-TOWER

Fig 1 - 6a

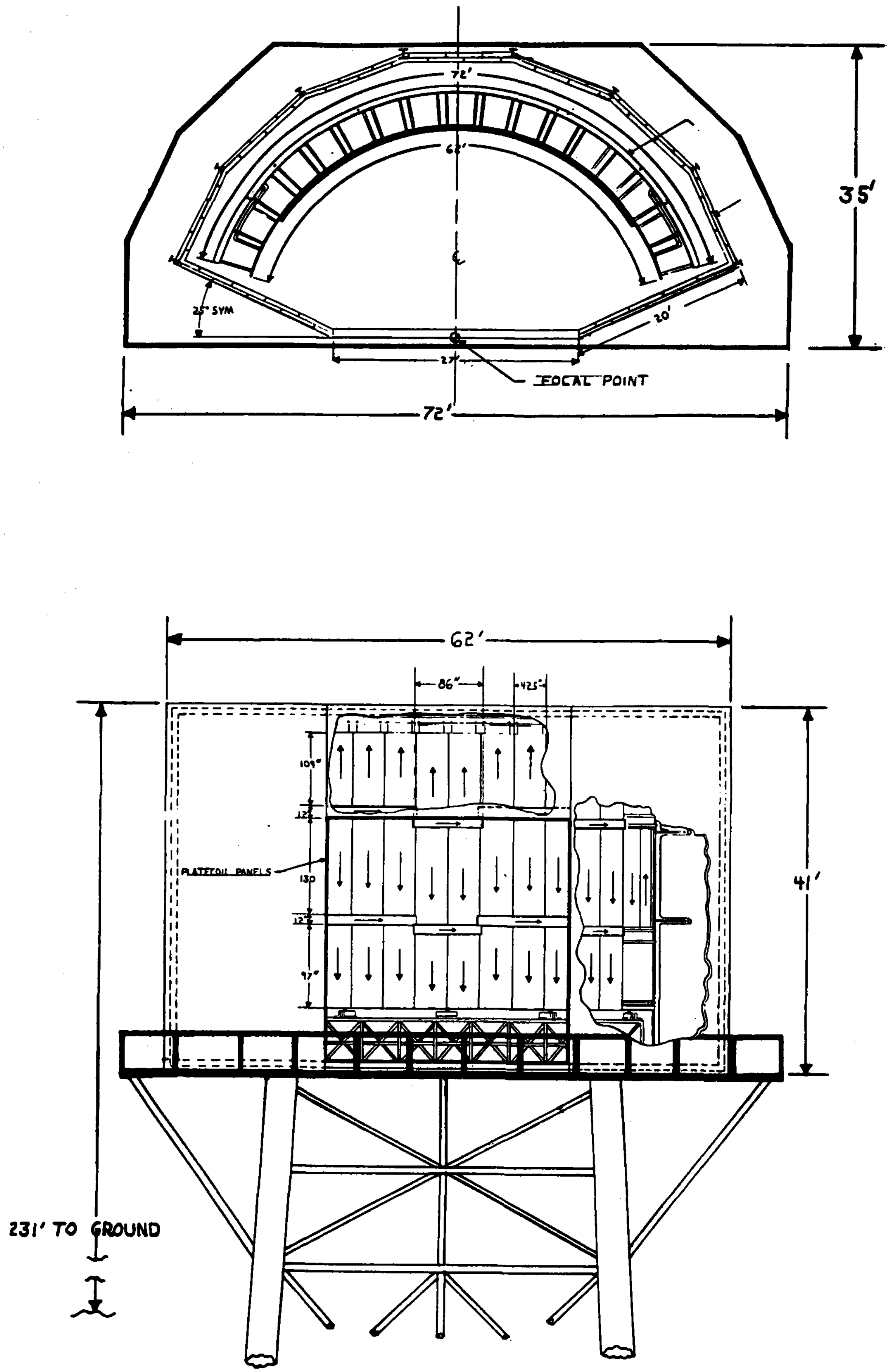


Fig 1-6b 9.5 MW_t Receiver - Tower

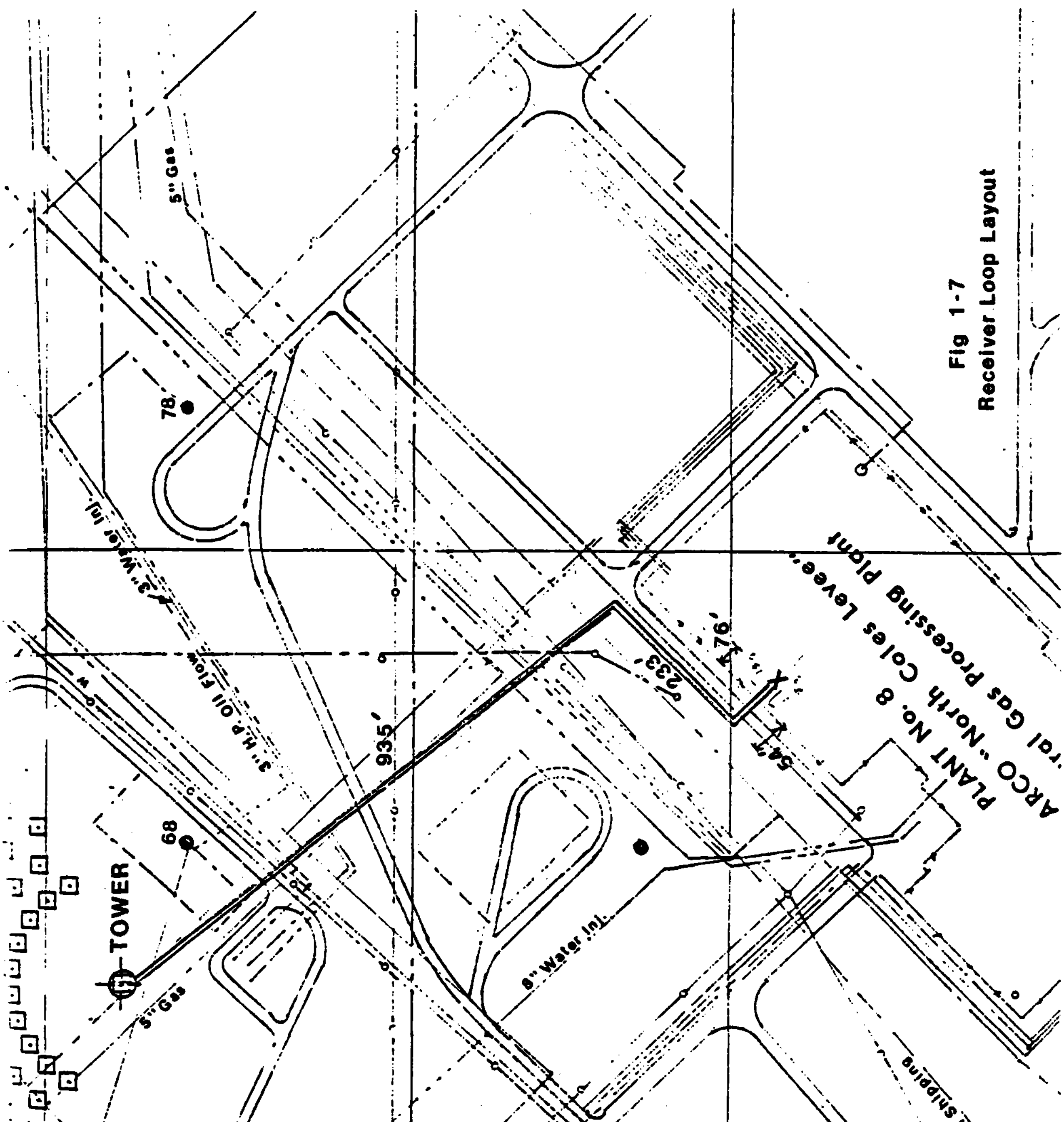
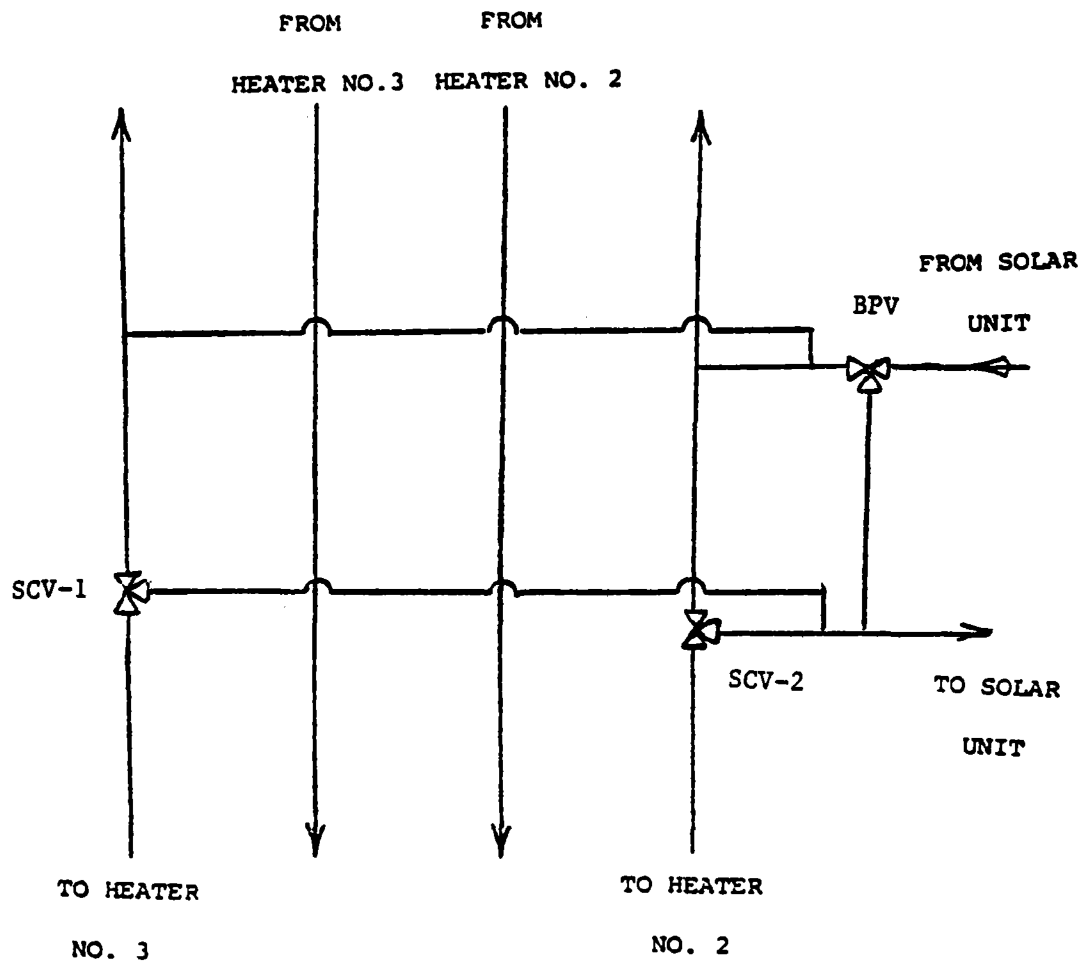


Fig 1-7
Receiver Loop Layout



SYSTEM CONTROL VALUES*

SCV-1 - Temperature Control Valve - 4 in. Reverse Acting
SCV-2 - Temperature Control Valve - 4 in. Reverse Acting
BPV - Temperature Control Valve - 6 in. Direct Acting

* Air actuated with manual over-ride

Figure 1-8

The receiver loop interfaces with the existing HMO system between the plant pump discharge and fired heaters. A flow diagram of the process, HMO and solar system interface was shown in Figure 1-2. During periods of sufficient insolation, all the HMO that normally flows to the fired heaters is diverted through the receiver and back to the heaters. The heaters then "top-off" the heat required to maintain their outlet temperature of 301°C (575° F). Fuel flow to the heaters is automatically controlled to supply only enough heat to meet the Δ T requirement, or to carry the entire plant load during periods of insufficient insolation. During periods of insufficient insolation, the control valves are closed and the system returns to fossil operation. If, overnight or during long periods of cloud passage, the temperature of the oil in the solar system falls below the minimum system temperature of 215.5° C (420°F), the pump in the receiver loop is turned on and the fluid in the loop is recirculated through the receiver until it reaches the plant system temperature.

Table 1.4-1

CONCEPTUAL DESIGN SUMMARY TABLE

Prime Contractor:	Northrup, Inc.
Major Subcontractor:	ARCO Oil and Gas Company
Site Process:	Natural gas processing utilizing hydrotreated light cycle oil at a temperature of 301° C (575° F).
Site Location:	ARCO North Coles Levee Natural Gas Processing Plant No. 8 located 35 km (22 miles) west of Bakersfield, Calif.
Design Point:	9,518 kW_t (32.5 x 10^6 BTU/hr) at noon summer solstice.
Receiver:	
Fluid:	Hydrotreated light cycle oil
Configuration:	Cavity
Type:	Once through forced circulation
Elements:	Heater only,
Output Fluid Temp:	293° C (560°F)
Output Fluid Pressure:	552 kPa (80 psi)
Heliostats:	
Number:	320
Individual Mirror Area	52.6 m^2 (566 ft^2)
Cost:	$301/$m^2$ (average)
Type:	Northrup, Inc., Northrup II
Field Configuration	North
Storage:	None
Total Project Cost:	a. Based on heliostat price of $301/$m^2$: (19 heliostats @ $414/$m^2$ and 301 @ $294/$m^2$) $8,336,034
	b. Based on heliostat price of $230/$m^2$: $6,448,056.
Construction Time	18 months

CONCEPTUAL DESIGN SUMMARY TABLE (Continued)

Solar Plant Contribution at Design Point:	9.518 mW_t
Solar Fraction (Annual):	24.4%*
Annual Fossil Energy Saved:	21,336 barrels of oil equivalent
Type of Fuel Displaced:	Natural Gas
Annual Energy Produced / Total Heliostat Mirror Area	1.34 $mWh_t m^2$
Capital Cost / Annual Fuel Displaced	\$368/mWh_t
Site insolation (direct Normal):	
Annual Average	2.488 mWh/m^2
Source:	Barstow Weather Tape (1976) x .9
Site Measurements:	Start Date Feb. 7, 1980 Continuing 1/2 hour data reduction

*24.4% of the process heat normally supplied by natural gas. Part of the total process heat utilized is supplied by exhaust heat from a turbine which would otherwise be wasted. It would be counter-productive to replace this part by solar; hence it was not considered in calculating the solar fraction.

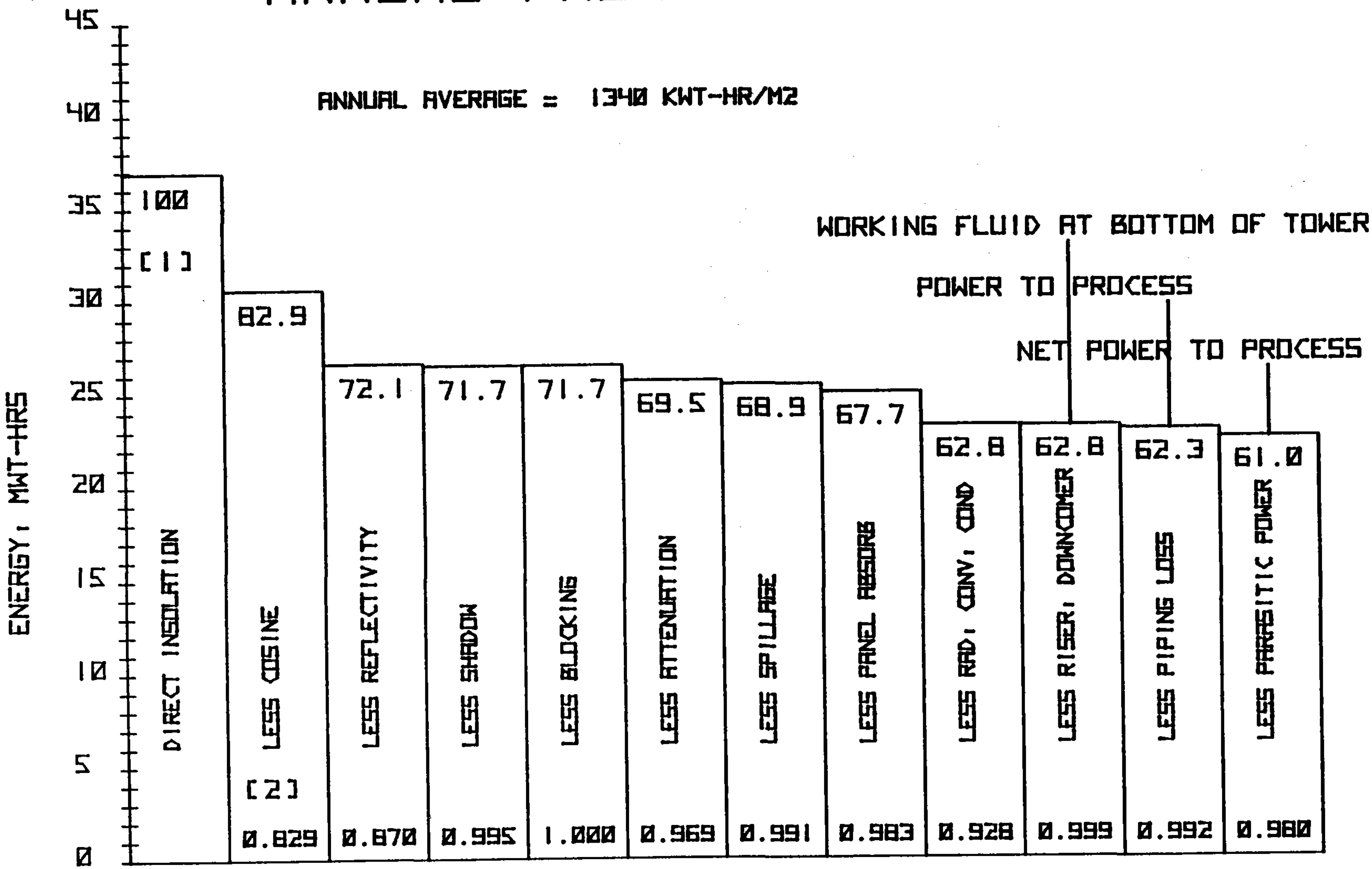
Table 1.5-1

Solar System Annual Energy Projection - Coles Levee Natural Gas Processing Plant

Delivery Point In System	Total Energy $\frac{kWh_t}{Yr}$	Total Energy $\frac{BTU}{Yr}$	Specific Energy $\frac{kWh_t}{m^2}$	Specific Energy $\frac{BTU}{ft^2}$
1. Potential Insolation above 500 KW/m^2	36.91×10^6	1.259×10^{11}	2193	6.95×10^5
2. To Receiver Cavity	25.43×10^6	8.679×10^{10}	1510.8	4.79×10^5
3. To "Heat Medium Oil" Loop	23.196×10^6	7.917×10^{10}	1378.1	4.37×10^5
4. To Process "Heat Medium Oil"	22.988×10^6	7.846×10^{10}	1365.7	4.33×10^5
5. Net Benefit to Plant after accounting for Parasitic Power Equivalent Heat	22.55×10^6	7.698×10^{10}	1340.0	4.25×10^5

Fig 1-9

ANNUAL PROCESS HEAT STAIRSTEP



[1] - NET CYCLE EFFICIENCY AT EACH POINT

[2] - EFFICIENCY OF EACH CONVERSION STEP

1.6 ECONOMIC FINDINGS

The total capital cost of the North Coles Levee solar installation is made up of three parts, the Design Phase, the Owner's cost and the Construction cost. The breakdown and total cost is:

1.	Design Phase	$ 1,658,762
2.	Owner's Cost	118,973
3.	Construction Cost	6,558,299
		$ 8,336,034

The project construction costs are summarized in Table 1.6-1.

Table 1.6-1

CONSTRUCTION COST SUMMARY

5100	Site Improvements		$ 95,390
5200	Site Facilities		138,605
5300	Collector System		4,840,602
5400	Receiver System		1,176,411
	5410 Receiver	$612,489	
	5420 Tower	563,922	
5900	Receiver Loop System		792,553
	Total Construction Costs		$ 7,043,561
	Reduced by items common to development module (Ref. SRS Table 9)		485,262
	NET CONSTRUCTION PHASE COST		$ 6,558,299

The evaluation of the economic feasibility of this project involves the use of several variables and assumptions, each of which can affect the answer significantly. The final decision to construct this project is a matter of judgement relative to the set of assumptions and forecasts into the future, and the goals which the participants wish to accomplish.

If viewed strictly from the standpoint of economic returns, in competition with wholesale natural gas the project is marginal, in that the rate of return on the investment is in the neighborhood of 6% to 10%, coupled with moderate risk. For risks of this nature, an investor normally would demand about 15% return.

However this project should be viewed at least partially from the standpoint of it being part of the early stages of development of a new energy source to offset the rapidly escalating price of fossil fuels. Therefore, an expenditure with a lower rate of return is justifiable, in that, as these systems are installed, operated, and improved, learning should increase, costs should decrease, and rates of return should increase. This project can accomplish a significant step in this process while returning a small to moderate rate of return on investment, which is a desirable situation. Our conclusion is that the project should be undertaken.

In order to evaluate the project economically, a set of values was assigned to each input parameter. These values were selected to be what we believe the real situation will be at the time of installing and operating the North Coles Levee project. These values are specified in Table 1.6-2.

Table 1.6-2

ECONOMIC ASSUMPTIONS

Initial System Cost	\$8.34 million
Cost of Money Use - Interest Rate	11.5%
System Life	20 years
1st Year Operation & Maintenance (O & M)	\$218,044
O & M Escalation Rate	8% per year
Federal Depreciation Period	11 years
Federal Depreciation Formula	DDB + SYD
California Depreciation Period	3 years
California Depreciation Formula	S.L.
Federal Income Tax Rate	46%
California Income Tax Rate	3.5%
Solar Energy Into Process	76,981 mil. Btu
Burner Efficiency	62.5%
Gas Price (at meter) Escalation Schedule	11% SNLL ARCO AVG.
Federal & California Tax Credits	10%, 15%, 10%

Using this set of assumptions, the following results are obtained:

	GAS ESCALATION SCHEDULE	
	11% SNLL	ARCO AVG.
Rate of Return	6.0%	9.2%
Energy Cost (20 yr. avg)		
. Solar	2.07 ¢/kWh_t	2.07 ¢/kWh_t
. Gas	2.27 ¢/kWh_t	3.00 ¢/kWh_t

Figure 1-10 and 1-11 illustrate the yearly trends and comparison of solar vs. gas energy cost.

Fig. 1-10 ECON CASE C, COLES, PILOT PROD HELIOSTAT DOE GAS ESCALATION SCHEDULE

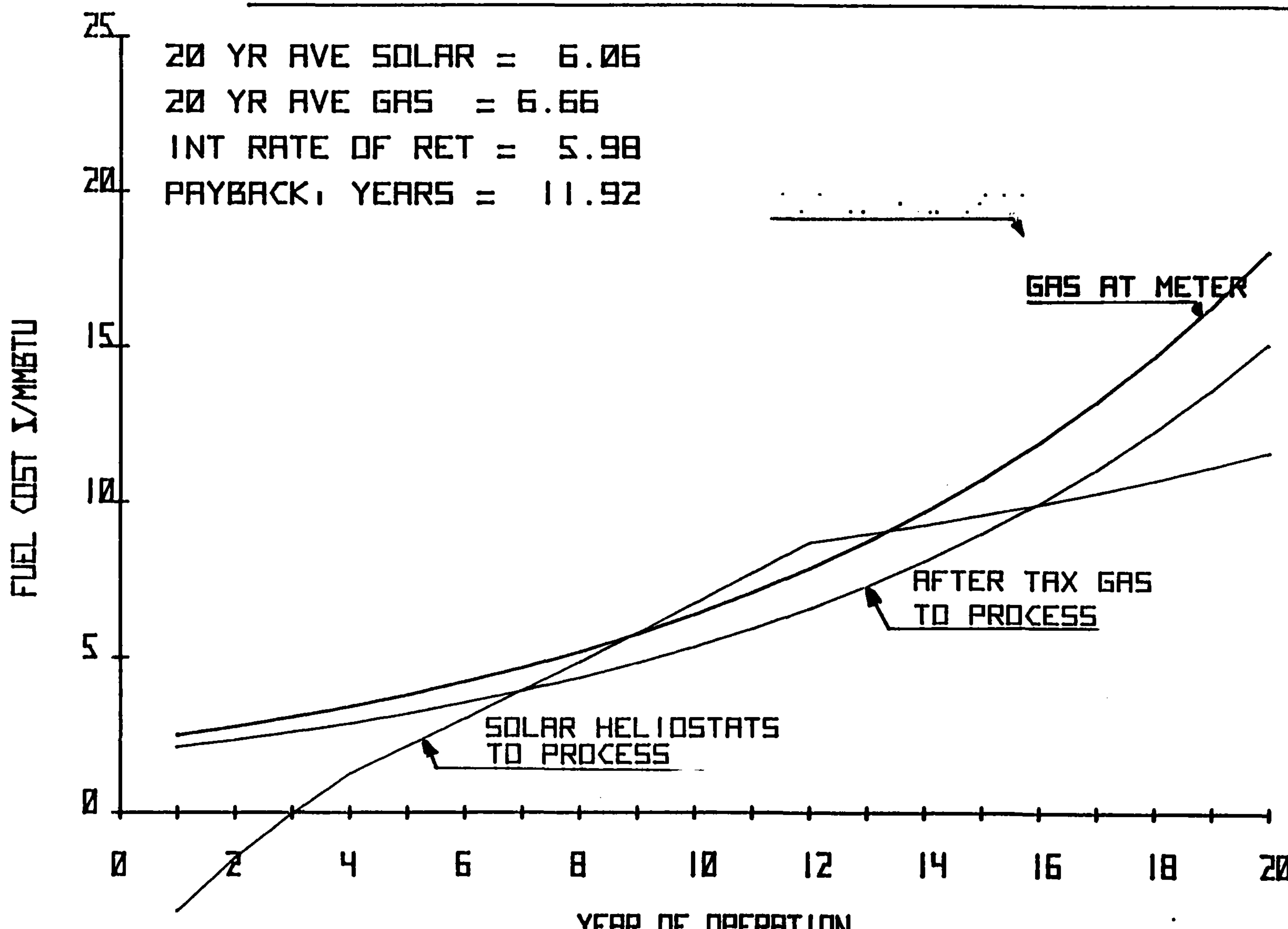
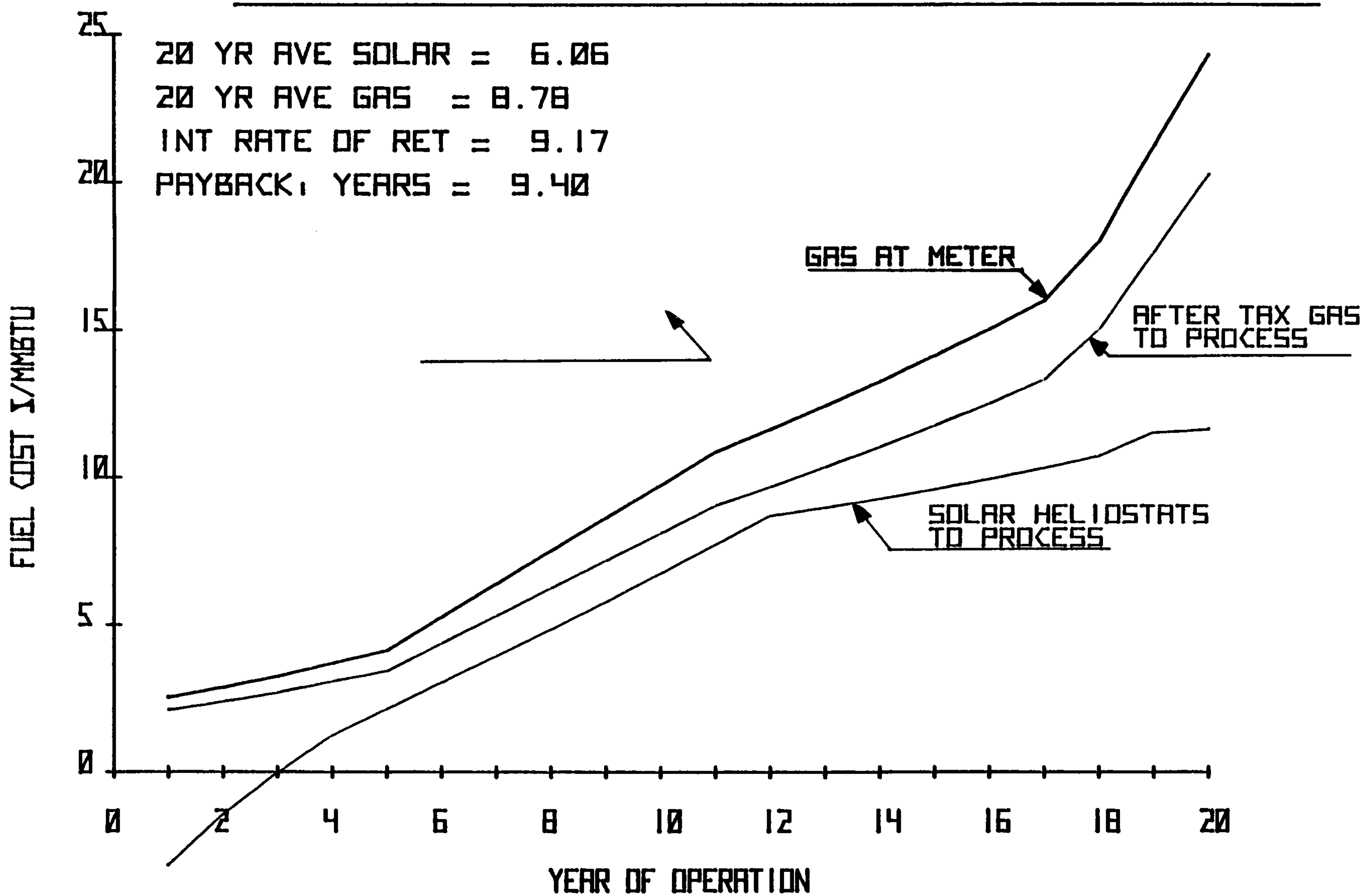


Fig. 1-11 ECON CASE D: COLES: PILOT PROD HELIOSTAT
ARCO BASE CASE GAS ESCALATION SCHEDULE



1.7 DEVELOPMENT PLAN

A phased development plan has been prepared which begins with the final design phase and culminates in an extended joint user/DOE operational phase. The phases that have been identified are presented along with their respective periods of performance in Figure 1-12.

Figure 1-12
DEVELOPMENT PLAN SCHEDULE

PHASE	ACTIVITY	YEAR 1981	1982	1983	1984	1985	1986	1987	1988	1989
I	Final Design	12 mo								
II	Construction		18 mo.							
III	Startup & Checkout			3 mo.						
IV	Performance Validation				3 mo.					
V	Joint Operations				60 mo.					

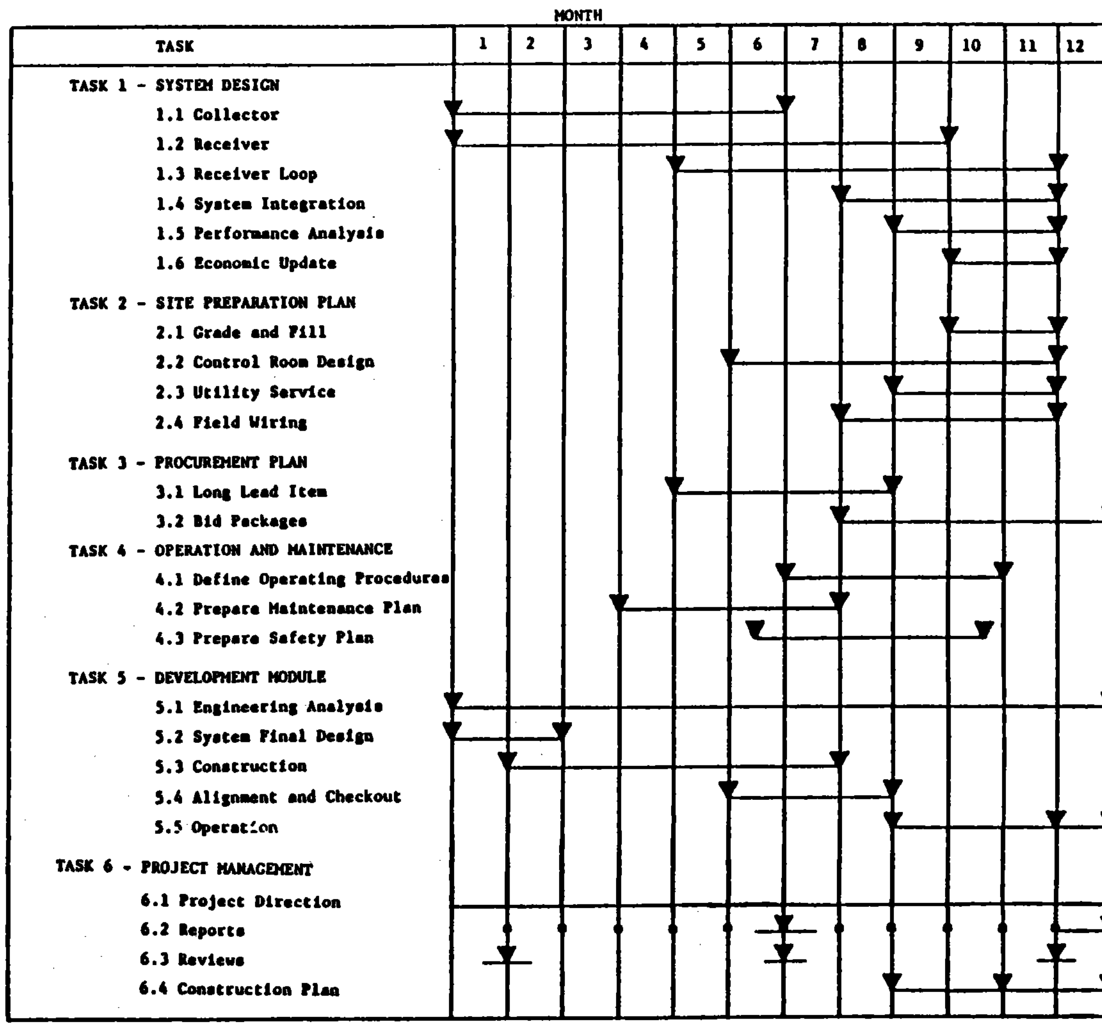
This schedule is consistant with the one presented in the DOE Solar Repowering/ Industrial Retrofit Program Element Plan, except that the two subphases, preliminary and final design, have been combined into a single final design phase. As a result, the period of performance for this site specific design is projected to be 12 months. This period of performance is justified on the basis of the relatively small and simplified system configuration and the extent to which existing technology has been incorporated into the design. The detailed design and construction phases have been planned in more detail in order to establish construction costs and schedules.

1.7.1 Detailed Design Phase

The task outline and schedule for this phase are presented in Figure 1-13. The 6 tasks and 24 subtasks provide for the final design of the solar system in sufficient detail to permit the development of

FIGURE 1-13

DESIGN PHASE SCHEDULE



all subsystem bid packages and the actual system construction during the next phase. Also provided are a set of detailed plans to assure the completion of the construction effort on schedule and with budgeted funds. These plans include a procurement plan, preliminary O & M plans and a detailed construction phase plan. An analysis of the effort required to accomplish all tasks within the 12 month performance period, shows that 162 manmonths is required.

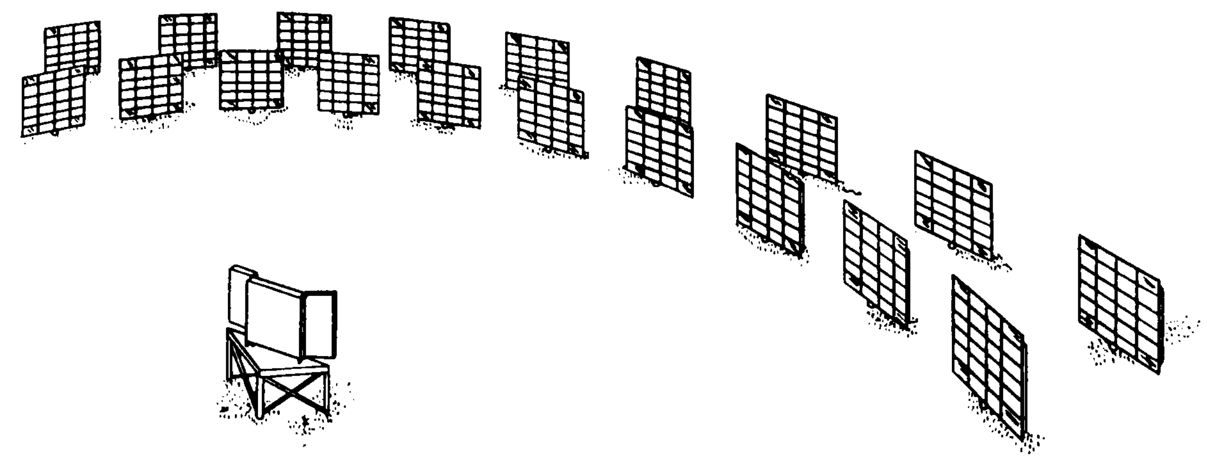
Since the design of the system has emphasized the use of existing technology and standard components, there have been no Subsystem Research Experiments identified. The advancement of solar technology is considered to be at the system level and as a result the design team has proposed the design, construction and operation of a Development Module during the design phase.

1.7.2 Development Module

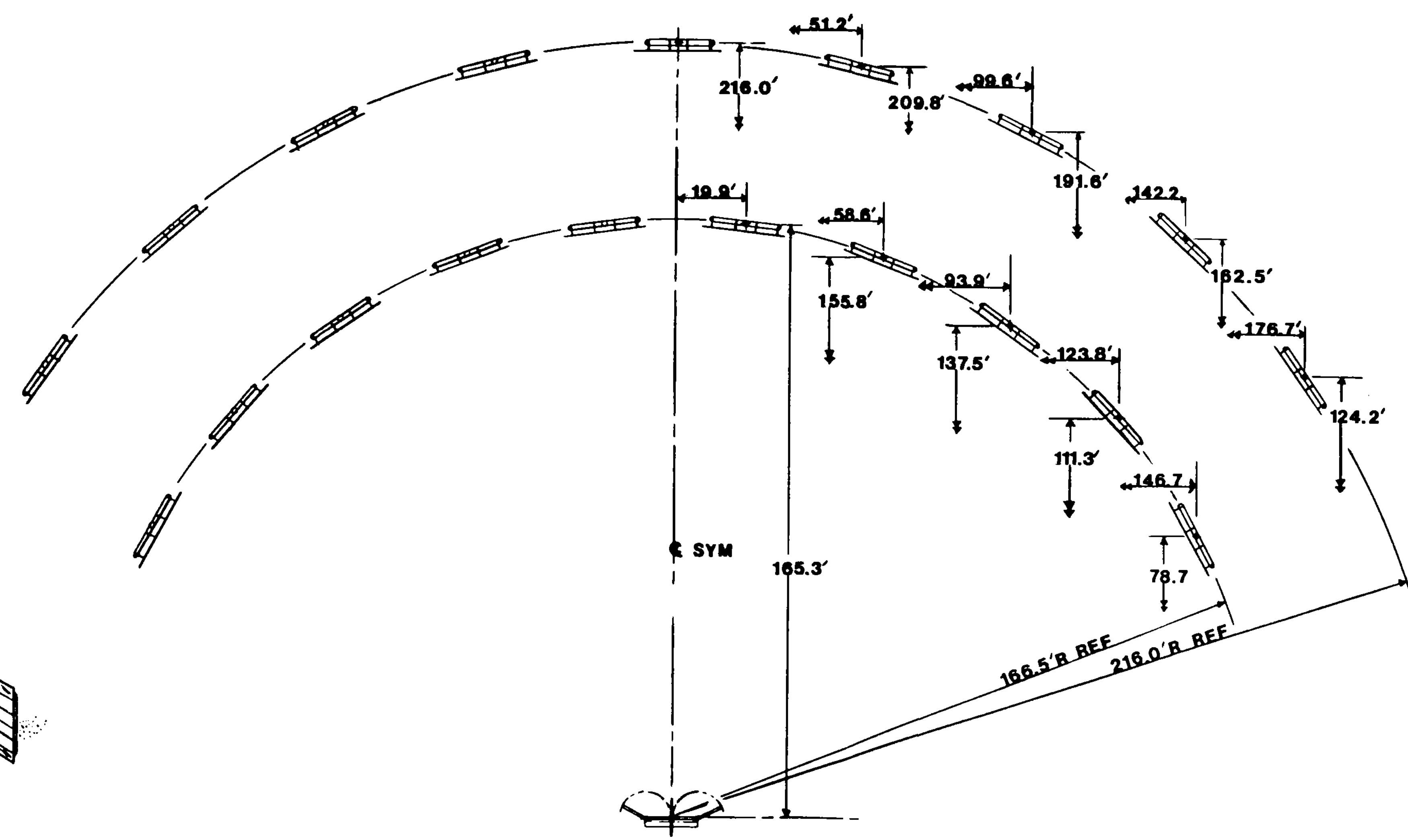
The purpose of operating the development module, which is a scaled down version of the solar retrofit system, would be to validate performance calculation, establish operational and safety procedures, develop control strate-ies, and provide a firm data point relative to construction cost estimates.

The Development Module will consist of two rows of heliostats (19) in a radial stagger arrangement with spacing between the 10 heliostats in the front row sufficient to allow the 9 heliostats in the back row to also focus on a ground level receiver. The receiver would be a flat plate configuration made up of the standard heat exchanger panels proposed for the 9.518 MW_t receiver. This field would be installed at the site of the full field. In fact, the heliostats would be the first two rows of the full field. The receiver loop and all valves and controls would be a scale down of the full sized loop and will operate in the same manner.

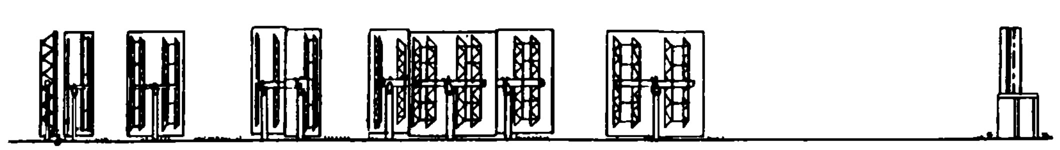
Figure 1-14 presents plan, elevation and isometric views of the Development Module.



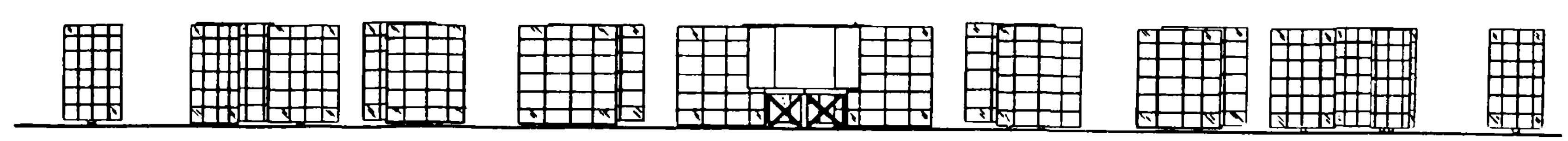
Perspective



Plot Plan



Looking East



Looking North

Figure 1-14

UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES	BLAKE LABORATORY SUITE 306, 726, S UNIVERSITY, LITTLETON, CO 80122
TOLERANCES	NINETEEN HELIOSTAT DEVELOPMENT MODULE
X = ± .125	

A cost analysis has been performed and shows that the Module can be constructed for $693,838 exclusive of the design and operational costs which are estimated to be $226,340.

1.7.3 Construction Phase

The construction phase is scheduled for an 18 month period immediately following the design phase. Figure 1-15 presents the schedule and milestone plan developed to show that the system construction can be completed within the alloted time period. The initial 3 months are devoted to bid advertising, sub contractor response, and contract award. The next 9 to 12 months provide time for subsystem installation and integration. The last three months are used for subsystem alignment and checkout.

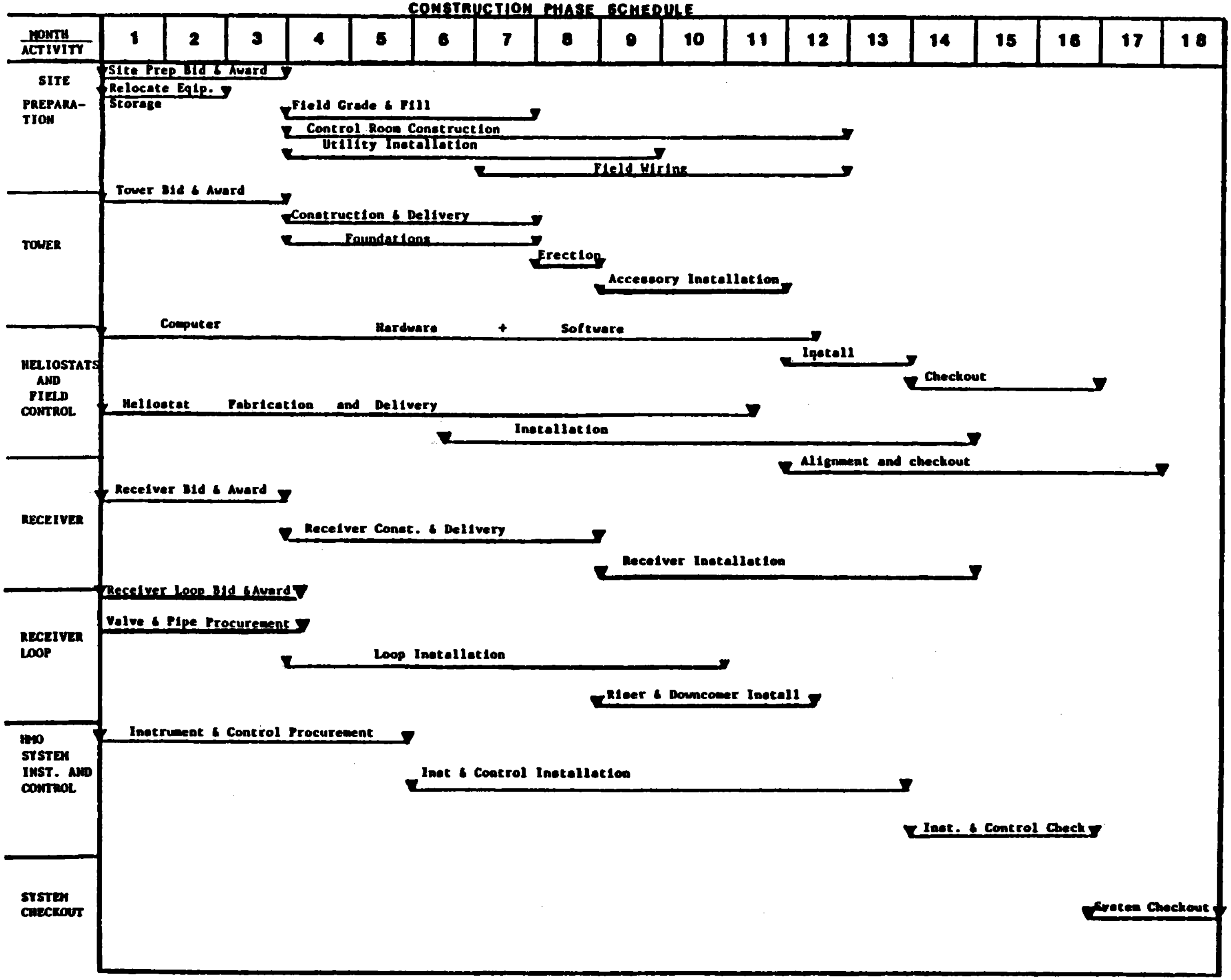
1.7.4 Post Construction Phases

There are three phases of project activity following the completion of system construction. The first is a short three month startup and checkout phase during which the user checks the operation and performance of all major components and subsystems relative to specifications. During this period the system is brought on-line using special operating procedures to assure the safety of personnel and hardware. Special runs will be made to establish the effect of solar operation on routine plant procedures.

The next phase is a 3-month performance validation phase during which a variety of special runs are made to permit system performance and acceptance tests to be made under operating conditions.

The last phase is a joint user/DOE operating phase covering an extended period of 60 months. During this time the plant will operate on a routine basis. In addition, large quantities of data related to all aspects of system operation and performance will be obtained and analyzed to firmly establish the system economics and reliability and provide a data base for future process heat system design.

FIGURE 1-15
CONSTRUCTION PHASE SCHEDULE



1.8 SITE OWNER"S ASSESSMENT

The following site owner's assessment was prepared by ARCO Oil and Gas Company's California District Gas Superintendent who is responsible for the North Coles Levee Natural Gas Processing Plant.

"This investigation of the use of solar power for process heating at the North Coles Levee gas plant shows that mechanically and technically, it has the potential to furnish large quantities of heat. Our original assumption was that construction of a solar facility would be pretty much a Research and Development type project that we could only enter into with financial aid from the Department of Energy. It is true that the economics are not as good as we normally require for our capitallized projects, since payout and rate of return do not meet present corporate guidelines. Therefore, Arco Oil and Gas Company cannot proceed with installation of the facility on its own, but the information will provide Corporate Management with enough data so that they can determine the degree of financial support that might be needed before a construction phase could be approved.

An advantage that solar energy has is that, once the equipment is installed, the raw material - sunshine - is never going to go up in price, while raw materials - fuels - for all other known heating equipment, with the possible future exception of fusion reactors, will continue to escalate. So, while it is true that equipment costs, installation costs and maintenance costs may continue to escalate indefinitely, this will be true for any heating system that we can envisage. Therefore, use of solar energy with its zero-cost fuel may become increasingly attractive and economic for industrial heating purposes.

Using solar energy to heat our heat transfer fluid (we call this fluid "heat medium oil") is the simplest way to use solar energy at North Coles Levee. Tie-in to the existing system is simple, control is simple, and the transition between sunlight hours and dark, or between sunny skies and cloudy skies is simple. And as long as there is enough sunlight to add heat to the system, it will be used, and will reduce natural gas consumption by a comparable BTU equivalent. The configuration using the central receiver is excellent, since it reduces both land requirements and piping costs from that required for multiple receivers. The system will operate easily and safely, and certainly will have no adverse environmental impacts.

1.8.1 Present Fuel Situation

Natural gas is becoming more scarce and higher in price each year - a trend that is quite certain to continue. The North Coles Levee field has already been in the position of having to purchase natural gas for its operations for several years - it does not produce enough gas to furnish its own energy needs. Just as an example, gas is so expensive and in such short supply that gas lift for oil wells is no longer economical. Coles Levee oil wells are being converted to mechanical lift as rapidly as possible, in spite of the fact that operating costs for gas lifted wells are much lower than for mechanically lifted wells except for one thing - natural gas fuel costs. Air Pollution Control District, Air Resources Board and Environmental Protection Agency regulations make alternative fuels expensive and difficult to use, since installation of exhaust scrubbers or catalytic converters, or finding some way of making emission trade-offs of some sort are often necessary to obtain the necessary approvals.

1.8.2 Solar Possibilities

Because of these things, any energy source that can take the place of some natural gas deserves thorough consideration. Certainly solar energy has some drawbacks. The quantity of solar heat falling on each square meter of the earth's surface is limited, and rather large land areas are needed to install the equipment that is required to concentrate this heat in a receiver that can convert it to useful energy. And of course the sun only shines during part of the day, and little or not at all on some days. Equipment for utilizing solar heat is not yet mass-produced, and therefore expensive. But outweighing these things, many areas in the western United States have plenty of land available, and these areas generally have a very high percentage of sunny days. Equipment for using solar energy has been designed, built and thoroughly tested, and there is no technological problem that would preclude successful operation.

Atlantic Richfield operates twenty five natural gas processing plants and is a participant in more than fifty plants that are operated by co-owners. Not all of these would be candidates for solar heating applications, of course, but many of them could be. Eight or ten ARCO plants and fifteen to twenty co-owner operated plants may have the proper conditions and land positions to make solar energy attractive. We have made no survey of total industry potential, or even just oil industry potential, but there certainly are several thousand industrial facilities that have potential uses for solar heat. Applications include heating of fluids for heat transfer uses, boiler feedwater heating, steam generation for processing heating and power generation, combustion air preheat for gas turbines, boilers and heaters, air heating for agricultural product drying, such as corn, walnuts, etc., and for many other uses limited only by man's ingenuity in designing methods to use the solar heat.

1.8.3 Plant Future

The chief uncertainty at the present time is the Life of the North Coles Levee plant. Current gas production decline rates in the areas serving the plant indicate that as these trends continue, seven to ten years might be as long as we could expect to operate the facility, at least in its present form. However, we are continually trying to obtain more outside gas for processing, and are optimistic that we will be successful. We are currently fractionating outside natural gas liquids for other companies, handling 50,000 gallons to 150,000 gallons per day at the present time. We expect to continue this service indefinitely, and we may add a butane splitter to our fractionation system so that we can separate iso-butane from normal butane. Addition of this unit will enable us to offer additional service and attract more fractionation customers. Additional drilling in the North Coles Levee field, and possibly other areas in the vicinity, may prove up new deeper production that could extend plant life for many years.

In any case, by the time that it will be necessary to commit funds to a construction phase for the solar project, we should know the results of our efforts to obtain other outside natural gas and natural gas liquid products for processing. We hope that within a few months we will be able to predict a plant life that will extend well beyond the years required for payout of a solar facility.

1.8.4 Conclusions

The work that has been done on this project has demonstrated that solar heating at the North Coles Levee plant could save natural gas fuel, but that payout is long and rate of return is quite low. It has demonstrated that the solar project is compatible with the existing facilities operationally and environmentally, and that there are no safety hazards or other detrimental characteristics. We have not yet reached a conclusion on plant life; however, by the time that the final design and construction phase needs to be entered into, we should be able to predict this with sufficient accuracy to properly determine its impact. This coupled with the final economics, will enable both ARCO Oil and Gas and Corporate Managements to evaluate the project worth and decide on our future course of action.

This work has been invaluable in that it demonstrates that many industrial facilities might benefit from the application of solar power, and that solar power may make a significant contribution to the nation's energy needs in the future.

SUPPLEMENT

TO THE

EXECUTIVE SUMMARY

FINAL TECHNICAL REPORT

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