ORIGINAL PAGE IS
OF POOR QUALITY

JPL NO. 9950 – 663

FINAL REPORT

FOR TASK 12 OF THE SMALL COMMUNITY

SOLAR THERMAL POWER EXPERIMENT

PARABOLIC DISH TECHNOLOGY FOR INDUSTRIAL PROCESS HEAT APPLICATION

April 9, 1981

Prepared for:

California Institute of Technology

Jet propulsion Laboratory

4800 Oak Grove Drive

Pasadena, California 91103

Contract 955637

CDRL Item No. 41

(NASA-CR-169061) THE SMALL COMMUNITY SOLAR THERMAL POWER EXPERIMENT. PARABOLIC DISH TECHNOLOGY FOR INDUSTRIAL PROCESS HEAT APPLICATION Final Report (Ford Aerospace and Communications) 169 p HC A08/MF A01

N82-26784

Unclas
G3/44 23512

Ford Aerospace &
Communications Corporation
Aeronutronic Division
Newport Beach, California 92663

SCSE Report 010
April 9, 1981

FINAL REPORT

FOR TASK 12 OF THE SMALL COMMUNITY

SOLAR THERMAL POWER EXPERIMENT

PARABOLIC DISH TECHNOLOGY FOR INDUSTRIAL PROCESS HEAT APPLICATION

Prepared for:

California Institute of Technology

Jet Propulsion Laboratory

4800 Oak Grove Drive

Pasadena, California 91103

Contract 955637

CDRL Item No. 41

Prepared by: R. E. Polzien and D. Rodriguez

Approved by: R. L. Pons, Technical Manager

Approved by: R. H. Babbe, Program Manager

Ford Aerospace &
Communications Corporation
Aeronutronic Division
Newport Beach, California 92663

9950-663

ORIGINAL PAGE IS
OF POOR QUALITY

Ford Aerospace &
Communications Corporation
Aeronutronic Division

Ford Road
Newport Beach, California 92660

G081-81-0061

April 30, 1981

California Institute of Technology
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91103

Attention: Mr. G. E. Saunders, MS 506/439
Senior Contract Negotiator

Subject: Final Technical Report
(CDRL) Task 12

Reference: Contract 955637

Gentlemen:

In accordance with the Contract Data Requirements List (CDRL), Item Number 41 of the referenced contract, enclosed is the Parabolic Dish Technology for Industrial Process Heat (IPH) Application Final Technical Report, SCSE-010.

Should you have any questions concerning this submittal or the referenced contract in general, please contact me at (714) 759-6068.

Very truly yours,

G. Kim Cashmer
Contract Administrator
Advanced Development Operation

GKC:TLG:rw
Enclosures

ORIGINAL PAGE IS
OF POOR QUALITY

CONTENTS

SECTION		PAGE
1	INTRODUCTION AND SUMMARY	1
	1.1 Introduction	1
	1.2 Summary of Results	1
2	STUDY REQUIREMENTS	3
	2.1 Statement of Work	3
	2.2 Structure of Study	5
	2.3 Selection of Baseline IPH Application	7
	2.3.1 Exxon Application	7
	2.3.2 Field Geometry	11
	2.3.3 Thermal Conversion Processes	11
3	OPTIMIZATION CODE VERIFICATION	21
	3.1 Precontractual Work.	21
	3.2 Contracted Optimization Code Verification	24
	3.2.1 Baseline Application Results	24
	3.2.2 JPL Coupling Effects	24
	3.2.3 Standard Pipe Sizes.	28
	3.2.4 Cost of Energy	28
4	CONVENTIONAL CONSTRUCTION COST MODEL	30
	4.1 Pipe Network Detailed Design	30
	4.2 Costing Assumptions	39
	4.3 Cost Data.	41
	4.4 Cost Matrix	43
	4.5 Results.	43
5	UNCONVENTIONAL CONSTRUCTION	51
	5.1 Pre-fabricated Omega-Shaped Expansion Joints	51
	5.2 Flexible Hose Expansion Joint	53
	5.3 Prefabricated Post Supports	53
	5.4 Automated Welding	57
	5.5 Buried Pipe	60
	5.6 Cost Results	60

CONTENTS (Continued)

SECTION		PAGE
6	PARAMETRIC STUDY RESULTS.	63
	6.1 Alternate Temperatures	63
	6.2 Alternate Plant Size	63
	6.3 Results	65
7	RISER AND DOWNCOMER DESIGN	68
	7.1 Design Considerations	68
	7.2 Selected Design	73
	7.3 Cost Estimates	76
	7.4 Cost Reduction Modifications	76
	7.4.1 Modifications to the LCC Design	76
	7.4.2 HA/DEC Dish Design	80
	7.4.3 Single Post Design	80
8	CONCLUSIONS AND RECOMMENDATIONS	83
	8.1 Conclusions	83
	8.2 Recommendations	84
APPENDICES		
A	Shading Loss Analysis	A-1
B	Optimization of Pipe Network Costs	B-1
C	Computer Cost Matrix Printouts.	C-1
D	Cost Data.	D-1
E	FACC Network Optimization Computer Output Sheets and Input Data	E-1

ILLUSTRATIONS

FIGURE		PAGE
2-1	IPH Study Program Structure.	6
2-2	Location of California Heavy Oil Fields.	9
2-3	72 Dish Field Geometry	13
2-4	Unfired Boiler System Schematic.	16
2-5	Unfired Boiler Sensitivity of Mass Flowrate to Solar Field Discharge Temperature.	17
2-6	Direct Generation of Steam in Receiver	19
4-1	Baseline STEOR Pipe Network.	31
4-2	Feeder Piping Network.	32
4-3	Weld and Pipefitting Labor Estimate.	33
4-4	Loads and Stresses for Field Constructed Expansion Joints. .	35
4-5	Maximum Stress and Thermal Expansion Loads in Factory Fabricated Bent Omega Joints	36
4-6	Combined Flexural and Pressure Stress in Water Line.	37
4-7	Maximum Spacing Between Water Pipeline Supports.	38
4-8	Insulation Cost Comparison	42
4-9	Baseline Pipe Network Cost Matrix.	44
4-10	Comparison of FACC and JPL Pipe Network Cost for STEOR Application.	45
4-11	Comparison of Labor and Material Cost for STEOR Pipe Network.	46
4-12	Overall Comparison of Pipe Network Cost for STEOR Application.	48
4-13	Distribution of Labor and Material Costs	49
4-14	Analysis of Labor and Material Costs, 72 Dish STEOR Pipe Network, FACC Cost Analysis.	50

ORIGINAL PAGE IS
OF POOR QUALITY

9950-699

ILLUSTRATIONS (Continued)

FIGURE		PAGE
5-1	Flexible Hose Thermal Expansion Joint.	54
5-2	Pipe Anchors	55
5-3	Pipe Supports.	56
5-4	AV-2 Pipe Welder	58
5-5	Astromatic Tube Welding System	59
5-6	Buried Pipe Concept.	61
5-7	Cost Reductions Using Unconventional Construction Techniques	62
6-1	Steam Pressure Requirements for STEOR.	64
7-1	Flexible Hose Design Across Gimbal Joints.	69
7-2	Flexible Hose Design Across Azimuth Gimbal	70
7-3	Coil Radius vs. Number of Turns for Coiled Tube Flexible Azimuth Joint	72
7-4	Flex Hose Assembly, LCC Elevation Gimbal	74
7-5	Flex Hose Assembly, LCC Azimuth Gimbal	75
7-6	12 Meter Diameter Collector, Equatorial Mount.	81
7-7	Post Supported Dish Design	82

9950-663

ORIGINAL PAGE IS OF POOR QUALITY

TABLES

TABLE		PAGE
2-1	Task 12 - IPH Study Requirements	4
2-2	Baseline IPH Application Solar Thermal Enhanced Oil Recovery	10
2-3	Baseline Case Field Geometry	12
2-4	STEOR Thermal Conversion Processes Considered for Baseline IPH Network	14
2-5	Comparative Costs for Alternate STEOR Thermal Conversion Processes	20
3-1	Optimization Code Verification Procedure	22
3-2	FACC Optimization Algorithm	23
3-3	Comparison of Pipe Network Optimization Computations FACC vs. JPL Code	25
3-4	Comparison of JPL and FACC Cost Optimization Techniques - Essential Features	26
3-5	Optimization Code Comparison Results	27
3-6	FACC Optimization Results Comparison of Real Vs. Mathematical Pipe Sizes	29
4-1	Cost Estimating Assumptions	40
5-1	Approaches to Reduced Cost	52
6-1	Results of Optimization Analyses for Alternate STEOR Pipe Networks - $1500/kW_t$ Cost of Energy	66
6-2	Results of Optimization Analyses for Alternate STEOR Pipe Networks - $500/kW_t$ Cost of Energy	67
7-1	Cost Estimate, Thermal Transport Modifications to LCC Dish	77
7-2	Breakdown on Production Cost Estimate to Incorporate Risers/Downcomers on LCC Dish	78
7-3	Potential Riser/Downcomer Cost Reductions for LCC	79

SECTION 1

INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

This report summarizes the results of a study performed by the Aeronutronic Division of Ford Aerospace & Communications Corporation (FACC) for the Jet Propulsion Laboratory (JPL) as part (Task 12) of the Small Community Solar Thermal Power Experiment, Phase II. The study objectives were to investigate several aspects of incorporating a thermal energy transport system (ETS) into a field of parabolic dish collectors for industrial process heat (IPH) applications. Specific objectives were to:

- Verify the mathematical optimization of pipe diameters and insulation thicknesses calculated by a JPL computer code.
- Verify the cost model developed by JPL for pipe network costs using conventional pipe network construction.
- Develop a design and the associated production costs for incorporating risers and downcomers on a JPL specified Low Cost Concentrator (LCC).
- Investigate the cost reduction of using unconventional pipe construction technology. This investigation was an uncontracted effort performed by FACC in connection with this study.

These objectives were accomplished by a detailed analysis of the pipe network design and costs for a particular IPH application, specifically solar thermally enhanced oil recovery (STEOR). The selected application has been under study by Exxon Research and Engineering Company, Linden, New Jersey and involves the hybrid operation of a solar powered steam generator in conjunction with a steam generator using fossil fuels to generate STEOR steam for the wells in Exxon's Edison Field, located near Bakersfield, California.

The STEOR application provided a baseline pipe network geometry used for optimization studies of pipe diameter and insulation thickness, and for development of comparative cost data. It also provided operating parameters for the design of riser/downcomer modifications to the Low Cost Concentrator (LCC).

1.2 SUMMARY OF RESULTS

The JPL methodology and mathematical procedures for optimization of pipe network diameters and insulation thicknesses are substantially validated by comparing results calculated by the JPL code with those computed for an identical case (pipe network geometry and cost model) using a FACC-derived optimization code based on a different mathematical approach. The comparison was based on conventional pipe network construction.

A detailed design and cost analysis of the solar thermally enhanced oil recovery (STEOR) pipe network shows that the pipe network costs compare reasonably well (within 20%) with those predicted by the JPL cost model. FACC recommends a minor modification in the way which the JPL code calculates the cost of thermal expansion joints which will bring the cost comparison within 10 percent. Other than this suggested change in calculation technique the JPL conventional pipe network cost model is substantially verified based on the results of this study.

The non-contracted FACC study conducted as part of this overall effort shows that the introduction of various non-conventional pipe network construction techniques can reduce the conventional costs by about 33%. The techniques which offer the reduction are:

- Use of flexible hose to replace field constructed expansion joints
- Use of pile driven prefabricated pipe supports
- Use of field shop construction and automated welding equipment

In addition a buried pipe approach is described herein which may offer large potential cost reductions.

The addition of risers and downcomers to the LCC presents a significant cost increase ($29/m^2) to the overall IPH system costs. The high costs are a particular problem with the LCC due to its design characteristics which increase the difficulty of providing flexible gimbal lines at the azimuth and elevation joints. The LCC design characteristics which contribute to the difficulty are: 1) the large separation between elevation and azimuth axes, 2) the large diameter azimuth wheel and track design, and 3) the unique outboard location of the elevation trunnions which are designed solely for inverting the dish.

Risers and downcomers for more conventional dishes show significant cost reductions since the orthogonal axes are generally co-located. It is estimated, for example, that riser/downcomer costs for a single post design could be reduced between 40 and 50 percent based on a design rationale presented in this report.

A more detailed summary of the conclusions and recommendations of the study is presented in Section 8 of this report.

SECTION 2

STUDY REQUIREMENTS

2.1 STATEMENT OF WORK

The key requirements of the JPL Statement of Work are summarized in Table 2-1. The work is divided into Tasks A and B. Task A includes assessment of the JPL piping methodology (computer code) and verification of the JPL conventional cost model. Task B includes the design of modifications to the SCSE (EE-1) solar electric system to incorporate IPH features, developing costs for the modifications, and generating pipe network costs parametrically as a function of IPH temperature and plant size.

Task A

The JPL pipe network optimization methodology utilizes a Lagrange multiplier method for calculating the pipe diameters and insulation thickness of individual pipe segments. This was used to find the minimum overall pipe network costs. The computed pipe diameters, lengths, and insulation thicknesses were then applied to the JPL conventional construction cost model to calculate the cost of the thermal transport network.

A pipe network optimization computer program based on a different mathematical approach was developed by FACC. Both the FACC and JPL programs were used to calculate the baseline STEOR pipe/insulation sizes and cost (based on the JPL conventional cost model). Assessment of the JPL optimization methodology consisted of comparing the results of these two codes.

Evaluation of the JPL conventional cost model was accomplished by comparing the results of a detailed cost analysis of the baseline STEOR pipe network with those predicted by the JPL cost model.

Task B

The major modification to the SCSE system required for its use in the selected IPH application would be the addition of riser/downcomer assemblies to the dish (no significant modifications will be requireed for the receiver to be used for steam generation). These assemblies must be capable of accommodating the dish motion about the elevation/azimuth gimbals.

The portion of Task B related to the parametric development of pipe network cost estimates as a function of IPH temperature and plant size was addressed by using the FACC pipe network optimization code and the JPL conventional cost model. Temperature variation was examined by generating pipe network costs for the baseline STEOR application and for two other oil field pressures corresponding to two lower steam temperatures. The variation of plant size was examined by maintaining the baseline STEOR temperature/pressure conditions, and increasing the plant size.

TABLE 2-1. TASK 12 - IPH STUDY REQUIREMENTS

- ● REQUIRED BY JPL STATEMENT OF WORK
- * NON-CONTRACTED WORK INCLUDED BY FACC

TASK A

- ● ASSESS THE JPL/TURNER PIPING OPTIMIZATION METHODOLOGY (COMPUTER CODE)
- ● VERIFY THE JPL CONCEPT (PRIMARILY COST) FOR CONVENTIONAL IPH THERMAL TRANSPORT
- * EVALUATE THE IMPACT OF ADVANCED (NONCONVENTIONAL) CONSTRUCTION TECHNOLOGY ON TRANSPORT SYSTEM COST

TASK B

- ● CONDUCT A PRELIMINARY DESIGN (CONVENTIONAL CONSTRUCTION) TO MODIFY THE SCSE (EE-1) SOLAR ELECTRIC SYSTEM TO INCORPORATE IPH FEATURES
- ● DEVELOP COST MODELS FOR PRELIMINARY DESIGN THUS DEFINED
- ● GENERATE COST ESTIMATES PARAMETRICALLY AS A FUNCTION OF IPH TEMPERATURE REQUIREMENTS (3) AND PLANT SIZE (2)
- * RERUN AT LEAST ONE OF THE ABOVE CASES USING AN ADVANCED (NONCONVENTIONAL) COST MODEL

Uncontracted Effort

FACC also conducted additional work to enhance the overall effort as indicated by the items in Table 2-1 flagged with an asterisk. The use of unconventional pipe network construction technology was studied and evaluated as part of Task A. The cost benefits derived from these approaches were incorporated as modifications to the conventional cost matrix in order to predict potential reductions in pipe network costs.

As part of the parametric study conducted in Task B, an additional case was computed based on the use of advanced, reduced cost, construction techniques.

2.2 STRUCTURE OF STUDY

The various elements of the IPH study have been addressed by selecting a baseline IPH application which provided the input data and requirements for all of the tasks to be performed. Figure 2-1 illustrates the interrelationship between the selection of the baseline IPH application and the work elements comprising the overall study effort.

All elements were keyed to the baseline solar thermal enhanced oil recovery (STEOR) application. The requirements of this application were used to size the solar collector field and define the thermal process parameters: pressure, temperature, and flowrates. The baseline field geometry and thermal properties were then specified in both JPL and FACC computer codes. These were used to calculate the pipe diameters and insulation thicknesses which in turn yielded minimum cost of the pipe network system*. A favorable comparison of the two sets of diameters and thicknesses served as a mutual validation of the two codes, thereby satisfying part of the Task A study requirement.

The remainder of Task A was completed by using the field geometry, pipe sizes, and insulation thicknesses calculated in the baseline optimization as the basis for generating an actual pipe network design. This involved the specification of fittings, valves, expansion joints, pipe guides, and anchors for the network. A bill of material was constructed and a detailed, bottoms-up costing of labor and material elements performed. These costs were entered into a cost matrix from which the total network cost was computed using appropriate labor rates, taxes, and indirect charges. The resulting pipe network cost was compared to the corresponding cost predicted by the JPL model as part of the earlier pipe network optimization computer code verification task. An analysis and evaluation of these results provided the basis for verification of the JPL conventional cost model.

The additional (uncontracted) effort performed as part of Task A was to identify and evaluate several unconventional or advanced approaches to pipe network construction which have the potential of reducing construction costs. This was accomplished by modifying the conventional cost matrix to account for the benefit of alternate low cost construction techniques and computing the

*Capital cost plus cost of thermal and frictional energy losses.

9950-663

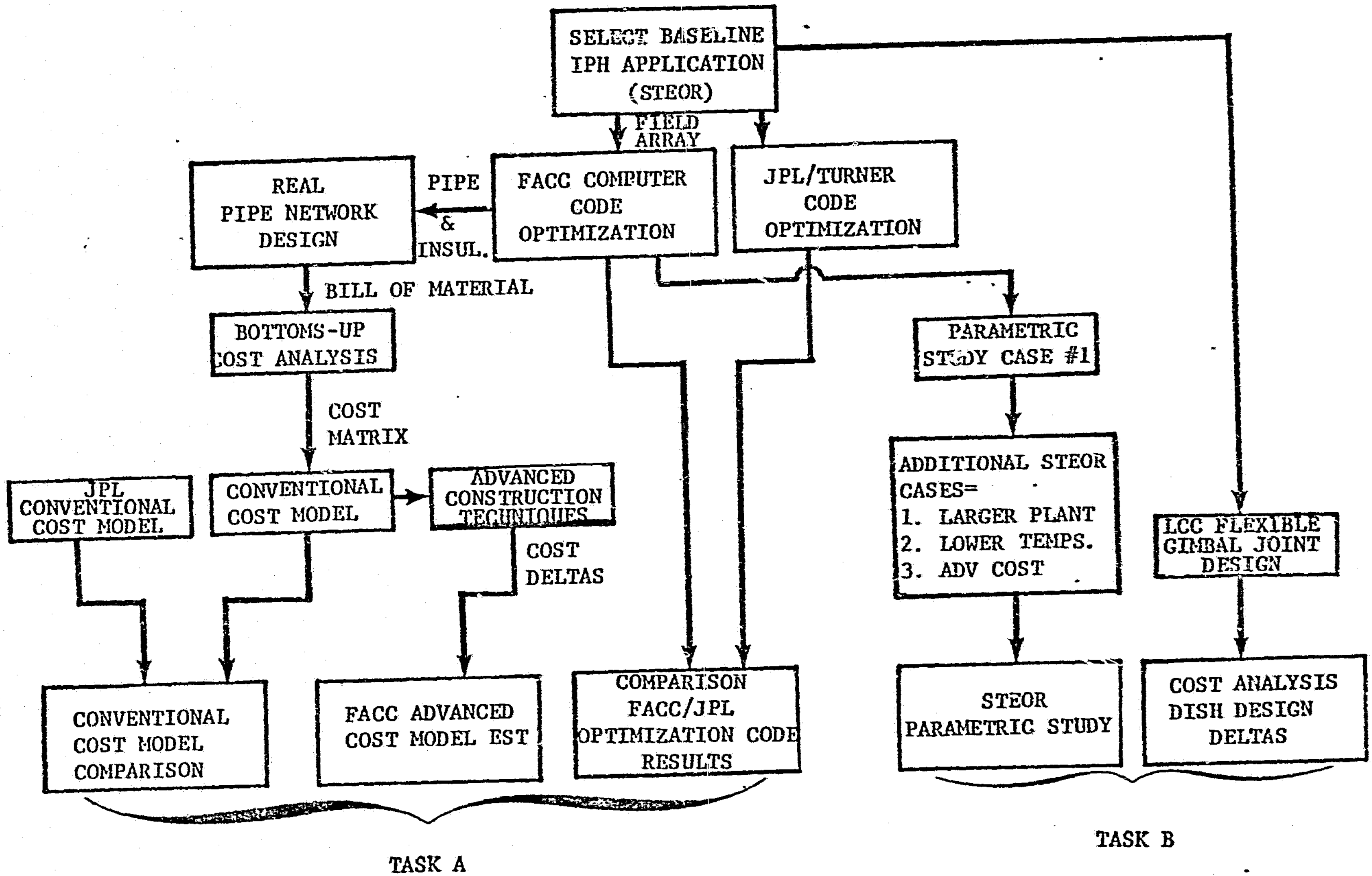


FIGURE 2-1. IPH STUDY PROGRAM STRUCTURE

resultant pipe network costs for comparison with the conventional construction cost estimate. Two of the advanced construction techniques, automated welding and prefabricated pipe supports, had been previously identified in JPL studies. Two other approaches were originated by FACC.

As shown in Figure 2-1, Task B was accomplished by performing a detailed design of the riser/downcomer assembly for the JPL-specified Low Cost Concentrator (LCC) using the baseline STEOR thermal parameters and flowrate requirements. Figure 2-1 identifies this task as the LCC flexible gimbal joint design. A cost analysis of the detailed riser/downcomer design was then prepared.

The second portion of Task B, the parametric study, used the baseline STEOR network and heat requirement, but recomputed the flowrates to correspond to two lower field pressures and temperatures. The lower temperature STEOR requirements were then input to the FACC pipe optimization code which reoptimized the pipe and insulation sizes and recomputed the pipe network cost for the reduced temperature conditions. The JPL conventional cost model was used for the pipe network cost calculation.

The baseline STEOR network and parametric analyses were computed using a JPL specified cost-of-energy of $\$1500/kW_t$. JPL later requested that the parametric study cases be reoptimized using a cost-of-energy of $\$500/kW_t$. Parametric results were, therefore, calculated for both cost-of-energy values.

The baseline STEOR case was also modified to study the effect of a larger network size (by 4.8 times) for the same temperature/pressure conditions as the baseline case. This larger size corresponds to the solar system required to completely replace the annual steam output of a fossil fuel generator.

An additional computer analysis (uncontracted work) was performed to determine the cost of the baseline STEOR pipe network using the JPL advanced (or unconventional) pipe network cost model.

2.3 SELECTION OF BASELINE IPH APPLICATION

A realistic solar IPH application was selected to define the field geometry and thermal requirements for the baseline pipe network. Potential process heat applications for the baseline case were identified at the SERI Solar Industrial Process Heat Conference held in Houston, Texas during December 16-19, 1980. A review of the potential applications showed that most were either too small (repowering of food processing plants, etc.) or too constrained by interfacing requirements with existing plant equipment or plant real estate limitations to be well suited to the purposes of this study. The exceptions were the STEOR applications described below.

2.3.1 EXXON APPLICATION

An application which appeared well suited to the objectives of this study was the solar thermal technology for enhanced oil recovery application described in a special presentation made by the Solar Thermal Systems Division of Exxon Enterprises, at the SERI IPH Meeting. In this application, injection of steam into oil fields is used to increase the production of heavy oil - like that found in southern California - from less than 10% to as much as 50% of the oil in place. The increases are currently realized by using steam produced from burning fossil fuels. The technique used is one in which steam is continuously injected into injection wells to force out oil in adjacent or producing wells. A considerable potential for energy savings exists because from one-sixth to one-third of the oil recovered is normally used to fire the fossil fueled steam generators.

The Exxon application is based on the Edison Field located about seven miles southeast of Bakersfield, California, as shown in Figure 2-2. The Edison field requirements are reasonably representative of Kern County, California heavy oil fields, except that the steam injection pressure is among the highest found in the area.

Separate investigations have been conducted by Exxon on the technical and economic feasibility of solar thermal technologies for enhanced oil recovery applications at the Edison field. Under DOE Contract No. DE-AC03-79CS30307, an Exxon-led team investigated the use of line focusing distributed receiver systems. Also Exxon was a subcontractor to Martin-Marietta on a team which examined the use of heliostat central receiver systems under DOE Contract No. DE-AC03-79SF10737. These studies suggested that solar energy systems could be technically capable of displacing fossil energy for enhanced oil recovery. Predicted system economic performance was highly dependent on uncertain future factors including: energy displaced, capital and operating costs, special tax and regulatory incentives, and displaced fossil energy cost determinants including taxes and escalation. A preliminary market screening analysis of California oil reservoirs indicated a significant potential for solar applications.

FACC contacted Exxon Enterprises for additional information on the STEOR application. Exxon was very helpful and provided copies of the final report for the line focusing distributed receiver system study. When the intent of the pipe network study was explained, Exxon suggested a "starter" solar system for which they had examined alternate solar collection technologies: 1) central receiver heliostats, 2) line focusing troughs, and 3) point focusing dishes. In the "starter" system application, a solar powered system would work in parallel with a fossil fueled steam generator to deliver steam continuously to the injection wells. The solar unit was sized to supply or replace about 20% of the annual fossil fuel steam generator output, rated at 25 MBTU/hour. At conditions of maximum insolation the solar generator contributes about 75% of the total steam generation and the fossil fuel unit is modulated to contribute the 25% balance. During the night, or conditions of zero insolation, all the steam is provided by the fossil fuel unit.

Table 2-2 summarizes the basic requirements of the STEOR requirement. The hybrid mode of operation has been described in conversations with Exxon Enterprises and has not been independently investigated by FACC.

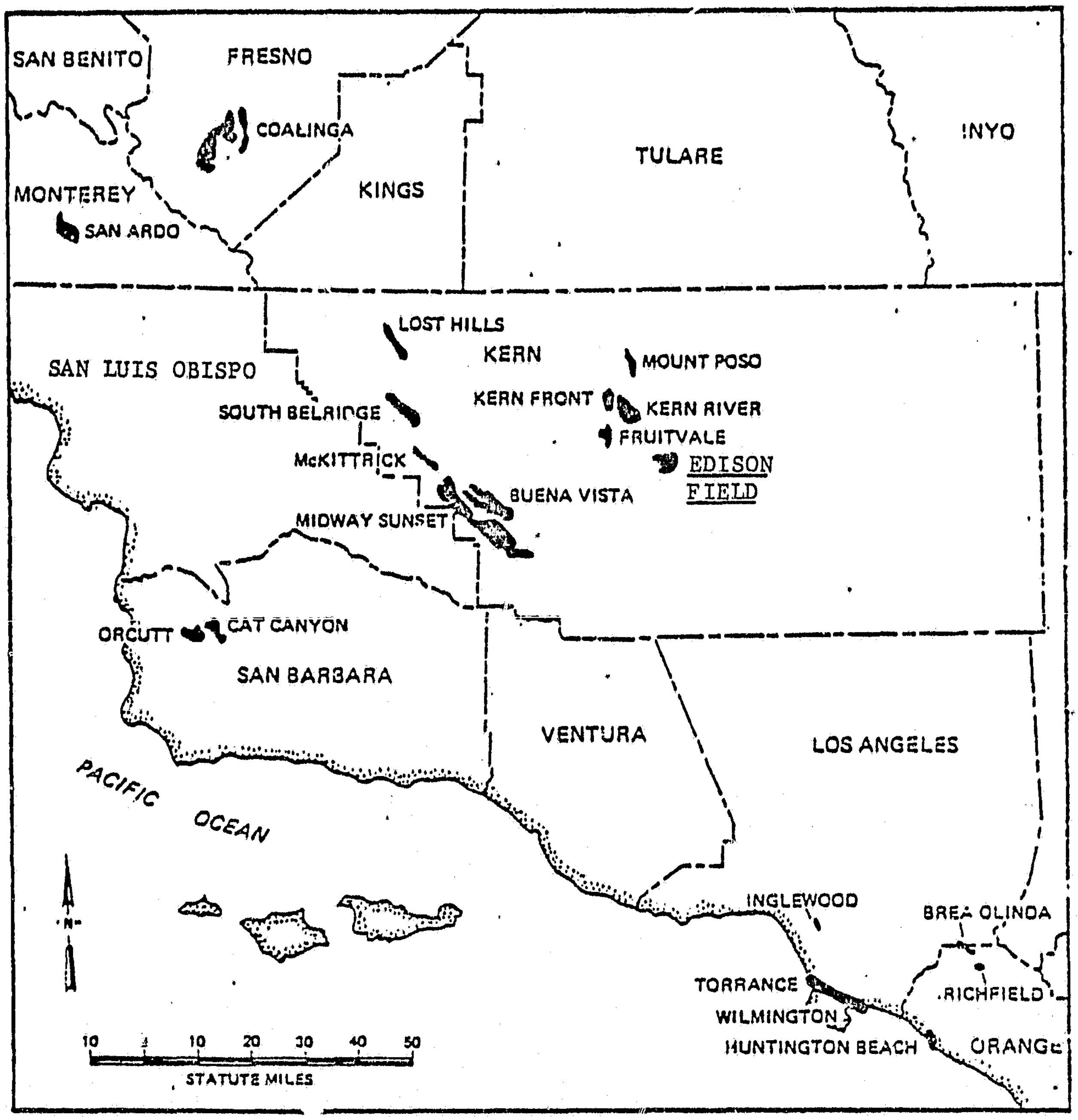


FIGURE 2-2. LOCATION OF CALIFORNIA HEAVY OIL FIELDS

TABLE 2-2. BASELINE IPH APPLICATION SOLAR THERMAL ENHANCED OIL RECOVERY

APPLICATION:

- SOLAR THERMAL ENHANCED OIL RECOVERY - EXXON COMPANY U.S.A.'s EDISON FIELD - BAKERSFIELD, CA
- "STARTER" SOLAR APPLICATION INVESTIGATED BY EXXON ENTERPRISES, INC., FLORHAM PARK, N.J.
- SOLAR STEAM GENERATOR TO OPERATE IN HYBRID MODE WITH 25 MBTU (RATED) FOSSIL FUELED STEAM GENERATOR
- SOLAR GENERATOR SUPPLIES ABOUT 20 PERCENT OF HEAT

STEOR GENERATION REQUIREMENTS:

- INPUT - PRESSURIZED & TREATED FEEDWATER
- OUTPUT - SATURATED STEAM AT 527°F, 850 psig, AT SOLAR FIELD DISCHARGE HEADER (80% QUALITY STEAM AT WELL HEAD)
- TOTAL HEAT LOAD: 39000 MBTU/YEAR (11.42×10^6 KWH/YR)
- ANNUAL INSOLATION: 720000 BTU/FT^2-YEAR (FRESNO TMY) (2270 KWH/M^2-YEAR)

2.3.2 FIELD GEOMETRY

The Low Cost Concentrator (LCC) development by General Electric Company was designated by JPL as the baseline dish for the present IPH study. The LCC was selected by JPL because it has well documented design characteristics. Table 2-3 summarizes the LCC dish spacing and field sizing parameters used to determine the baseline field geometry. A simplified layout of the field is shown in Figure 2-3.

Ideally, the optimum sizing and geometry of a dish-solar array should take into account all of the system cost elements, including the cost of real estate, the pipe-network costs and thermal and shading losses. Selection of the baseline field geometry did not include the cost of real estate. Instead, the field was made as compact as possible to minimize the lengths of pipe required, but with sufficient spacing between dishes to:

(1) Have acceptable mutual shading losses from adjacent dishes and,

(2) Permit truck access for construction and maintenance.

A brief analysis of shading losses was performed to determine their variation with ground cover ratio (packing density) and for various north-south (LNS) and east-west (LEW) spacings (expressed in dish diameters). The results of this study are documented in Appendix A. The results show that a ground cover ratio of 0.42 and a 1.25 LNS x 1.50 LEW dish spacing will result in an annual shading loss of about 8 percent. When this shading loss was combined with the LCC collection efficiency and a nominal allowance made for thermal losses (see Table 2-3), the field size calculated to satisfy the STEOR thermal requirement was 72-1/2 dishes. For purposes of this study a 72 dish, 9x8 field array was used as shown in Figure 2-3. This field geometry is about the most compact considered practical within the constraints of vehicle access and acceptable shading losses.

The pipe network configuration consists of 18 identical feeder lines, each servicing four dishes and oriented in a north-south direction. The feeders supply (and tap) a centralized header which discharges at the east end of the field. The orientation of feeder and header lines was derived by minimizing the number of pipe sizes and the summed product of diameter times length for the various segments, both of which translate directly to pipe network cost.

2.3.3 THERMAL CONVERSION PROCESSES

The optimum thermal process for converting treated and pressurized feedwater to saturated steam at the solar field discharge header was not self-evident. In earlier studies of trough collector fields for an Edison field application, Exxon Enterprises had considered several thermal processes. These were reevaluated for the dish-solar system. Table 2-4 lists the three thermal conversion processes examined and a brief summary of the evaluations.

TABLE 2-3. BASELINE CASE FIELD GEOMETRY

- SHADING CONSIDERATIONS: 1.25 LNS x 1.50 LEW (0.83 AR) SELECTED AS OPTIMUM DISH SPACING FOR 0.45 PACKING FRACTION
  - THIS GEOMETRY CONSIDERED MINIMUM SPACING FOR DISH CONSTRUCTION AND MAINTENANCE OF FIELD
  - ANNUAL SHADING LOSS - 8 PERCENT

- FIELD SIZING: LCC 12m DIA DISH, $\eta_{COL} = 0.68$, $A_C = 113.1\ m^2$

  SHADING LOSS, $\eta_{SHADE} = 0.92$

  THERMAL TRANSPORT LOSS $\eta_{ETS} = 0.98$

  ANNUAL INSOLATION, H = 2270 KWH/m^2 - YEAR (FRESNO TMY)

  ANNUAL HEAT LOAD, $Q_R = 11.42 \times 10^6$ KWH/YEAR

  NUMBER DISHES REQUIRED:

  $$N = Q_R/A_C\ \eta_{COL}\ \eta_{SHADE}\ \eta_{ETS}\ H$$

  $$= [11.42 \times 10^6/(113.1)(0.68)(0.92)(0.98)(2270)]$$

  = 72.5 DISHES
  (72 DISHES USED FOR FIELD SYMMETRY)

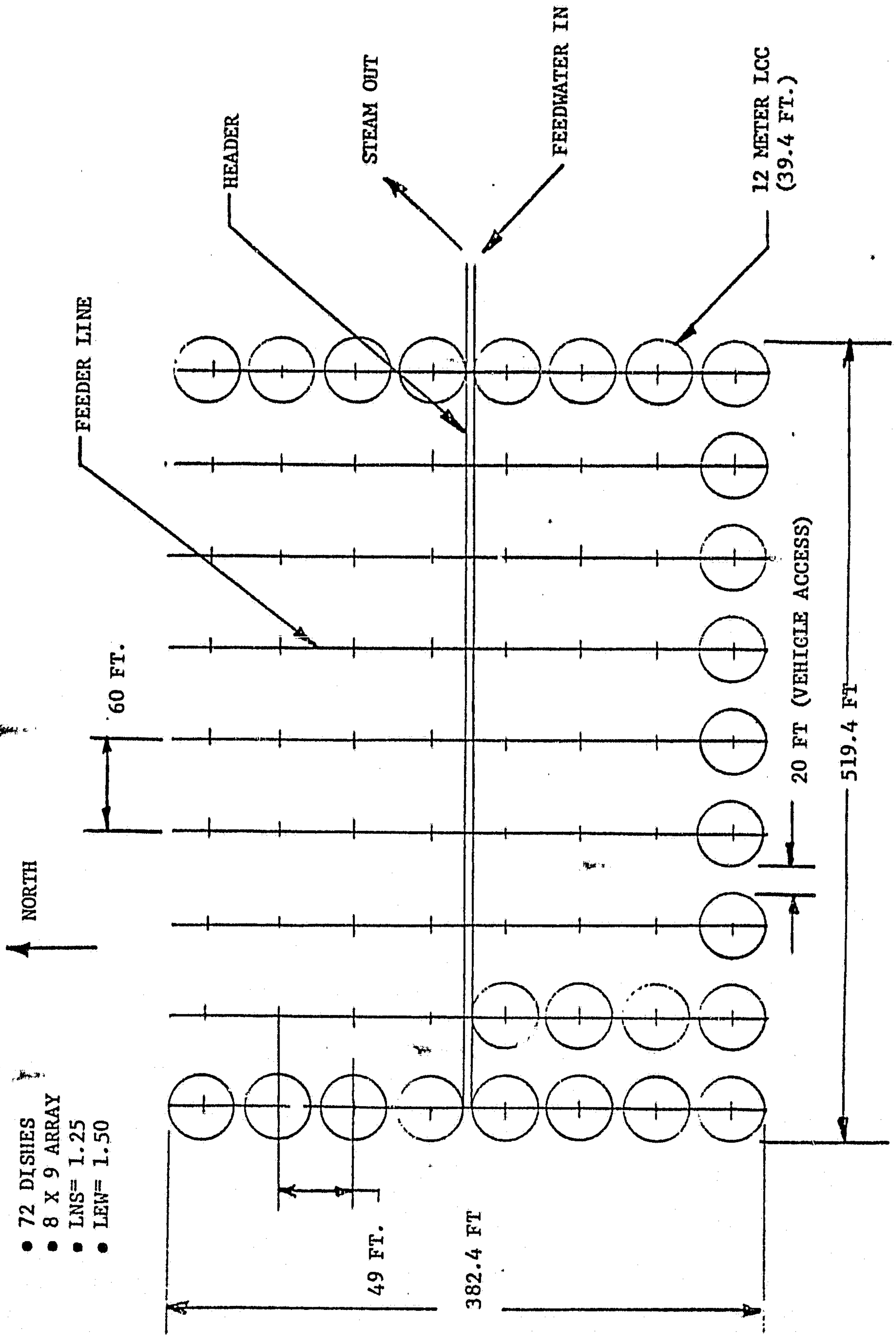


FIGURE 2-3. 72 DISH FIELD GEOMETRY

TABLE 2-4. STEOR THERMAL CONVERSION PROCESSES CONSIDERED FOR BASELINE IPH NETWORK

PROCESS	DESCRIPTION	EVALUATION
• FLASH SEPARATOR.	HIGH PRESSURE (1200 PSI) WATER DIRECT HEATED TO 600^oF IN SOLAR RECEIVERS. FLASHED (THROUGH VALVE) TO WATER/STEAM AT 850 PSIA.	1. RESULTS IN ONLY 2 PERCENT OF WATER CONVERTING TO STEAM. 2. LARGE FLOW RATE AND TRANSPORT LOSSES.
• UNFIRED BOILER	HEAT TRANSFER FLUID (THERMINOL 88) HEATED IN RECEIVERS AND PASSED IN SERIES THROUGH CENTRAL BOILER AND FEED WATER HEAT EXCHANGER.	1. LOW STRESS UNPRESSURIZED PIPE NETWORK. 2. EFFICIENCY VERY SENSITIVE TO TEMPERATURE OF DELIVERED H.T. FLUID. 3. COST OF UNFIRED BOILER AND FEED-WATER HEAT EXCHANGERS IS CHARGEABLE TO ETS. 4. FIRE HAZARD OF THERMINOL. 5. HIGH THERMINOL FLOW RATES.
• DIRECT GENERATION OF 850 PSI STEAM WITHIN RECEIVER.	70^oF FEEDWATER PUMPED TO 850 PSI AND CONVERTED DIRECTLY TO STEAM WITHIN INDIVIDUAL RECEIVERS.	1. NO NEED TO INSULATE FEED WATER LINES. 2. NO THERMAL CONVERSION EQUIPMENT. 3. ACCEPTABLE SAFETY. 4. SOME RECEIVER MODIFICATION MAY BE REQUIRED.

Flash Separator. The flash separator consists of heating water pressurized to 1200 psia in the individual receivers and passing the collected hot water through a central expansion valve where it is isenthalpically expanded to 850 psia to produce a liquid/vapor mixture. However, this process results in only 2% of the water converting to steam. The residual water must then be repumped to 1200 psia and returned to the individual receivers for reheat. The large flowrates and heat losses which result from this process eliminated it from further consideration.

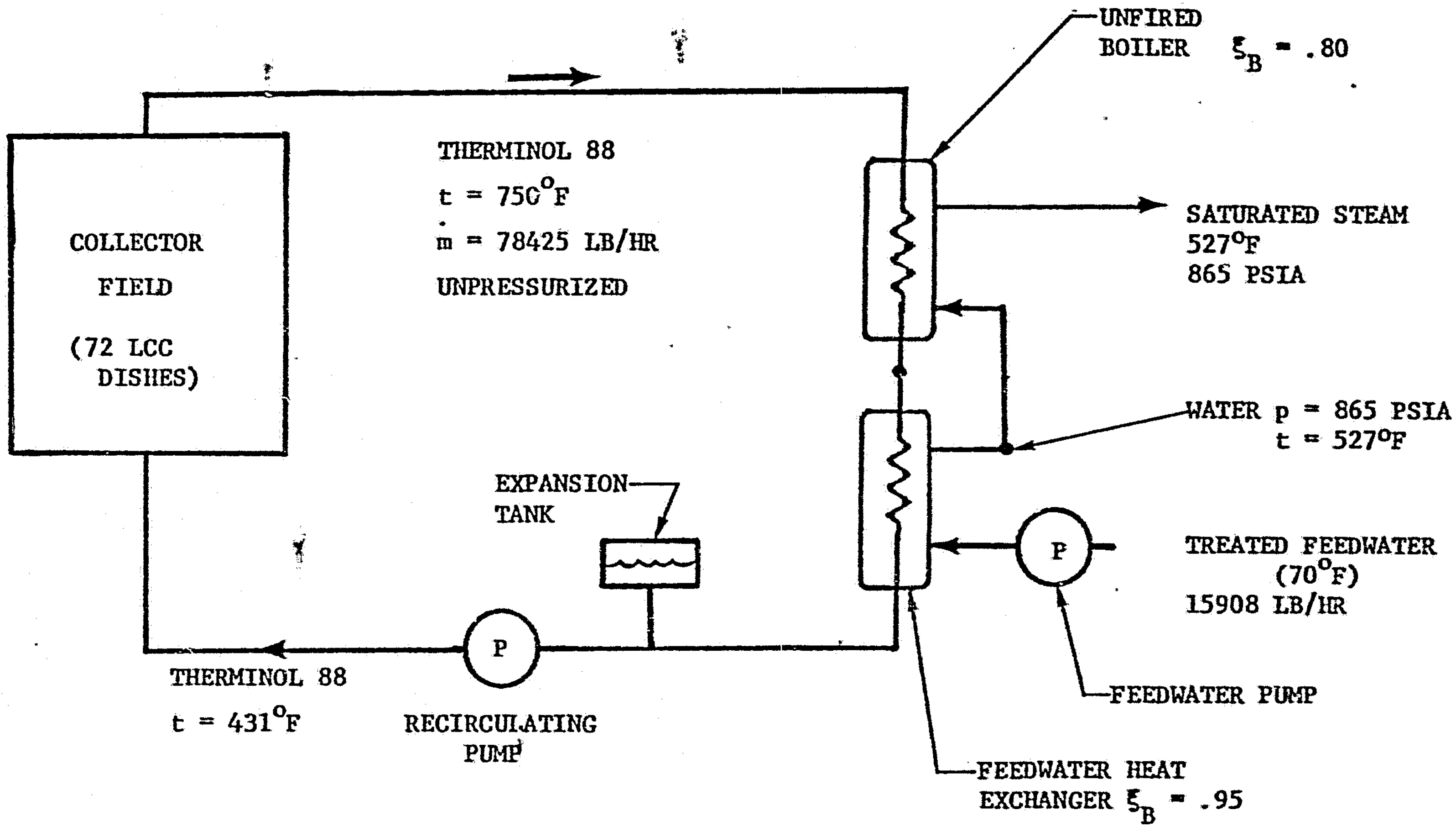
Unfired Boiler. The second process considered was an unfired boiler in which low pressure heat transfer fluid is circulated through the solar field and steam is generated in two centrally located heat exchange units. A schematic of this approach is shown in Figure 2-4. Two separate heat exchangers are required, a feedwater heater and a boiler.

The apparent advantage of the unfired boiler approach is that the pipe transport network is unpressurized. In the particular STEOR application selected, this benefit is greatly offset by the upper operating temperature limit of the heat exchange fluid which results in low temperature differentials across the heat exchangers and large flowrates and line sizes. Figure 2-5 shows the problems encountered with the unfired boiler heat exchanger. Therminol 88 was selected for the heat transfer fluid because it has one of the highest operating temperature capabilities of all the available commercial candidates. From Figure 2-5A it is obvious that the temperature of Therminol leaving the boiler must exceed 527°F steam saturation temperature. If the boiler inlet temperature of the Therminol (T_H) is set by the maximum service temperature of the fluid - about 750°F - and the exit temperature (T_E) set above the saturation temperature (e.g.; 527°F), the boiler effectiveness was a reasonable value of about 0.80. The mass flowrate of the Therminol is then automatically set by the relationship

$$\dot{m} = \frac{Q_B}{C_p(T_H - T_E)} \qquad (1)$$

where Q_B is the latent heat of vaporization required to vaporize the steam flowrate required for TEOR injection. Note that all values of Equation (1) are relatively fixed; Q_B by the thermal load requirements, T_H by the upper operating temperature limit for Therminol, and T_E by the saturation temperature of the steam.

In the series-connected heat exchanger arrangement shown in Figure 2-4 the mass flowrates of both Therminol and water are fixed by the boiler heat exchange, and hence the inlet and discharge temperature of both water and Therminol in the feedwater heater is also fixed. Figure 2-5B shows the variation of Therminol return temperature to the solar field as a function of discharge temperature from the field for two assumed boiler efficiencies. Also shown is the variation in required flowrate of Therminol, nondimensionalized in terms of the steam flowrate. As shown in Figure 2-5B, operation at the highest temperature allowed for Therminol 88 results in a flowrate requirement six times that of the water or steam flowrate.



- FLOW PARAMETER FOR $I_{d,n}$ = 1000 W/m^2
- Q_{TOTAL} = 18.44 x 10^6 BTU/HR (5402 KW_t)

FIGURE 2-4. UNFIRED BOILER SYSTEM SCHEMATIC

9950-663

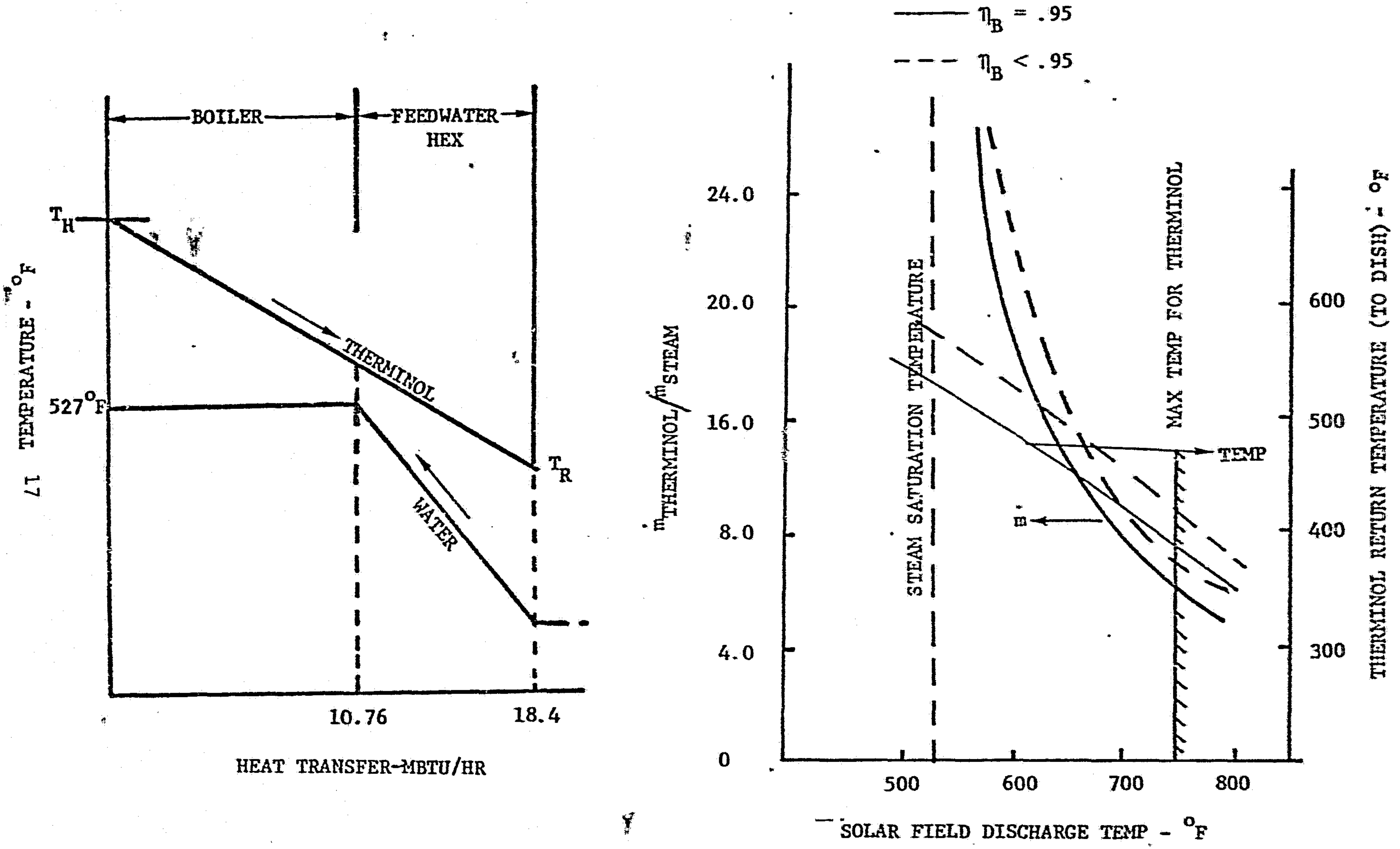


FIGURE 2-5. UNFIRED BOILER SENSITIVITY OF MASS FLOWRATE TO SOLAR FIELD DISCHARGE TEMPERATURE

The primary disadvantage of the unfired boiler is that large flowrates of fluid (Therminol 88) are required to achieve the desired heat transfer. This results in large pipe sizes, and a larger volume of heat transfer fluid. In addition to the more expensive pipe and fluid, the cost of the two heat exchangers should also be assigned to the pipe network cost.

Direct Generation of Steam in Receiver

Direct generation of steam within the solar receiver is shown schematically in Figure 2-6. The disadvantage of this approach is that the entire pipe network and receiver must be pressurized to 850 psig. However, pressurized steam pipe networks are very common industrial installations and are routinely constructed of carbon steel pipe. The ASME Standard Code for Pressure Piping for schedule 80 pipe allows A-53B and A-106B carbon steel pipe to operate at temperatures to 600°F and pressures of 1200 psia. At a temperature of 800°F the allowable pressure is 830 psia.

The direct heated receiver FACC has developed during the SCSE Phase II program is designed to heat toluene at supercritical pressure (≈650 psia) to a temperature of 750°F. Examination of the receiver design indicates it is structurally capable of operating with 527°F steam at 850 psig at about one-half the allowable ASME stress level.

As indicated in Table 2-4 the direct generation of steam within the receivers has the benefits that there is no need to insulate the feedwater supply lines, and no need to provide additional heat exchanger units as in the case of the unfired boiler.

Comparative Pipe Network Costs.

In order to make a comparison of the pipe network costs for the unfired boiler with that for the direct generation of steam, the data for both approaches was input to the FACC pipe network optimization program. This program incorporated the JPL conventional pipe network cost model. The 72-dish network geometry was the same as shown in Figure 2-3, except that an equal north-south and east-west spacing of 1.5 dish diameters was used, which did not affect the comparison. (The dish spacing was later refined to a more compact field for the baseline network.) The results of the optimization for the two thermal processes are presented in Table 2-5 and show clearly that direct generation of steam in the receivers has about a 28 percent lower pipe network cost. The costs of feedwater and boiler heat exchangers were not included in the cost of the unfired boiler (Therminol 88) pipe network costs; these would drive the cost comparison even more to the approach of direct generation of steam within the receivers. Thus, direct generation of steam was the thermal process selected for the baseline STEOR pipe network application.

RECEIVER/BOILER

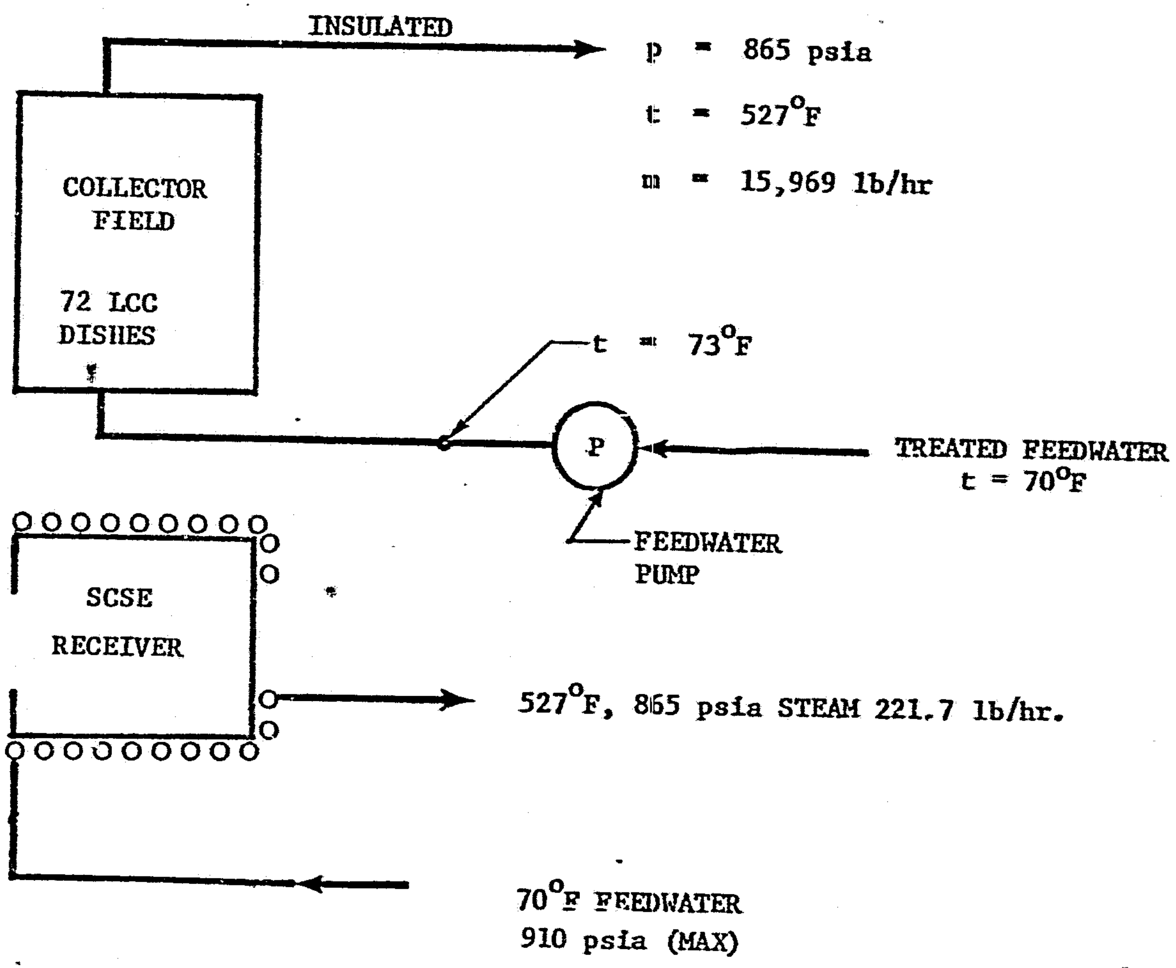


FIGURE 2-6. DIRECT GENERATION OF STEAM IN RECEIVER

TABLE 2-5. COMPARATIVE COSTS FOR ALTERNATE STEOR THERMAL CONVERSION PROCESSES

THERMAL CONVERSION PROCESS	SOURCE TEMP. (°F)	RETURN TEMP. (°F)	BASIC FLOW UNIT (LB/SEC)	HEAT DELIVERED (KW_t)	PIPE NETWORK COST ($\$/KW_e$)
• UNFIRED BOILER THERMINOL 88	750	430	.300	5162	124.77
• DIRECT GENERATION OF STEAM IN RECEIVER	550	70	.0616	5263	99.04

1. COSTS CALCULATED ONLY TO COMPARE THERMAL PROCESSES
2. 72 DISH FIELD SPACED 1.5 LNS (60') x 1.5 LEW (60')
3. JPL INSULATION (20 $/CU FT) AND INSTALLED PIPE COSTS (CONVENTIONAL CONSTRUCTION - SCHEDULE 40)

9950-663

ORIGINAL PAGE IS
OF POOR QUALITY

SECTION 3

OPTIMIZATION CODE VERIFICATION

The JPL pipe network optimization code uses the input data for the pipe network geometry and thermal input/output requirements, and calculates the diameters and insulation thicknesses of the individual pipe segments to yield a minimum overall pipe network cost.* The minimization process includes the following:

(1) Cost of installed pipe

(2) Cost of insulation surrounding the pipe

(3) Cost of energy (or power) loss by heat conduction

(4) Cost of energy required to pump the fluid

(5) Cost of the fluid which fills the network.

A major portion of Task A of the Statement of Work was for FACC to independently verify the JPL pipe optimization code. The procedure by which this verification was accomplished is summarized in Table 3-1.

3.1 PRECONTRACTUAL WORK

As indicated in Table 3-1 the verification process was started on a precontractual basis. JPL supplied their pipe optimization code and documentation to FACC for review. In addition JPL supplied the input data for a 512-dish network. These inputs included the data for the five cost elements of the pipe network identified at the beginning of this section. The cost-of-energy required to pump fluid or to evaluate thermal losses was specified as $\$1500/kW_t$.

FACC reviewed the JPL supplied documentation, generated a FACC optimization code which used a different mathematical approach, and performed comparative optimization calculations on the 512-dish network using the JPL and FACC codes. Examination of the JPL mathematical optimization showed that the equations for calculating friction and heat loss were conventional relationships.

The mathematical optimization procedure used by FACC was based on a Lagrange multiplier technique, in which the optimization of the insulation thickness was decoupled from the optimization of the pipe diameter. The details of the procedure used are described in Appendix B. FACC utilized a different mathematical approach than JPL for determining the minimum pipeline cost (Appendix B). The FACC approach, summarized in Table 3-2, minimized the total cost function for each pipe segment by setting to zero the partial derivatives of total cost with respect to diameter (d_i) and with respect to insulation thickness (δ_i). The result was a coupled pair of transcendental equations in d_i and δ_i. These

*Capital cost plus cost of thermal and frictional energy losses.

TABLE 3-1. OPTIMIZATION CODE VERIFICATION PROCEDURE

PRECONTRACTUAL

- REVIEWED TURNER CODE DOCUMENTATION
- MODIFIED FACC PIPE COST CODE TO PERFORM SIMILAR OPTIMIZATION USING DIFFERENT MATHEMATICAL APPROACH
- RAN COMPARITIVE OPTIMIZATION SOLUTIONS USING BOTH CODES ON A JPL SPECIFIED FIELD ARRAY OF 512 DISHES
- OBTAINED GOOD COST COMPARISON (WITHIN 1/2 PERCENT) AND REASONABLE PIPE DIA./INSULATION THICKNESS COMPARISON
- REPORTED RESULTS
  - JANUARY 8, 1981 FACC INTERNAL MEMO
  - COPY TO JPL

POST CONTRACTUAL

- RAN COMPARITIVE OPTIMIZATION SOLUTIONS USING BOTH CODES ON BASELINE STEOR 72 DISH NETWORK
- RESULTS - COSTS IN GOOD AGREEMENT (WITHIN 5%)
  - VERY GOOD COMPARISON OF HOT SIDE PIPE DIAMETERS & INSULATION THICKNESSES
  - MODERATE DIFFERENCES IN COLD SIDE PIPE DIAS.
- RECONCILED DIFFERENCES
  - DIFFERENCES IN COLD SIDE PIPE DIAMETERS RESULT FROM MATHEMATICAL COUPLING IN JPL CODE BETWEEN HOT AND COLD SIDES
  - DECOUPLING HOT/COLD SIDES OF JPL CODE PRODUCES COLD PIPE DIAS. IN AGREEMENT WITH FACC CODE
  - FURTHER SMALL IMPROVEMENT IN COST BY HOT/COLD SIDE DECOUPLING

TABLE 3-2. FACC OPTIMIZATION ALGORITHM

TOTAL COST FUNCTION

$$C_T = \sum_{i=1}^{N} \left\{ C_{P_i}(d_i) + C_{I_i}(d_i, \delta_i) + C_{\theta_i}(d_i, \delta_i) + C_{f_i}(d_i) + C_{Fl_i}(d_i) \right\}$$

- $C_{P_i}(d_i)$: PIPE COST
- $C_{I_i}(d_i, \delta_i)$: INSULATION COST
- $C_{\theta_i}(d_i, \delta_i)$: COST OF THERMAL LOSS
- $C_{f_i}(d_i)$: COST OF FRICTIONAL LOSS
- $C_{Fl_i}(d_i)$: COST OF FLUID

N = NUMBER OF SEGMENTS

d_i = PIPE DIAMETER OF ith SEGMENTS

δ_i = INSULATION THICKNESS OF ith SEGMENT

FOR EACH SEGMENT, SOLVE.

$$\frac{\partial C_T}{\partial d_i} = 0, \qquad \frac{\partial C_T}{\partial \delta_i} = 0$$

THESE EQUATIONS ARE A PAIR OF COUPLED TRANSCENDENTAL EQUATIONS IN d_i AND δ_i.

THESE EQUATIONS ARE SOLVED INDEPENDENTLY FOR EACH PIPE SEGMENT equations were solved independently for each pipe segment and the resultant diameters and thicknesses were used to compute the minimum value of the total cost function.

An existing FACC pipe network code was modified to incorporate the optimization technique described above as part of the precontractual effort. The case of the 512-dish network specified by JPL was then optimized using both the FACC and the JPL codes. A comparison of the results is presented in Appendix B and shows that the two codes are in good agreement, with the minimum network pipe cost agreeing within one-half percent. Hot side pipe sizes and insulation distributions compared reasonably well, but minor disagreements were obtained between the cold side diameters calculated by the two codes. These disagreements became more pronounced in subsequent verification comparisons of the baseline STEOR application and are discussed later in this section.

3.2 CONTRACTED OPTIMIZATION CODE VERIFICATION

As described in Section 2.2 the baseline IPH network was used as an additional case for mutual verification of the JPL and FACC pipe network optimization codes. The pipe network geometry shown in Figure 2-3 was input to both codes along with the steam system thermal inputs shown on Figure 2-6. There was no cold side insulation since 70°F feedwater was used.

3.2.1 BASELINE APPLICATION RESULTS

Table 3-3 compares the pipe diameters and insulation thicknesses calculated by the two codes for the baseline STEOR pipe network. A comparison of the calculated hot side pipe diameters and insulation thicknesses shows very good agreement, however, the agreement for the cold side pipe diameters was not good. For example, the smallest cold side pipe diameter calculated by the FACC code is 0.234 inch and is 0.160 inch for the JPL code (see Table 3-3). The reason is discussed in Paragraph 3.2.2.

The cost comparison shown in Table 3-3 indicates agreement within about 5%, which is reasonably good.

3.2.2 JPL COUPLING EFFECTS

The essential features of each code are compared in Table 3-4. The source of the difference was found to be due to the mathematical coupling of hot and cold side diameters in the JPL code. If the cold side network optimization is decoupled from the hot side optimization, the JPL code calculates the cold side pipe sizes shown in the last column of Table 3.3. The recalculated cold side diameters are then in much better agreement with the FACC code results.

Table 3-5 is a summary of the pipe size and pipe network costs calculated by the two codes. Good agreement is obtained when the optimization of pipe size and insulation thicknesses on the hot and cold side are decoupled in the JPL code. A slight improvement in network costs (which were already in reasonably good agreement, as indicated above) is achieved by this decoupling. The lower pipe network costs calculated by the FACC code (4.8 percent lower) are

32

ORIGINAL PAGE IS
OF POOR QUALITY

9950-663

TABLE 3-3. COMPARISON OF PIPE NETWORK OPTIMIZATION
COMPUTATIONS FACC VS. JPL CODE

BASELINE STEOR PIPE NETWORK

72 DISH - 9 x 8 ARRAY
N-S SPACING - 45 FEET
E-W SPACING - 60 FEET
FACC CODE USES JPL FRICTION MODEL

PIPE NO.	FLOW(1) UNITS	HOT SIDE PIPE I.D. (INCHES)		HOT SIDE INSULATION (INCHES)		COLD SIDE PIPE I.D. (INCHES)		
		FACC	JPL	FACC	JPL	FACC	JPL (2)	(3)
1	1	.446	.450	2.92	3.00	.234	.160	.234
2	2	.639	.636	3.15	3.20	.326	.217	.331
3	3	.788	.779	3.31	3.32	.396	.263	.405
4	4	.913	.900	3.42	3.42	.454	.302	.468
5	8	1.302	1.273	3.71	3.68	.633	.422	.662
6	16	1.853	1.800	4.02	3.96	.882	.588	.936
7	24	2.274	2.205	4.21	4.14	1.070	.714	1.147
8	32	2.629	2.546	4.35	4.27	1.228	.819	1.324
9	40	2.941	2.846	4.46	4.37	1.366	.912	1.480
10	48	3.223	3.118	4.55	4.46	1.491	.995	1.621
11	56	3.482	3.367	4.63	4.53	1.605	1.071	1.751
12	64	3.723	3.600	4.70	4.59	1.711	1.142	1.872
13	72	3.948	3.818	4.76	4.65	1.810	1.208	1.985

*(1) FLOW UNIT = .061 LB/SEC

(2) TURNER CODE HOT/COLD SIDES COUPLED

(3) TURNER CODE HOT/COLD SIDED DECOUPLED

PIPE NETWORK COST =

FACC 71.81 $\$/KW_t$

JPL 75.45 $\$/KW_t$(2)

33

TABLE 3-4. COMPARISON OF JPL AND FACC COST OPTIMIZATION TECHNIQUES -ESSENTIAL FEATURES

JPL	FACC
• PARTIALLY DECOUPLES FRICTIONAL AND THERMAL LOSS EFFECTS	• MAINTAINS COUPLING BETWEEN THERMAL AND FRICTIONAL LOSSES
• USES LAGRANGE MULTIPLIER METHOD WHICH RELATES DIAMETER OF EACH PIPE SEGMENT TO THE DIAMETER OF SMALLEST HOT SIDE SEGMENT - BASED ON CONSIDERATION OF FRICTIONAL LOSSES ONLY	• USES PARTIAL DIFFERENTIATION OF TOTAL COST FUNCTION TO OBTAIN OPTIMUM PIPE DIAMETER AND INSULATION THICKNESS
• INSULATION THICKNESS OF EACH SEGMENT IS DEPENDENT ON THICKNESS OF INSULATION ON SMALLEST HOT SIDE SEGMENT	• OPTIMIZATION OF EACH SEGMENT IS INDEPENDENT OF THE OTHER SEGMENTS
• MINIMUM COST IS FOUND BY VARYING TWO PARAMETER-DIAMETER AND INSULATION THICKNESS OF SMALL EST HOT SIDE PIPE SEGMENT	• MINIMUM COST IS FOUND BY SOLVING A PAIR OF COUPLED TRANSCENDENTAL EQUATIONS FOR PIPE DIAMETER AND INSULATION THICKNESS ON EACH SEGMENT

TABLE 3-5. OPTIMIZATION CODE COMPARISON RESULTS

CODE	MINIMUM DIAMETER HOT SIDE	MINIMUM DIAMETER COLD SIDE	COST $/$KW_t$	COMMENT
FACC	.446	.234	71.81	
JPL (CASE 1)	.450	.160	75.45	HOT AND COLD SIDE COUPLED
JPL (CASE 2)	.450	.234	75.14	HOT AND COLD SIDE DECOUPLED

APPROXIMATE RECONCILIATION OF FACC & JPL RESULTS

	FACC	JPL CASE #2	DIFFERENCE $/$KW_t$
THERMAL LOSS	94 KW_t	104 kW_t	2.83*
FRICTION LOSS	10.5 KW_t	11.8 kW_t	.37*
INSULATION COST	$32819	$32248	<.11>
PIPE	$187353	$188690	.24
			$ 3.33 (JPL HIGHER)
			$71.81 (FACC)
			$75.14 (JPL CASE #2)

*LOSSES @ 1500 $/$kW_t$ COST OF ENERGY

35

attributed to the fact that the optimization procedure of the JPL code is not mathematically exact; that is, the decoupling of the pipe diameter optimization from the insulation thickness optimization introduces a certain degree of approximation into the results. The FACC procedure avoids mathematical approximations and yields a lower value for the optimized network cost.

3.2.3 STANDARD PIPE SIZES

In the comparisons of the JPL and FACC optimization codes described above the minimum cost pipe was first calculated based on the computed minimum inside pipe diameter. The FACC program also has the capability to select the diameter which yield the minimum cost from a table of standard pipe sizes (using the appropriate pipe schedule). The results shown in Table 3-6 for the baseline STEOR network compare pipe diameters and costs for optimum networks constructed of mathematical and standard pipe sizes. Table 3-6 shows the total cost of a network constructed of standard pipe sizes is \$78.53/kW_t versus \$73.60/kW_t for a network constructed of mathematical sizes, or 6.7 percent higher. The total system cost includes all system costs, both capital as well as the cost of lost energy due to friction and heat loss.

3.2.4 COST OF ENERGY

The cost of lost energy is part of the pipe network optimization code input data. In the 512-dish network input data originally supplied by JPL for the pre-contractual effort, the cost of energy was assessed at \$1500/kW_t. This value was used in computing the pipe diameters and insulation thicknesses for the baseline STEOR pipe network design and also for detailed analysis of conventional construction costs (discussed below). Near the end of this study JPL requested that parametric optimization results be generated using a cost-of-energy of \$1500/kW_t and \$500/kW_t. The influence of specified cost-of-energy on pipe network optimization results is discussed in Section 6.0.

9950-663

TABLE 3-6. FACC OPTIMIZATION RESULTS COMPARISON OF REAL VS. MATHEMATICAL PIPE SIZES

- 72 DISH ARRAY
- N-S SPACING 49 FEET
- E-W SPACING 60 FEET
- SCHEDULE 80 PIPE

TYPICAL PIPE SEGMENT COMPUTATIONS - HOT SIDE

PIPE NO.	FLOW UNITS	OPTIMUM MATHEMATICAL I.D. (INCHES)	OPTIMUM REAL PIPE DIAMETERS I.D. (INCHES)	NOM. (INCHES)	O.D. (INCHES)	OPTIMUM MATHEMATICAL INSULATION (INCHES)	OPTIMUM INSULATION FOR REAL PIPE OUTSIDE DIA. (INCHES)
1	1	[illegible]	.546	.500	.840	2.99	3.35
2	2	.713	.742	.750	1.050	3.23	3.52
0	4	1.012	.957	1.000	1.315	3.50	3.71
6	18	2.026	1.939	2.000	2.375	4.10	4.24
8	32	2.861	2.900	3.000	3.500	4.43	4.63
10	48	3.498	3.364	3.500	4.000	4.63	4.76
12	64	3.944	3.944	4.000	4.500	4.76	4.85

PIPE NETWORK COSTS

MATHEMATICAL SIZES 73.60 $\$/kW_t$

REAL PIPE SIZES 78.53 $\$/kW_t$

37

ORIGINAL PAGE IS
OF POOR QUALITY

SECTION 4

CONVENTIONAL CONSTRUCTION COST MODEL

The second part of Task A of this study was to verify the JPL cost model for IPH thermal transport based on the use of conventional pipe network construction technology. This was accomplished by using the baseline STEOR pipe network geometry shown in Figure 2-3 and the optimized standard (real) pipe diameters and insulation thicknesses shown in Table 3-6 to construct a detailed pipe network. This network included a specification of the pipe, fittings, valves, expansion joints, pipe supports, and insulation. From the detailed pipe network design a bill of material was constructed and material and labor costs were estimated. This bottoms-up cost estimate of the network was then compared to the costs predicted by the JPL conventional cost model.

4.1 PIPE NETWORK DETAILED DESIGN

Figure 4-1 shows a layout of the baseline STEOR pipe network. As shown in Figure 4-1 (and previously in Figure 2-3) the network consists of an 8x9 dish array with four dishes connected to eighteen north-south running feeder lines. Each feeder line is connected to four dishes and consists of both the feedwater supply and steam discharge pipe. The eighteen feeders are connected to a central east-west header running the length of the field and discharge at the east end of the field. The feedwater supply line runs parallel to the steam lines except they span the steam-line expansion joints.

Figure 4-2 shows two of the feeder lines which are typical of all eighteen feeders. The north-south axis of the feeders has been rotated 90 degrees for easier presentation. The outer circle at each dish location represents the diameter of the concrete pad on which the LCC is mounted.

Arrangement of Pipe Anchors

The riser/downcomer design discussed in Section 7 emerges at the edge of each pad and enters the feeder line using welded 3,000 lb 'sockolet' fittings of the type shown in Figure 4-3. The feeder lines are anchored at the point where the riser/downcomer enters the dish. The anchor is a reinforced steel concrete pillar to which the steam feeder line is welded and the water line is clamped. A similar pipe anchor, shared by both water and steam lines, is located on each header at the location where opposing feeder lines penetrate the header. Details of the construction are given in Section 5.

Pipe Size

All pipe in the proposed network is schedule 80 type A-106B or A-53B carbon steel. The ASME Standard Code for Pressure Piping specifies an allowable stress level of 15,000 psi at operating temperatures to 600°F for A-106B and A-53B welded pipe construction.

ORIGINAL PAGE IS
OF POOR QUALITY

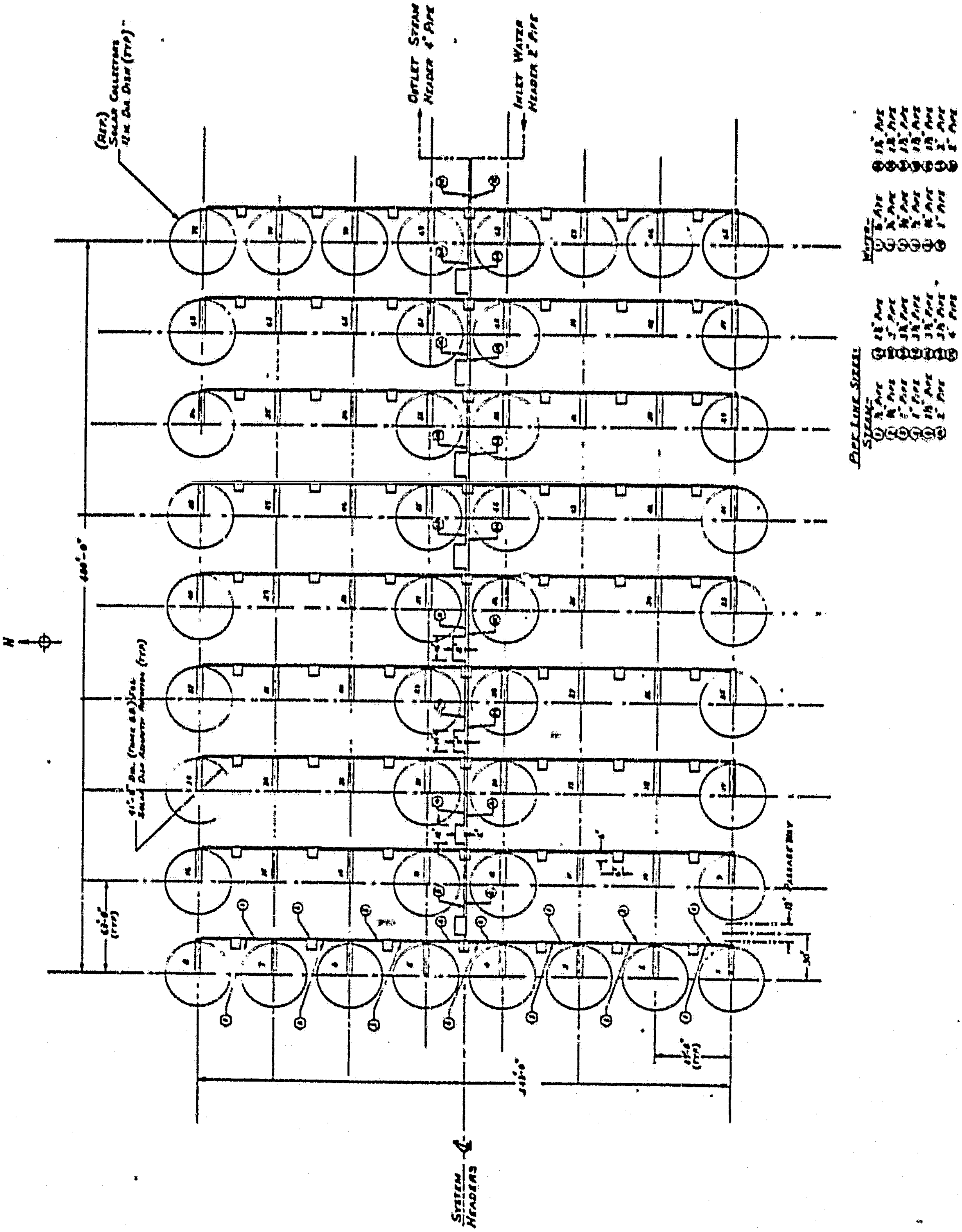


FIGURE 4-1. BASELINE STEOR PIPE NETWORK

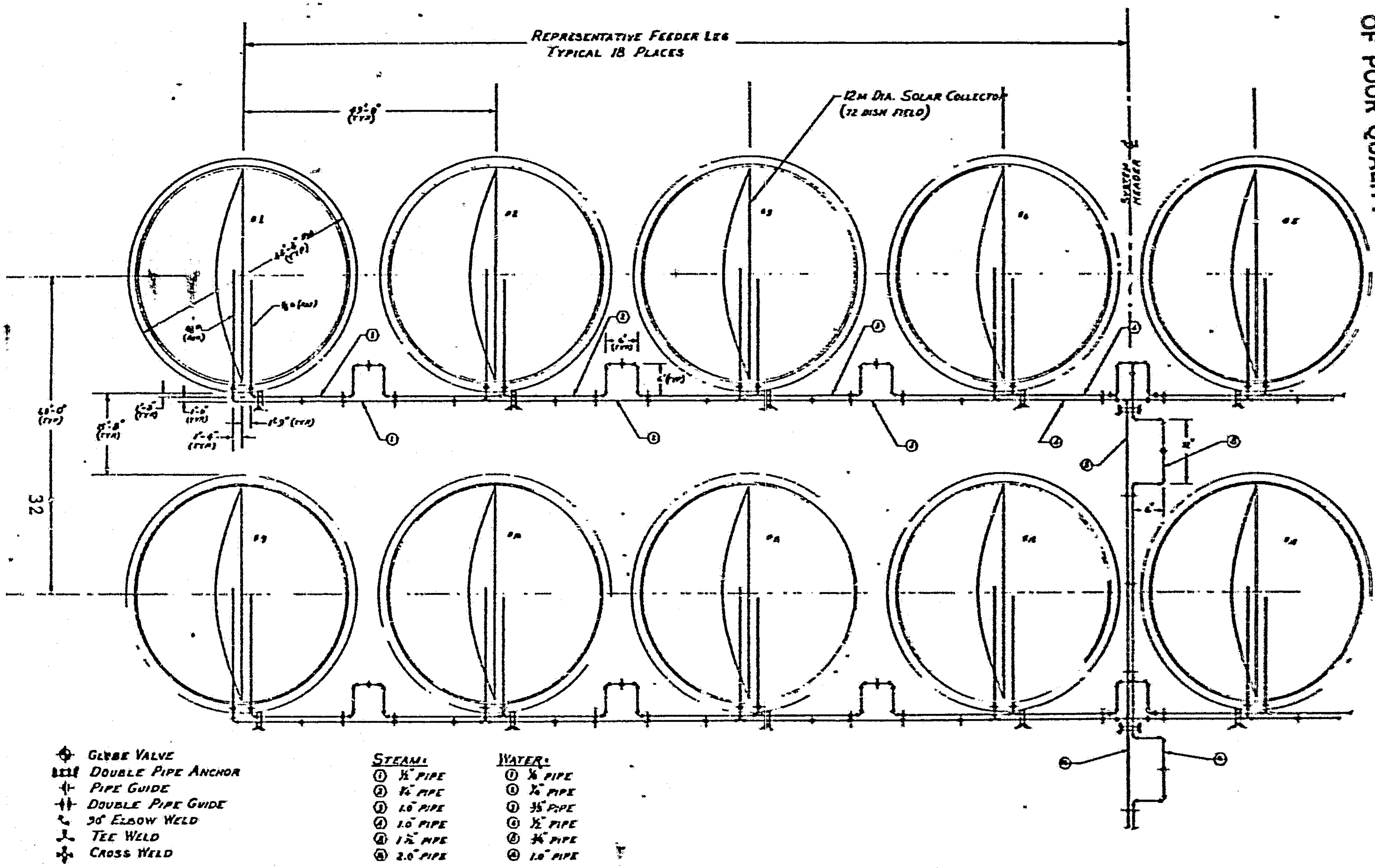
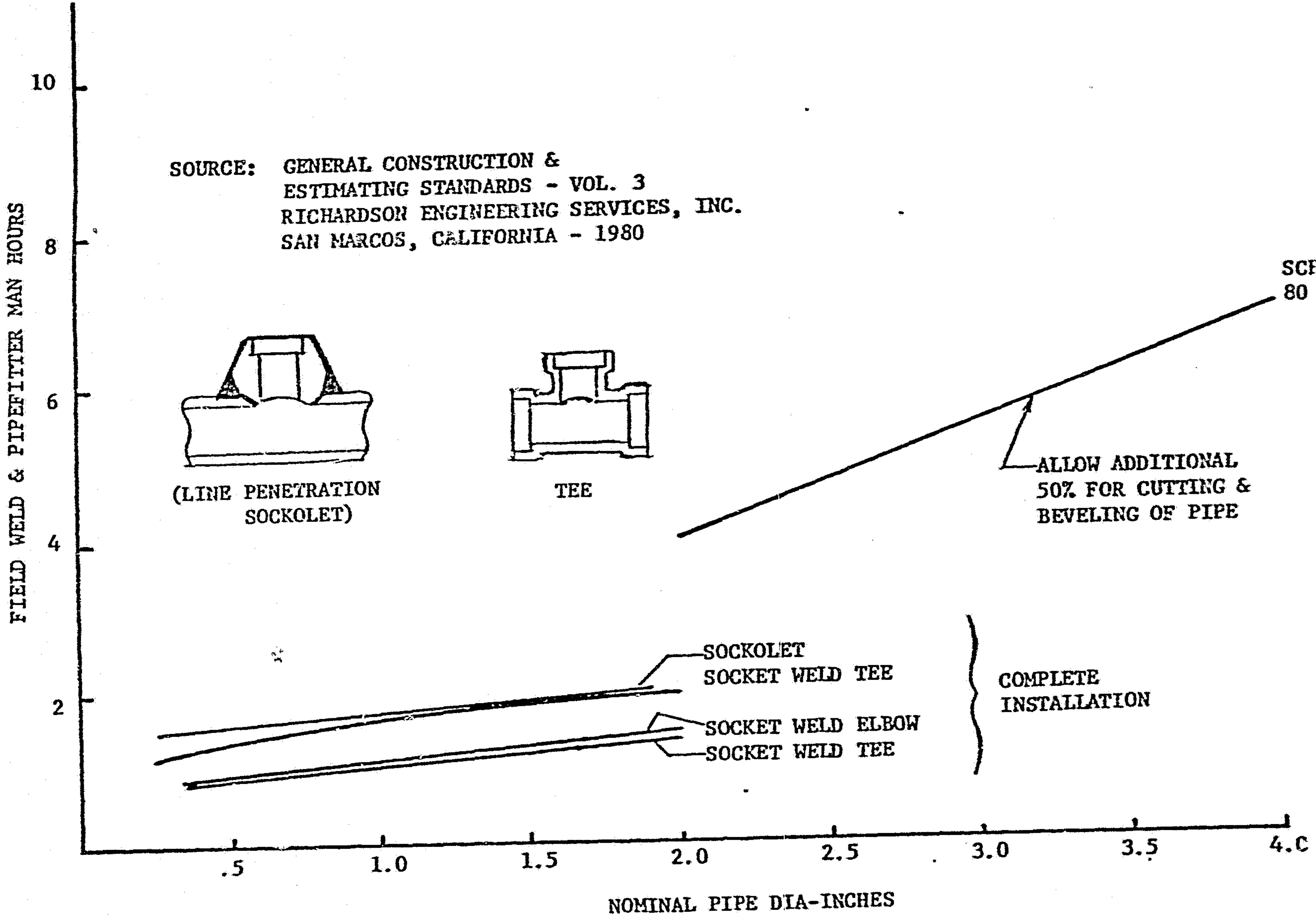


FIGURE 4-2. FEEDER PIPING NETWORK



9950-663

FIGURE 4-3. WELD & PIPEFITTING LABOR ESTIMATE

Fittings

Fittings selected for pipe sizes up to 2-1/2 inch nominal diameter were the welded 'sockolet' design. This type of fitting is more expensive than butt-welded fittings but requires less labor for joint preparation, installation and welding. Characteristics of the sockolet design and line penetration are shown in Figure 4-3. The sockolet fitting would be used in place of tees at the penetration points of risers and downcomers into feeders, and penetrations of feeders into headers. Sockolet unions were assumed to occur over every 20 ft span of pipe not otherwise interrupted by a reducer, elbow, or tee.

Expansion Joints

Approximately 2.5 inches of thermal expansion will occur between the anchor points of each feeder line and 3.0 inches between the anchor points on each header. This expansion was accommodated by field fabricated expansion joints constructed of elbows and straight sections of pipe. The construction of an expansion joint involves at least eight elbow welds and also the placement of additional pipe supports to support the offset sections of pipe.

The expansion joint dimensions for the baseline STEOR network were selected by calculating the maximum combined (pressure plus bending) pipe stresses and axial loads for a range of pipe diameters and joint dimensions as shown in Figure 4-4. The design points, indicated by the circles in Figure 4-4, were selected to provide some uniformity of construction while affording comfortable margins of stress. The use of factory fabricated 'omega-shaped' joints was also investigated as an alternative to the field fabricated expansion joints. The design curves used to size and cost the omega joints are shown in Figure 4-5.

Pipe Guides

In addition to the anchors some guide-type pipe supports will be required to support the weight of the pipe against bending. For example, a roller type guide will be required at both ends of the field-fabricated expansion joints as well as at the middle of the joint to support the offset sections of pipe. Since these guides require a concrete support pillar, the pillar is also used to mount a simple water line pipe support (shown in Section 5, Figure 5-3A). In the case of the steam lines the larger pipe diameter yields a stiffness (high section modulus) such that the distance between anchors and pipe guides used to support the expansion joints provides sufficient vertical support to the steam line. However, calculations presented in Figures 4-6 and 4-7 show that additional guide-type pipe supports are required at more frequent spacing along the water lines (lower pipe diameters and section modulus).

ORIGINAL PAGE IS
OF POOR QUALITY

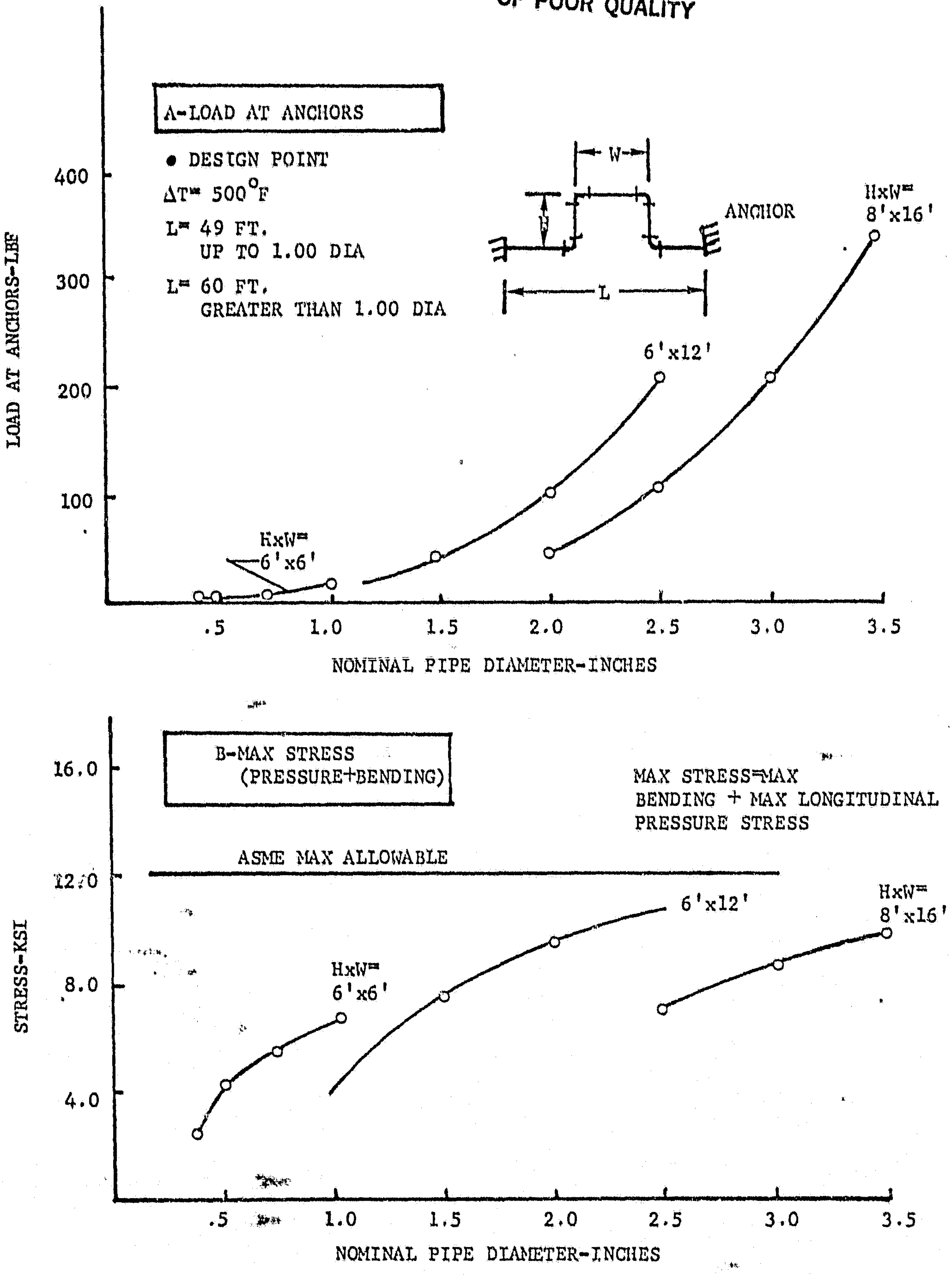
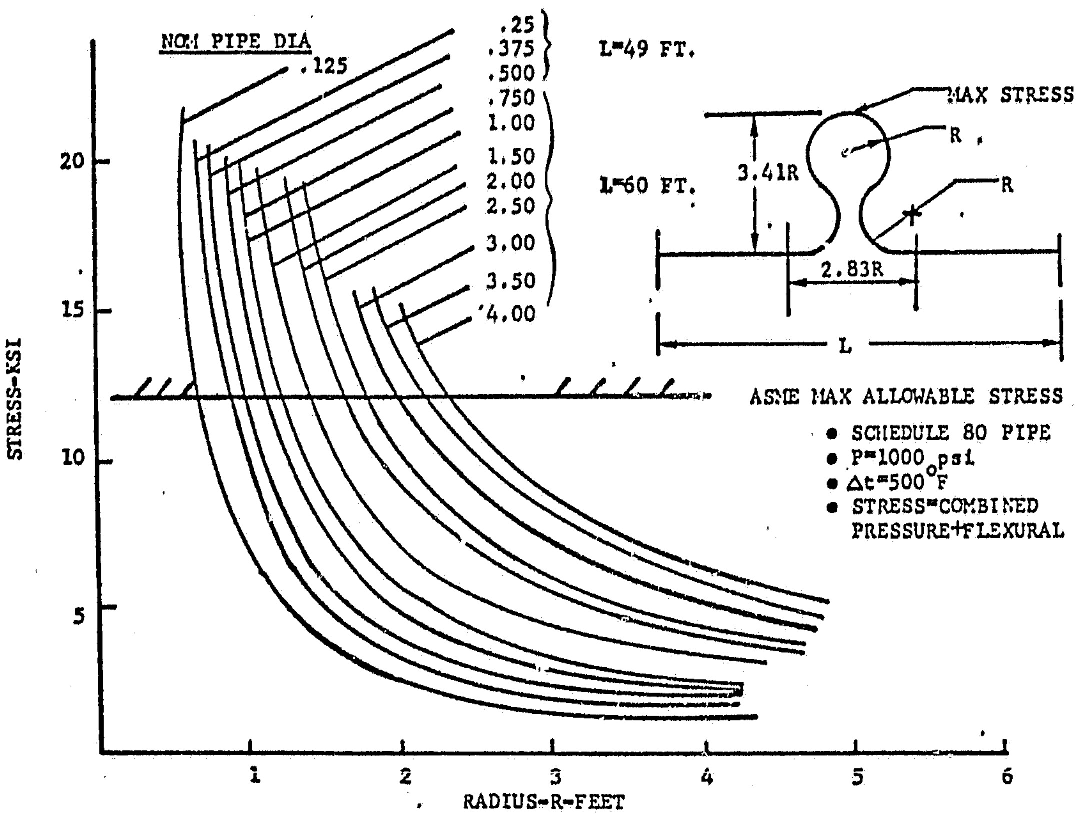


FIGURE 4-4. LOADS AND STRESSES FOR FIELD CONSTRUCTED EXPANSION JOINTS



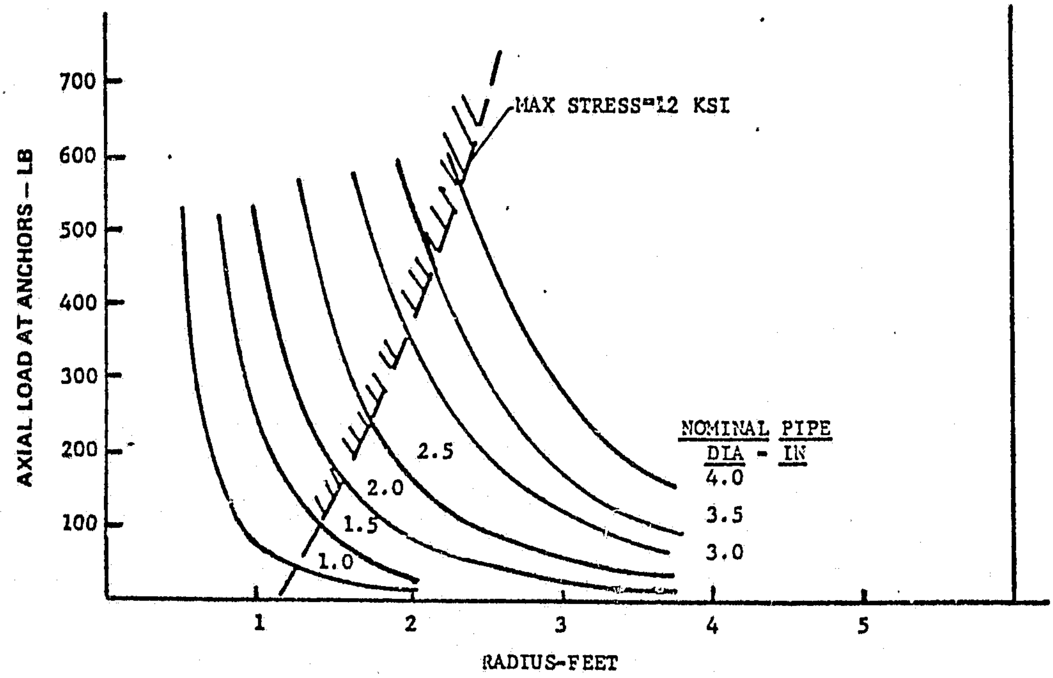


FIGURE 4-5. MAXIMUM STRESS AND THERMAL EXPANSION LOADS IN FACTORY FABRICATED BENT OMEGA JOINTS

9950-663

ORIGINAL PAGE IS
OF POOR QUALITY

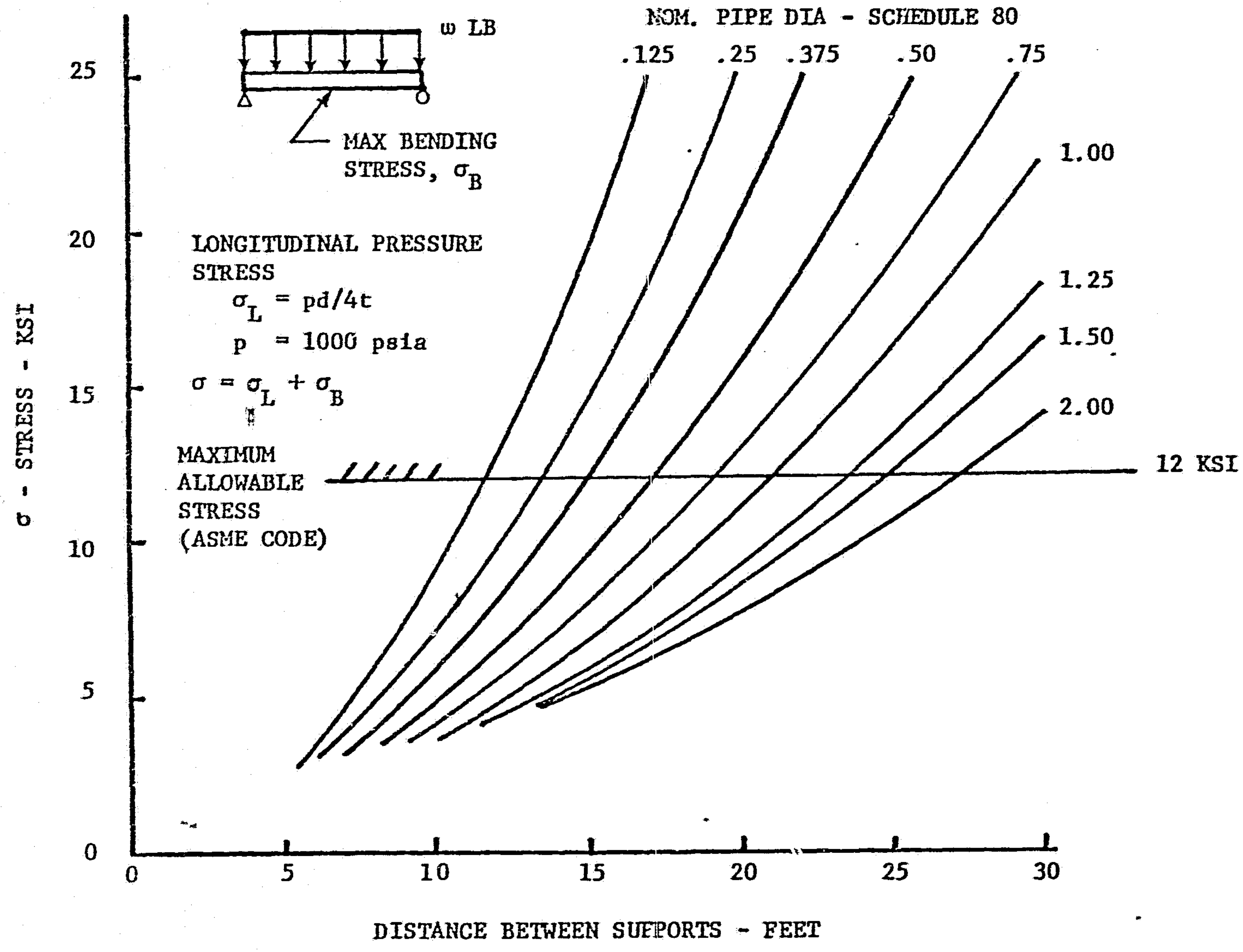


FIGURE 4-6. COMBINED FLEXURAL AND PRESSURE STRESS IN WATER LINE

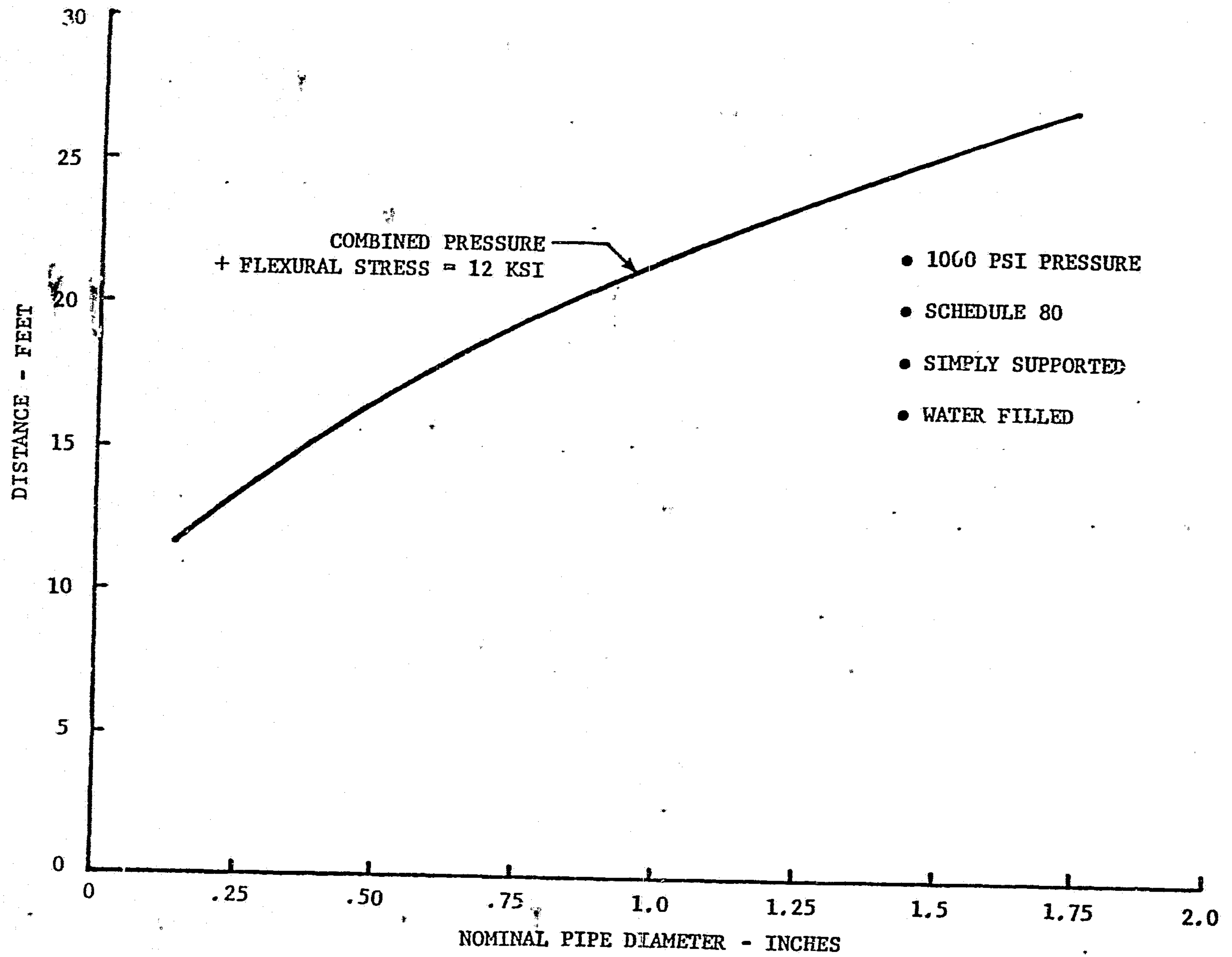


FIGURE 4-7. MAXIMUM SPACING BETWEEN WATER PIPELINE SUPPORTS

Valves

Shutoff valves were assumed to be required to shut off the water and steam lines to each dish (144 valves) as well as to each feeder line (36 valves). Hand operated socket welded globe valves were specified at all locations. In addition it was assumed that each steam line would include a pressure relief valve (18 valves). A valve was not used at the steam header discharge point, but a 2-inch main feedwater inlet valve was specified, as well as a main water-line checkvalve.

All valves were assumed to be hand operated types, but it is likely that some valves in a real application would be automatically operated and integrated into the overall control system. Since this study did not address the control aspects of the IPH application, the cost for addition of automatic pneumatic or electromechanical valve operators was not included as a pipe network cost.

Insulation

The steam line was insulated using molded high temperature calcium silicate insulation. This material was specified because of the 530°F steam application. The insulation would be field installed over the pipes and valves using standard thicknesses that most closely approximate the thicknesses calculated by the pipe-network optimization computer code. A field installed, prefabricated aluminum jacket would be used to weather-seal the insulation.

4.2 COSTING ASSUMPTIONS

The purpose of specifying a detailed design for the baseline STEOR piping network was to conduct a detailed, bottoms-up cost analysis with which to compare similar costs obtained from the JPL cost model for conventional pipe construction. The cost estimating assumptions used in performing this task are listed in Table 4-1. Conventional field construction would be used to perform all tasks on the pipe network construction site. This includes all cutting and preparation (end beveling, etc.) of pipe, and welding of pipe joints and the joints of the fittings and valves. The foundations and pillars for pipe supports would be reinforced concrete with the concrete poured into hand framed forms or preformed fiber 'sonotubes'. The pipe insulation would be premolded sections installed in the field.

The majority of pipe network material and labor costs were obtained from General Construction Cost Estimating, Volumes 1 and 3, Richardson Engineering Services, Inc., San Marcos, California, 1980. Some of the material costs in this reference were independently checked by consulting suppliers or supplier's catalogs. A formal quotation was obtained on mill-run quantities of A-106 and A-53 pipe and the responses are presented in Appendix D. The independent checks of material prices indicated that the Richardson estimating costs may be a few percent high, which probably reflects a nominal allowance for delivery of materials.

9950-663

TABLE 4-1. COST ESTIMATING ASSUMPTIONS

- CONVENTIONAL FIELD CONSTRUCTION
- SCHEDULE 80 CARBON STEEL (A-106) PIPE CONSTRUCTION
- IDEAL SURFACE, ACCESSIBILITY, LABOR AVAILABILITY CONDITIONS (NO CONTINGENCY FACTORS USED)
- ALL LABOR AND MATERIAL RATES OBTAINED FROM

  GENERAL CONSTRUCTION & ESTIMATING STANDARDS
  VOLS. 1 & 3
  RICHARDSON ENGINEERING SERVICES, INC.
  SAN MARCOS, CALIF. - 1980

  PIPE AND FITTING COSTS VERIFIED BY PURCHASING INQUIRIES TO SUPPLIERS:

  KILSBY TUBE SUPPLY
  TUBE SALES
  FUTURE METALS
  JMC SALES
  FEE AND MASON

  INSULATION COSTS - INDASCO, INC.

- 1980 RATES

	DIRECT $/HR.	INDIRECT $/HR.
PIPEFITTING, WELDING	16.95	10.00
CONCRETE	12.85	5.90
INSULATION	9.00	5.40
INSPECTION	16.95	10.00

SALES TAX 6% OF MATERIAL
PERFORMANCE BONDS 1.5% OF TOTAL
PROFIT 10%

The 1981 labor rates specified by Richardson are shown on Table 4-1 and include no allowances for contingencies such as remote site travel, hazard pay, or other factors. The indirect cost is the contractor's overhead cost. A sales tax of six percent was assumed on all material, and 1.5 percent allowed for the cost of insurance and performance bonds. A contractor's profit of 10 percent was included.

4.3 COST DATA

As previously stated the majority of material and labor cost data was obtained from the Richardson book. However this reference did not have data for the two items of the construction costs discussed below, i.e., insulation and inspection.

Insulation

Premolded calcium-silicate insulation was used for the steam line because the 530°F condition precludes use of slightly less expensive insulating materials (e.g., fiberglass). A quotation was solicited from INDASCO, Inc., for the insulation sizes required on the baseline network. A quotation was also obtained for aluminum weather seal jacketing for the insulation. A copy of the INDASCO quotation is presented in Appendix D. The labor to field install the insulation and weather seal was estimated with the assistance of FACC plant engineering personnel. A direct labor rate of $9/hr was applied to the estimated labor hours.

The JPL conventional cost model uses an insulation cost of $20 per cubic foot to account for material and direct labor for all pipe sizes. The FACC data for insulation was recomputed on a cubic foot basis and the cost distribution versus nominal pipe diameter is shown in Figure 4-8. The lower line of The figure shows the insulation material cost for straight sections of pipe. An additional material cost allowance of 10 percent was used to account for insulation around valves and fittings as shown by the second lowest line. To this was added the cost of aluminum jacketing to arrive at the total insulation material cost. Direct labor for installation was added to arrive at total insulation cost. The JPL estimate of $20/cubic foot is shown for reference. The JPL estimate appears to be lower for small pipe sizes, but nears the FACC cost for larger pipe sizes.

Inspection

Inspection requirements for the baseline network were defined to consist of dye penetrant inspection of all welds followed by a low pressure (snoop) leak check, followed by static hydrostatic proof testing. The majority of the costs were related to the dye penetrant and leak checks on the individual welds. The number of welds of each pipe diameter were counted and a reasonable labor effort per joint for the inspection described was assigned. A direct labor rate of $16.95 per hour (equivalent to a pipefitter or welder) was applied to the labor hour estimate.

9950-663

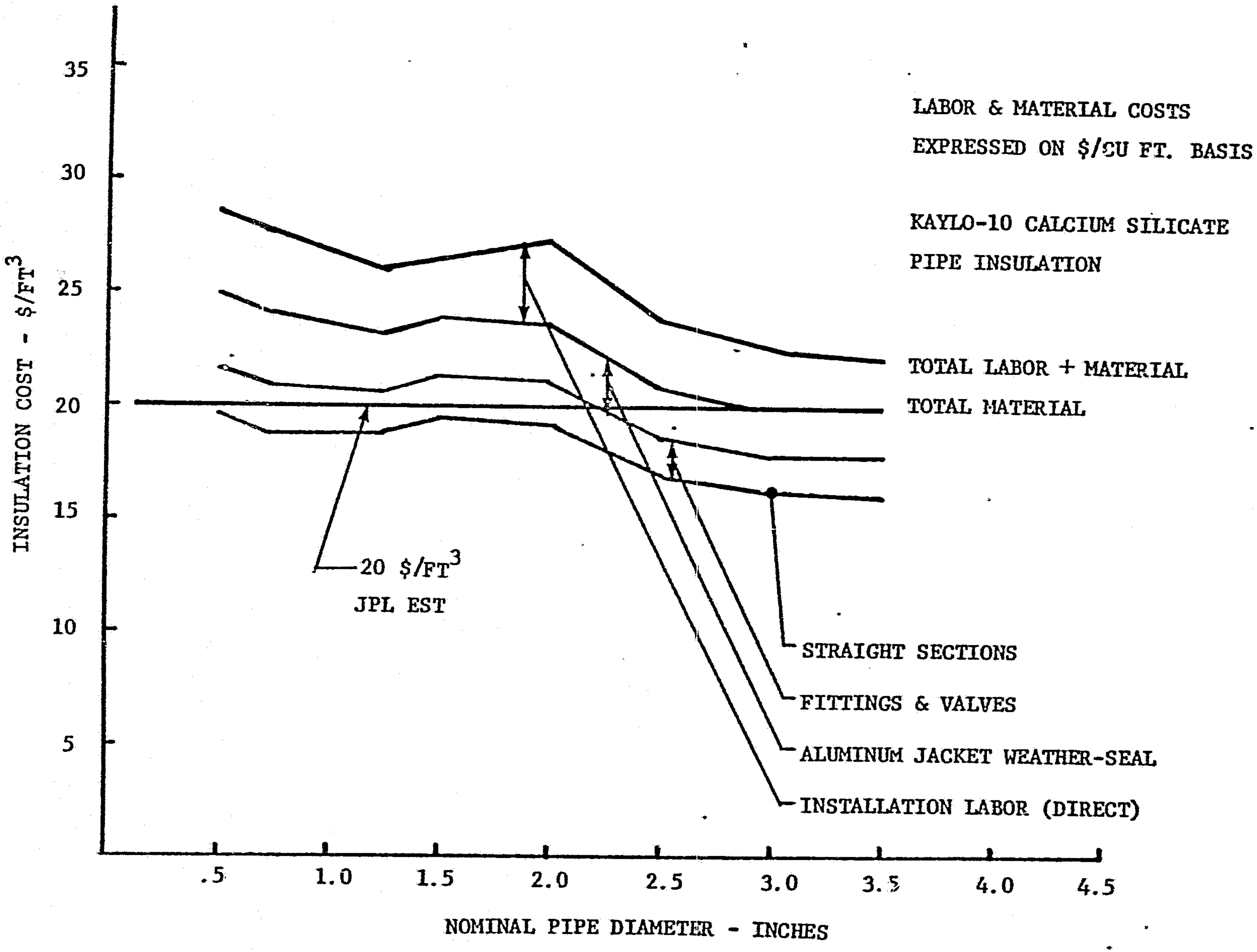


FIGURE 4-8. INSULATION COST COMPARISON

4.4 COST MATRIX

The cost data obtained for the various categories of pipe network labor and material were entered into a cost matrix having the format shown in Figure 4-9. The costs were classified by pipe diameter and included the cost categories of pipe, expansion joints, fixtures, valves, anchors, pipe guides, foundations, insulation, and inspection. The costs of each category were separated into labor, material, direct, indirect and surcharges as shown under the "pipe" category in Figure 4-9. The matrix of network costs was entered into a computer code to perform various accounting functions and arrive at totals. A sample of the computerized matrix for the baseline pipe network is included in Appendix C (Figure C-1). The utility of a computerized cost matrix is that the costs of alternate construction techniques can be introduced and the total network cost recomputed with minimum effort and good accuracy.

4.5 RESULTS

An over-all comparison of the pipe network costs obtained from the detailed (bottoms-up) cost analysis and the costs predicted by the JPL cost model is shown in Figure 4-10. The JPL cost model does not include indirect contractor costs, profit, or taxes and bonds, which should be considered an accounting omission. Therefore, a fair comparison of costs required the use of only the direct labor and material costs, as indicated by the line of comparison shown in Figure 4-10. All subsequent comparisons made in this report will address only direct labor plus material costs.

As indicated in Figure 4-10, the JPL cost model predicts a labor plus material cost about 20 percent lower than the detailed FACC cost model. This is considered a fair comparison of the two methods. An examination of the JPL cost model a revealed the likely source of the difference was the method by which JPL accounts for the cost of expansion joints. JPL employs a curve of installed pipe cost (excluding insulation) versus nominal pipe diameter. The pipe cost includes material and direct labor for pipe, fittings, valves, etc. To account for the thermal expansion joints in hot-side pipes, the length of hot pipe segments are multiplied by $\sqrt{2}$ and then multiplied by the cost-per-foot ($/ft) value for the corresponding pipe diameter. JPL has indicated that the $\sqrt{2}$ factor to account for expansion joints represents an approximate average of a rather wide range of observed values (≈1.2 to 1.6). In the FACC detailed network cost the addition of field fabricated expansion joints actually added about 24 percent to the straight runs of pipe. If a 1.24 factor were applied to the JPL hot-side pipe cost instead of a $\sqrt{2}$ factor, the total pipe network cost predicted by the JPL model would reduce from $237K to $212K, which was within 10 percent of the detailed overall pipe network cost.

Figure 4-11 shows the over all cost comparison for labor plus material for both steam and water-side pipelines. As shown, the majority of the difference occurs on the water-side of the network. Since 86 percent of the water-side pipe is of nominal diameters between 1/8 and 1/2-inch, the JPL model may not be accurate for these small sizes.

51

NOMINAL DIA	.50	.75	1.00	1.50	2.00	2.50	3.00	3.50	4.00	TOTAL
STRAIGHT LENGTH	882	882	1323	60	60	60	60	120	134	
EXP JOINT LNGTH	216	216	324	12	12	12	16	32	32	
TOTAL LENGTH	1098	1098	1647	72	72	72	70	152	166	
PIPE COST										
LABOR HOURS										
LABOR $										
MATERIAL $										
SALES TAX										
INDIRECT										
PROFIT										
BONDS										
EXPANSION JOINTS										
FIXTURES										
VALVES										
ANCHORS										
GUIDES										
FOUNDATIONS										
INSULATION										
INSPECTION										
TOTALS										

FIGURE 4-9. BASELINE PIPE NETWORK COST MATRIX

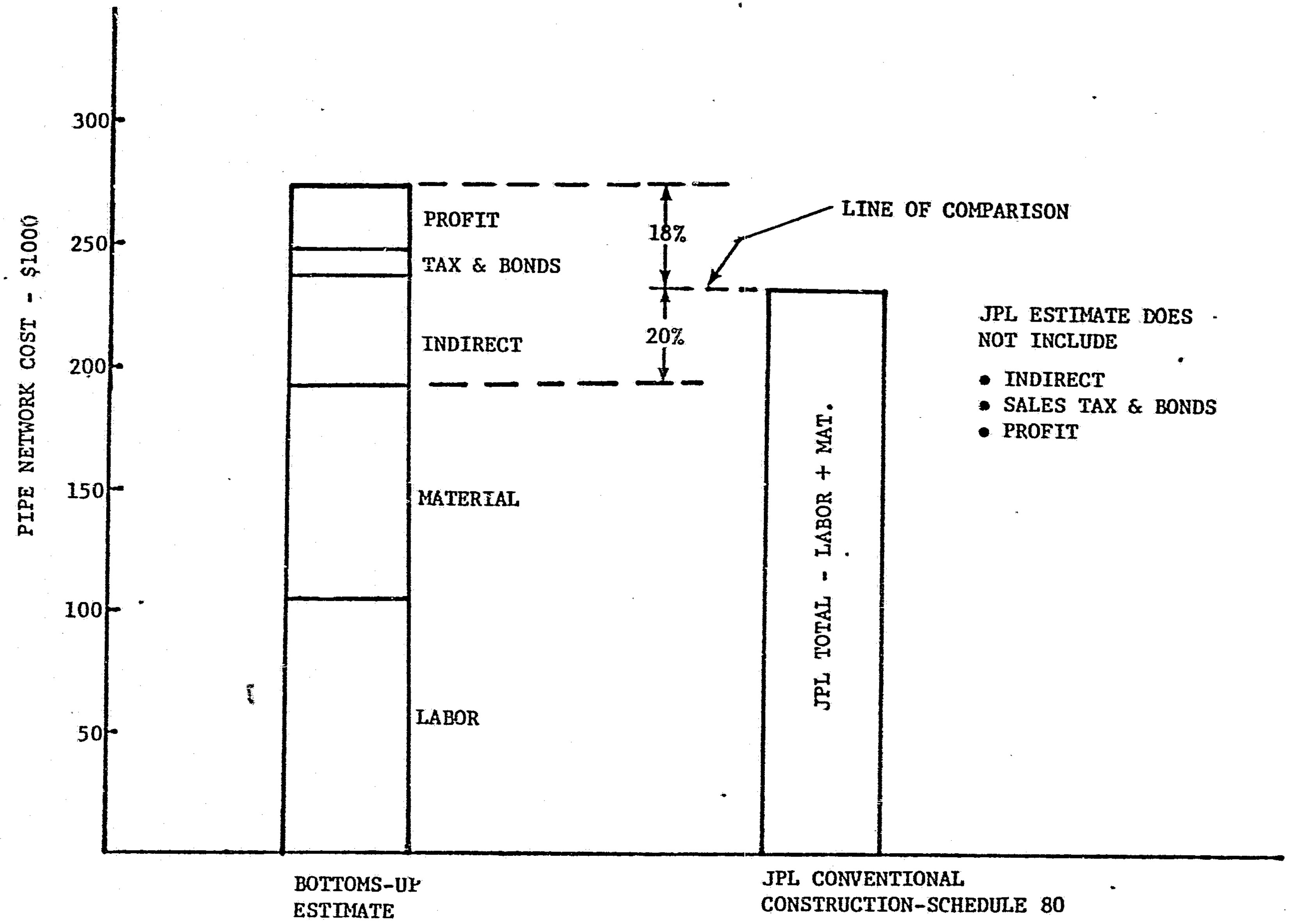


FIGURE 4-10. COMPARISON OF FACC AND JPL PIPE NETWORK COST FOR STEOR APPLICATION

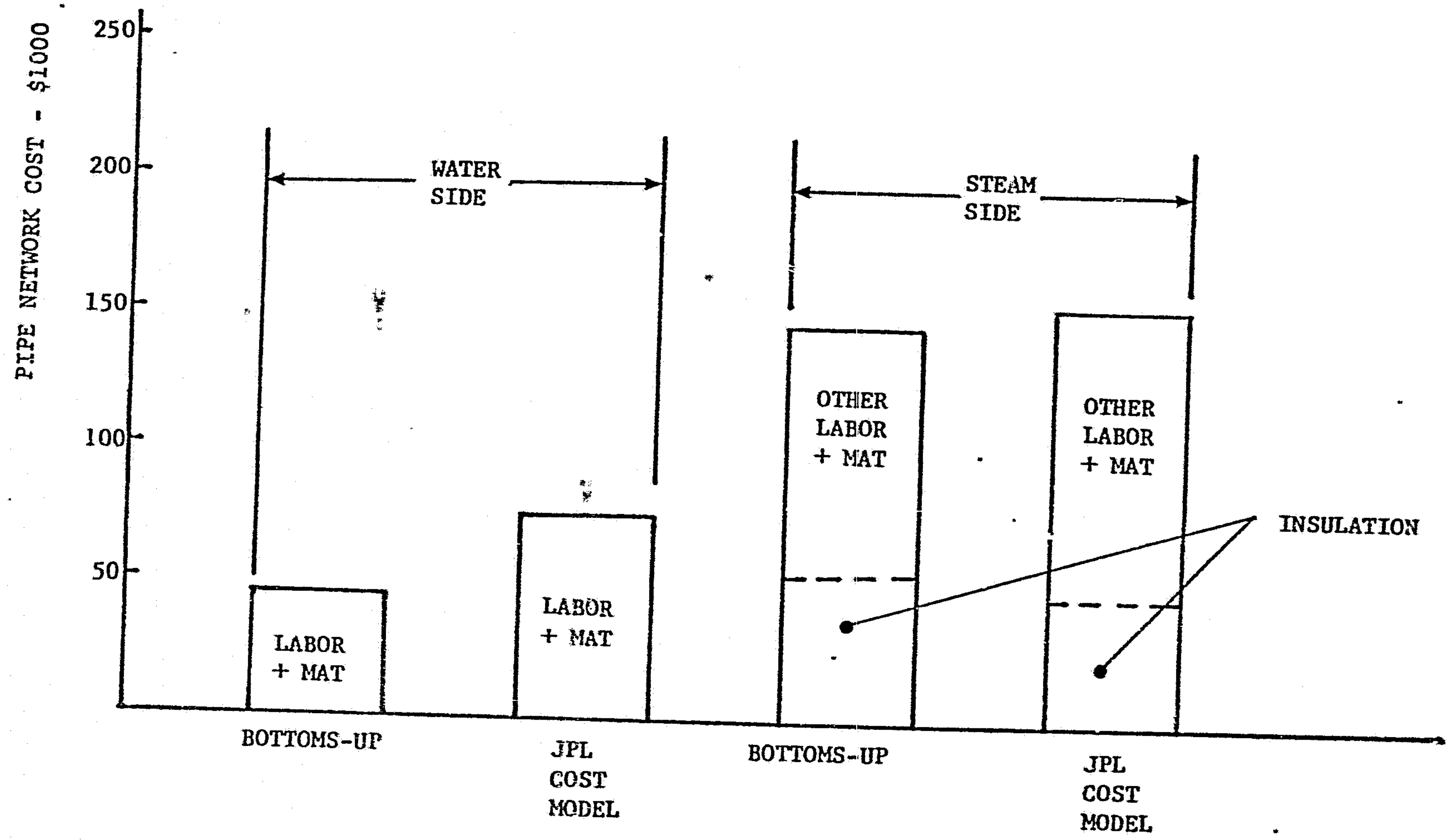


FIGURE 4-11. COMPARISON OF LABOR AND MATERIAL COST FOR STEOR PIPE NETWORK

Figure 4-12 compares the makeup of costs for the steam-side 1-inch diameter pipe (which makes up 37 percent of the hot side STEOR network) with a similar breakdown for 1-inch pipe reported by JPL. Since the JPL cost breakdown was for schedule 40 pipe, the JPL breakdown was adjusted to schedule 80 by fixing the cost of supports and proportioning the other costs based on the ratio 22.00 (\$/ft)/19.60 (\$/ft) totals (schedule 80/schedule 40) reported by JPL. As shown the installed pipe cost per linear foot for the 1-inch (most common) pipe size agrees within 10 percent. The comparison shown in Figure 4-12 does not include the $\sqrt{2}$ factor for expansion joints previously discussed.

Figure 4-13 shows the labor plus material cost breakdowns obtained from the bottoms-up STEOR analysis distributed according to nominal pipe diameter. The dotted line shows the total labor plus material cost distribution predicted by the JPL cost model. Since the majority of STEOR pipe sizes are less than 1-inch diameter, the comparisons shown in Figure 4-13 resulted in predicting a lower detailed network cost than predicted by the JPL cost model. The large cost for the 1-1/2 to 4 inch pipe diameters may occur because these are the header size pipes and have a larger number of penetrations, etc.

Figure 4-14 shows a more detailed analysis of a breakdown on the total STEOR costs. The left hand column refers to total cost with no breakdown between labor and material. The right hand column breaks down the total cost between labor and material.

The significant conclusions from Figure 4-14 are:

1. Dominant elements of labor plus material cost are:

   A. Cost of insulation (26.3%)

   B. Cost of pipe supports (37%)

2. Use of automated welding and field shop construction has the potential of reducing the following labor costs:

   A. Cutting and welding costs 21% of total cost

   B. Mechanical costs* 15%

   TOTAL 36% (Maximum possible reduction if all labor eliminated)

The areas outlined above have the greatest potential for cost reduction by the use of nonconventional and advanced construction techniques.

---

* Mechanical fastening, aligning, etc.

9950-665

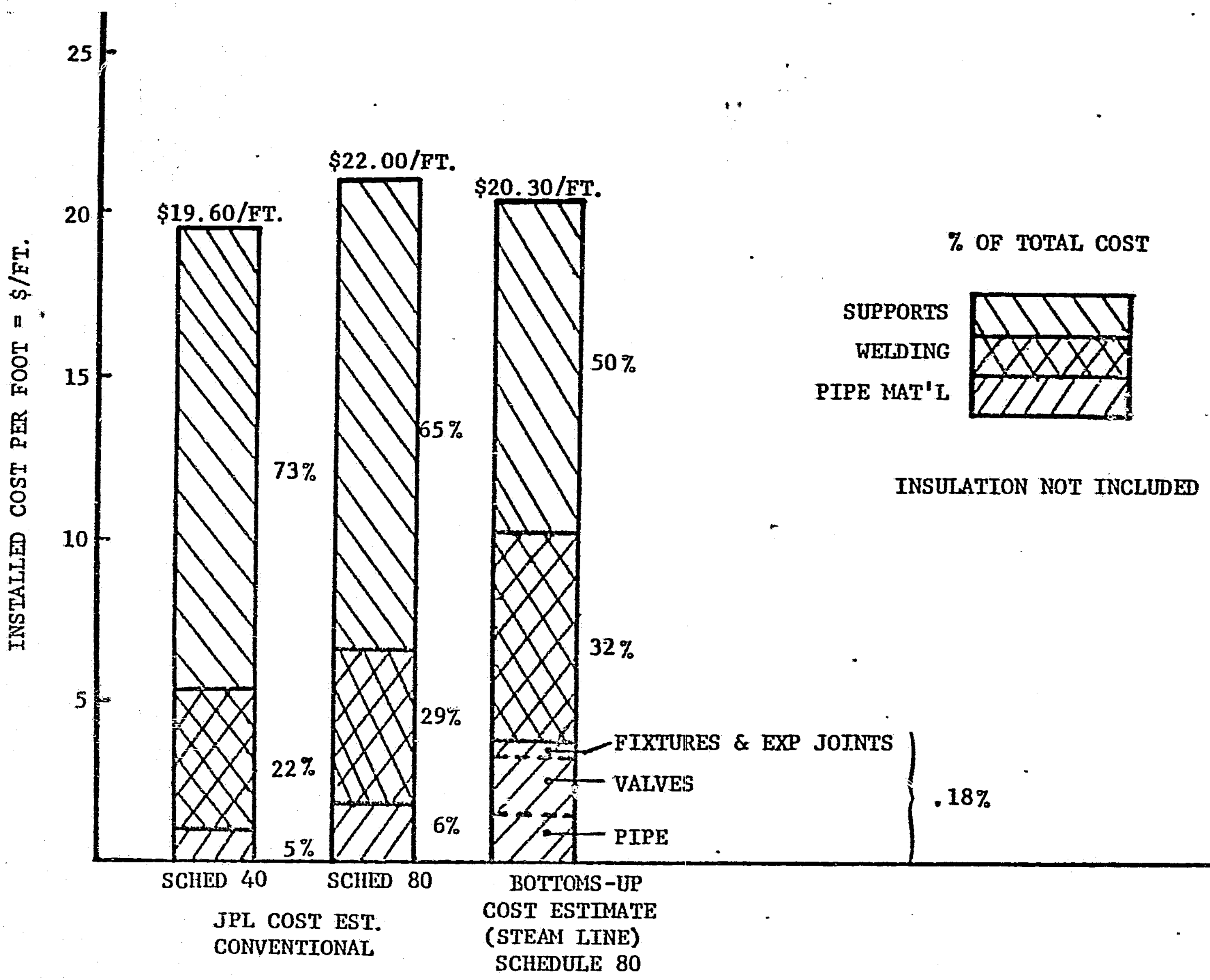


FIGURE 4-12. OVERALL COMPARISON OF PIPE NETWORK COST FOR [illegible] APPLICATION

56

ORIGINAL PAGE IS
OF POOR QUALITY

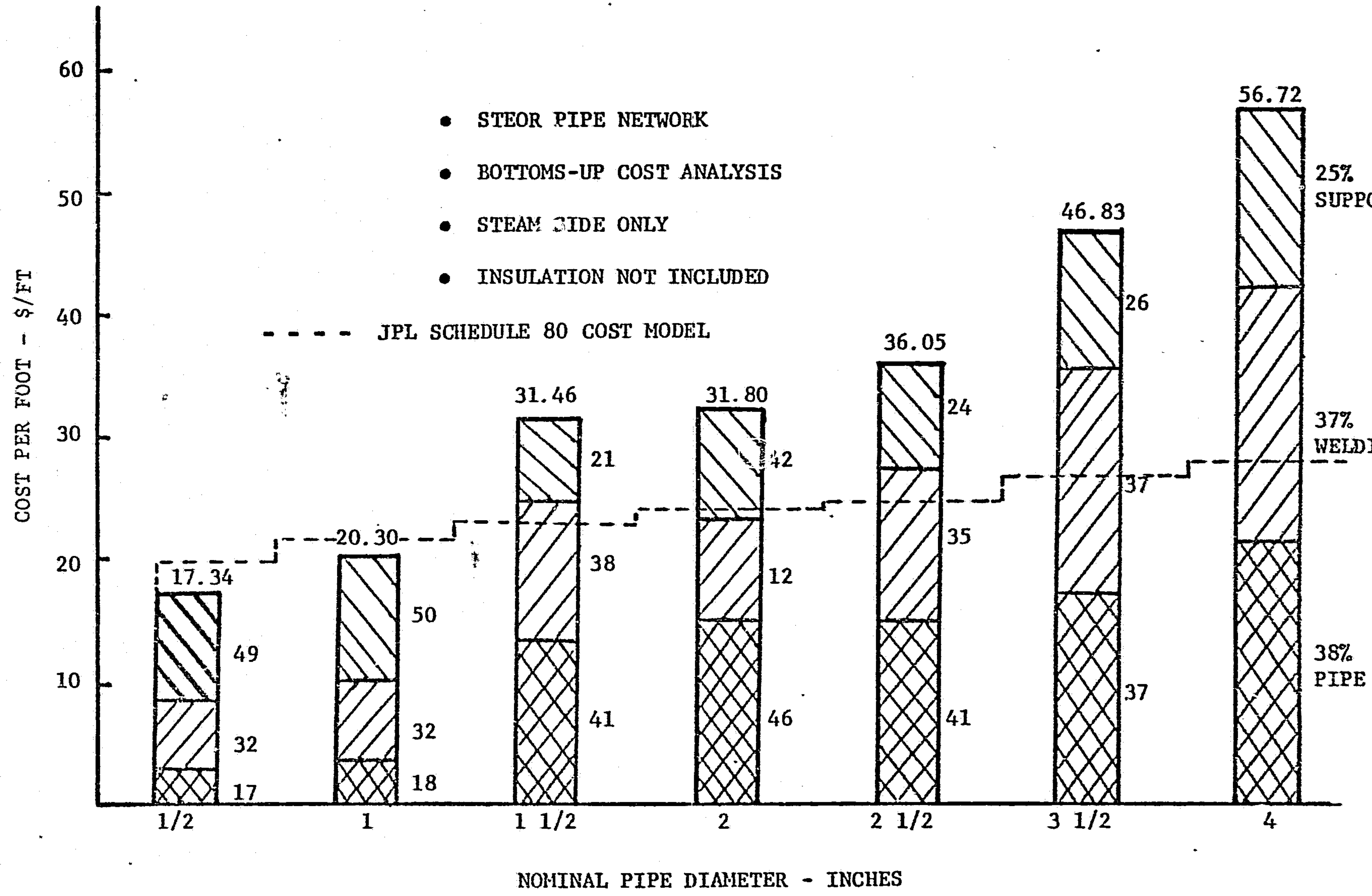


FIGURE 4-13. DISTRIBUTION OF LABOR & MATERIAL COST

57

9950-663

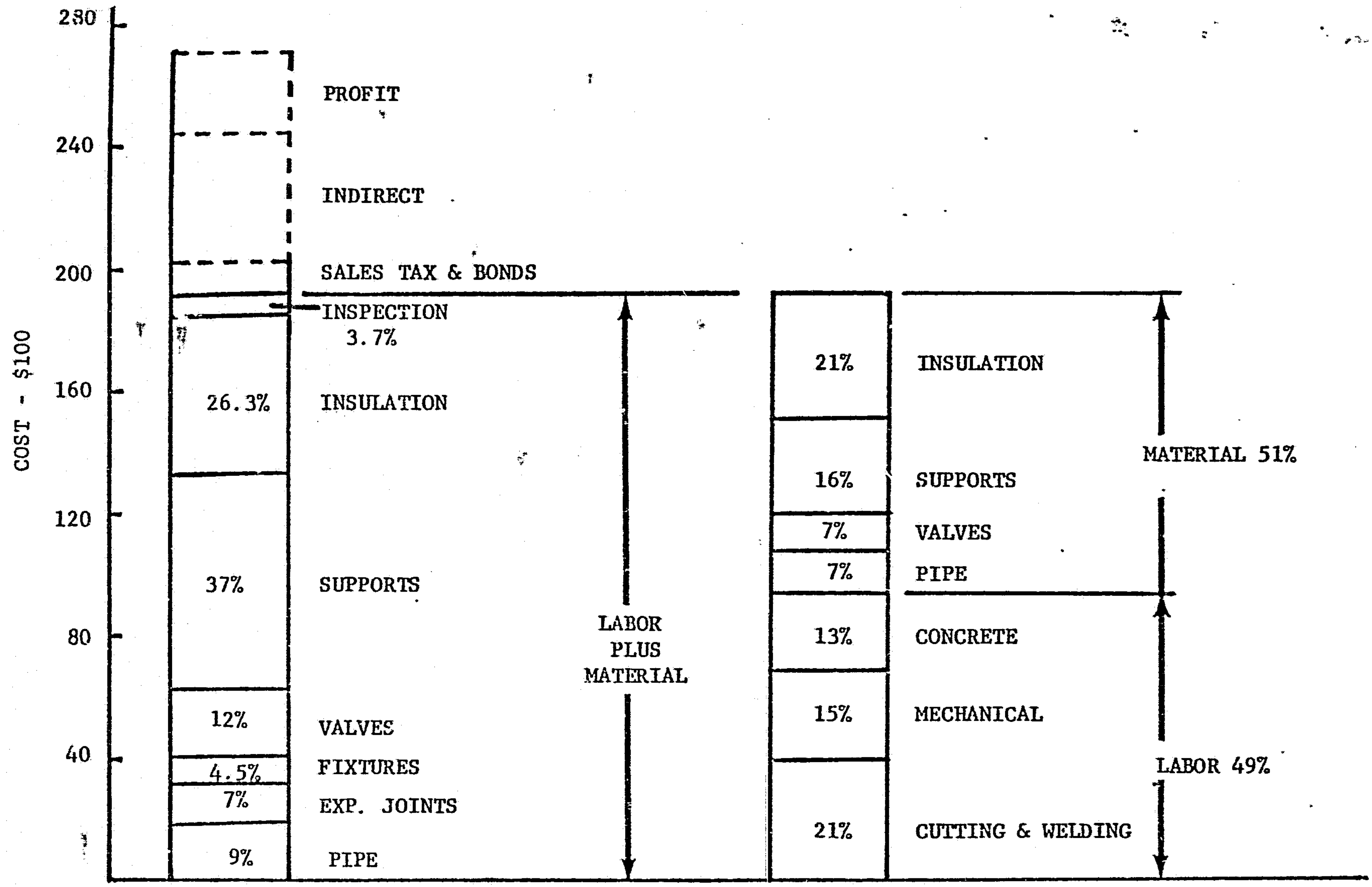


FIGURE 4-14. ANALYSIS OF LABOR AND MATERIAL COST, 72 DISH STEOR PIPE NETWORK, FACC COST ANALYSIS

58

SECTION 5

UNCONVENTIONAL CONSTRUCTION

This section discusses some approaches to pipe network construction to reduce overall cost. These represent existing or near-term technology not traditionally used in pipe network construction. The use of technologies that require major capital investment, such as new factories or automated tooling to manufacture prefabricated assemblies, is not included.

The approaches that were investigated to reduce cost are summarized in Table 5-1. Two of these, automated welding and prefabricated pipe supports, have previously been identified by JPL. The FACC study independently defined the application of these approaches to the baseline STEOR network and used the cost matrix developed for the network to assess the impact on overall pipe network cost.

In addition to the unconventional construction approaches listed in Table 5-1, a brief investigation was conducted to determine the cost benefit of using prefabricated expansion loops in place of field constructed expansion joints. These results are reported in this section.

5.1 PRE-FABRICATED OMEGA-SHAPED EXPANSION JOINTS

Substitution of prefabricated omega-shaped expansion joints in place of field constructed expansion joints made of welded elbows and straight sections of pipe offers a cost savings in total labor plus material of about five percent. The factory fabricated joint would be bent from a single piece of pipe into an omega shape. The prefabricated omega joints would be slightly more cumbersome to ship and handle in the field, but would reduce the number of field welds from eight elbow welds to two welds for installing an omega.

The cost evaluation of using omega joints was made by designing the joints for the STEOR pipe network using design curves shown in Figure 4-6 and submitting these designs to an outside fabricator for quotation. A copy of the quotation is presented in Appendix D. The cost matrix for the baseline pipe network was modified to include the quoted material cost of the prefabricated omega joints and the reduced labor to install the joints. The result was the net five percent reduction in labor plus material cost quoted above.

An interesting aspect of using the omega joint is that if the joints are mounted vertically, their higher stiffness may permit elimination of at least one pipe support per expansion joint. If this support can be eliminated, the overall pipe network cost reduction is 11 percent. The cost matrix corresponding to the vertical omega is presented in Appendix C, Figure C-2. The analyses and investigation required to make a thorough evaluation of the vertically mounted omega could not be included in the scope of this study.

TABLE 5-1. APPROACHES TO REDUCED COST

A. USE OF FLEX HOSE
   - REDUCES COST TO FIELD CONSTRUCT EXPANSION JOINTS
   - REDUCES NUMBER OF SUPPORTS

B. USE OF PILE DRIVEN POSTS FOR PIPE SUPPORTS
   - ELIMINATES EXCAVATION AND CONCRETE COSTS
   - REDUCES MATERIAL AND LABOR COSTS FOR INSTALLING PIPE GUIDES AND ANCHORS

C. AUTOMATED WELDING AND USE OF FIELD SHOPS
   - REDUCES CUTTING AND WELDING LABOR COSTS
   - PERFECT WELDS--NO REWORK

D. BURIED PIPE
   - POTENTIAL TO GREATLY REDUCE COST OF SUPPORTS
   - PERMITS USE OF MUCH LESS EXPENSIVE BLOWN OR CAST SLURRY INSULATION

5.2 FLEXIBLE HOSE EXPANSION JOINT

The elimination of expansion joints by use of flexible hoses to accommodate the thermal expansion at each dish was found to offer about a 15 percent reduction to the baseline STEOR costs. Figure 5-1 shows the flexible hose installation at the downcomer of a dish. In this arrangement the symetrically arranged feeder lines, Figure 2-3, would be allowed to grow away from the central header. No pipe anchors would be used on the feeder lines, and the number of pipe supports (guides) can be reduced because all support foundations and pillars are shared by both water and steam lines. There are no supports required to carry the offset sections of the field constructed expansion joints.

The flexible hose installed farthest from the header must accommodate about 8.5 to 9.0 inches of pipe expansion, which will be no problem for a hose installation. At dish locations closer to the header the expansion is proportionally less.

A similar installation of hoses would also be used where the 1-inch diameter feeder lines penetrate the header. Three anchor points are used along the length of the header. Expansion of the header between the anchor points is accommodated by large diameter flexible hoses installed in series with the header. These are expensive, but are not as costly as the expensive field fabricated expansion joints and additional pipe supports.

An informal quotation was obtained from Anaconda Metal Hose for the insulated hose assemblies required for the thermal expansion loops. The material cost of the hoses and their weld installation labor costs were substituted in the baseline STEOR cost matrix in place of the cost of the field fabricated expansion joints. Also, the number of anchors, pipe guides, and related foundation and pillars was reduced to account for a fewer number of pipe supports. The resulting cost matrix is shown in Appendix C (Figure C-3) and indicates a 15 percent reduction in total labor plus material cost.

5.3 PREFABRICATED POST SUPPORTS

In the conventional construction costing performed for the baseline STEOR network it was assumed that each pipe anchor and each pipe guide will be affixed to a reinforced concrete pillar. Construction of the pillar involves excavation to a shallow depth, wood forming of a footing, placement of steel reinforcing rod and a fiber pillar (sonotube) form, and pouring of concrete. The labor also included fastening steel anchor fixtures and roller guides to studs cast into the concrete.

Figures 5-2 and 5-3 compare the alternate construction techniques. The left side of each figure shows the conventional concrete construction and the right side shows prefabricated steel channels which are driven 3 to 4 feet into the ground using a post driver.

The steel channels would be purchased as predrilled and pointed posts. A fence company was contacted which stated that its fee is $600 per day for driving 200 posts per day, including equipment and crew. A more generous

61

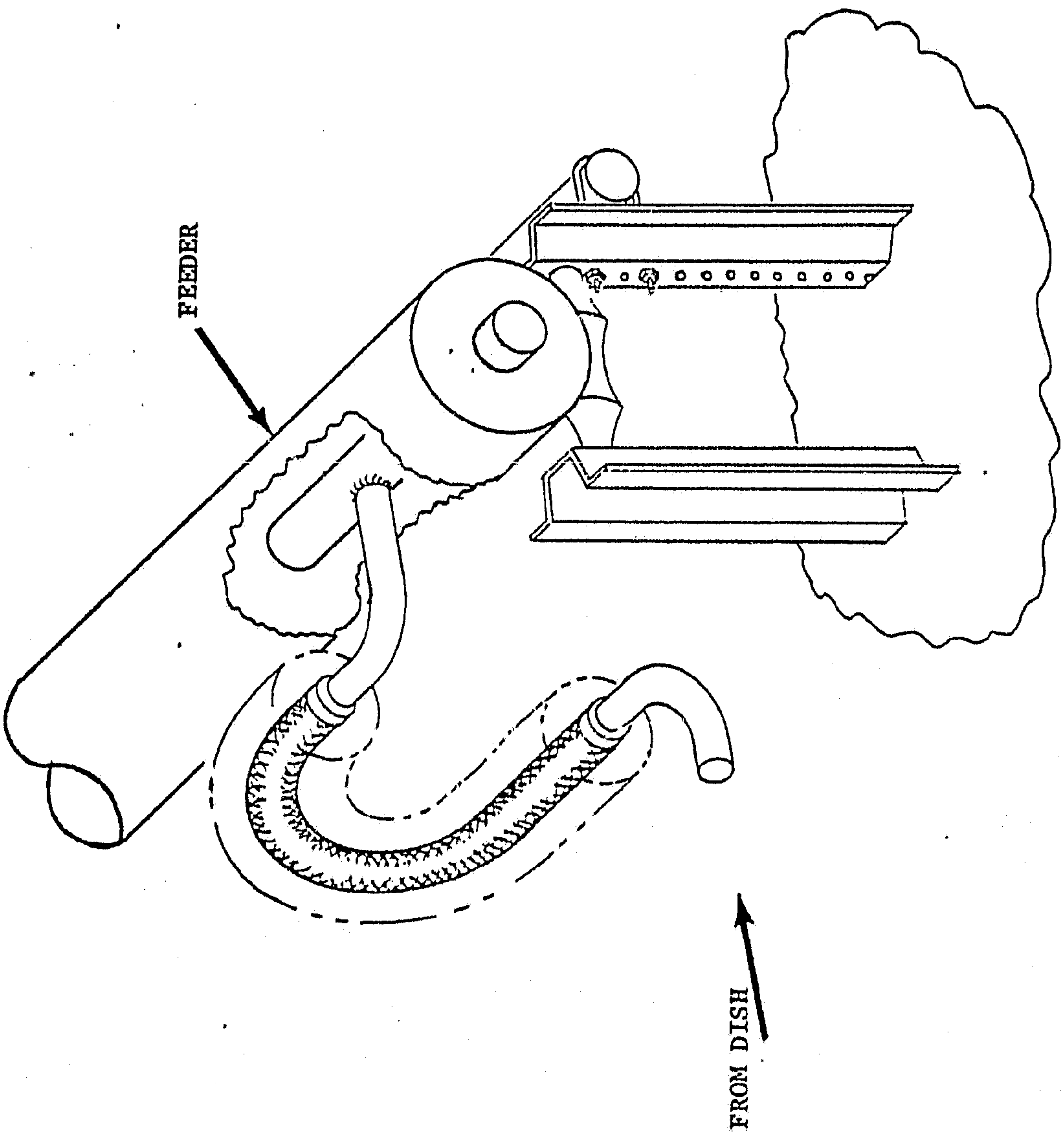


FIGURE 5-1. FLEXIBLE HOSE THERMAL EXPANSION JOINT

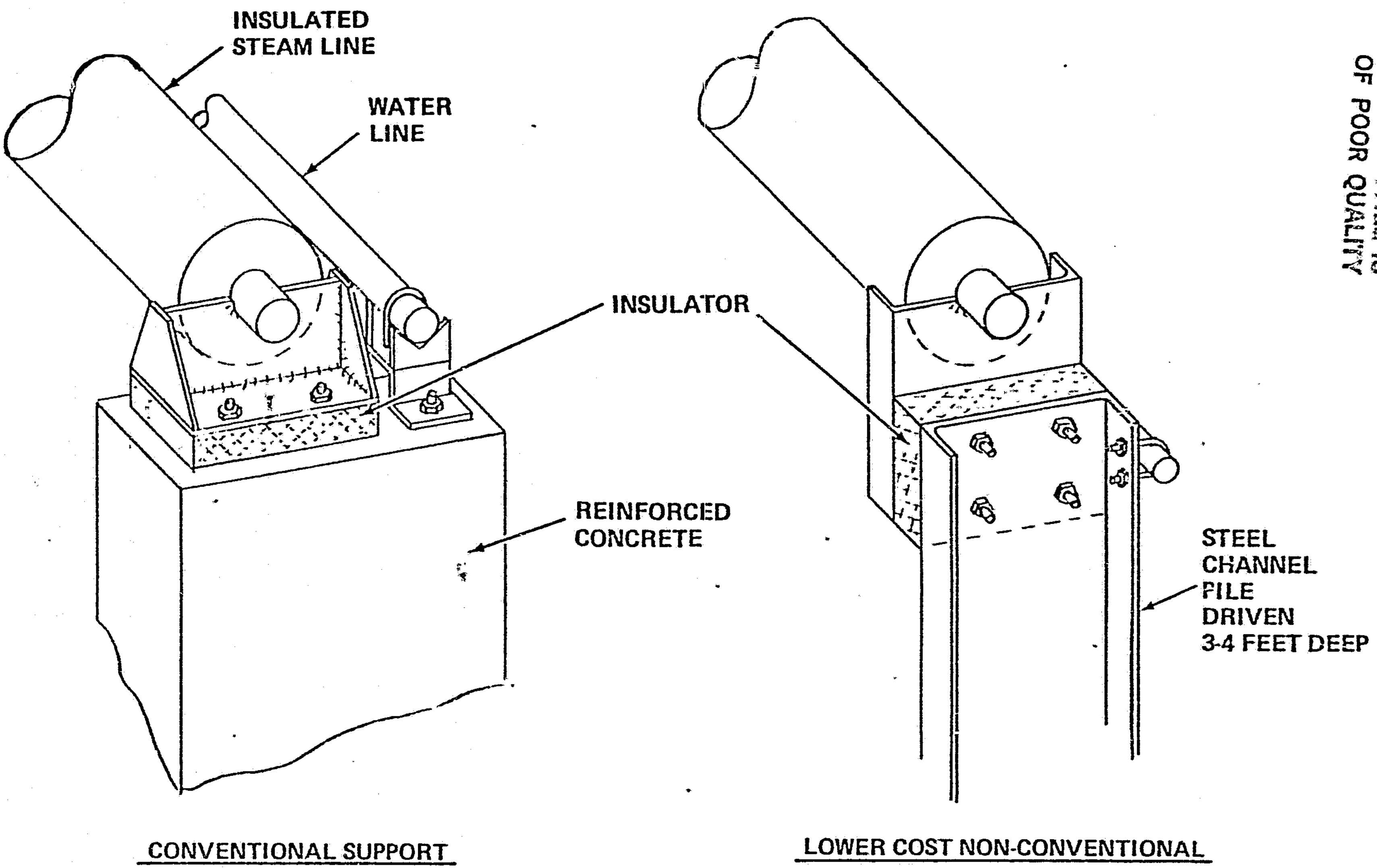


FIGURE 5-2. PIPE ANCHORS

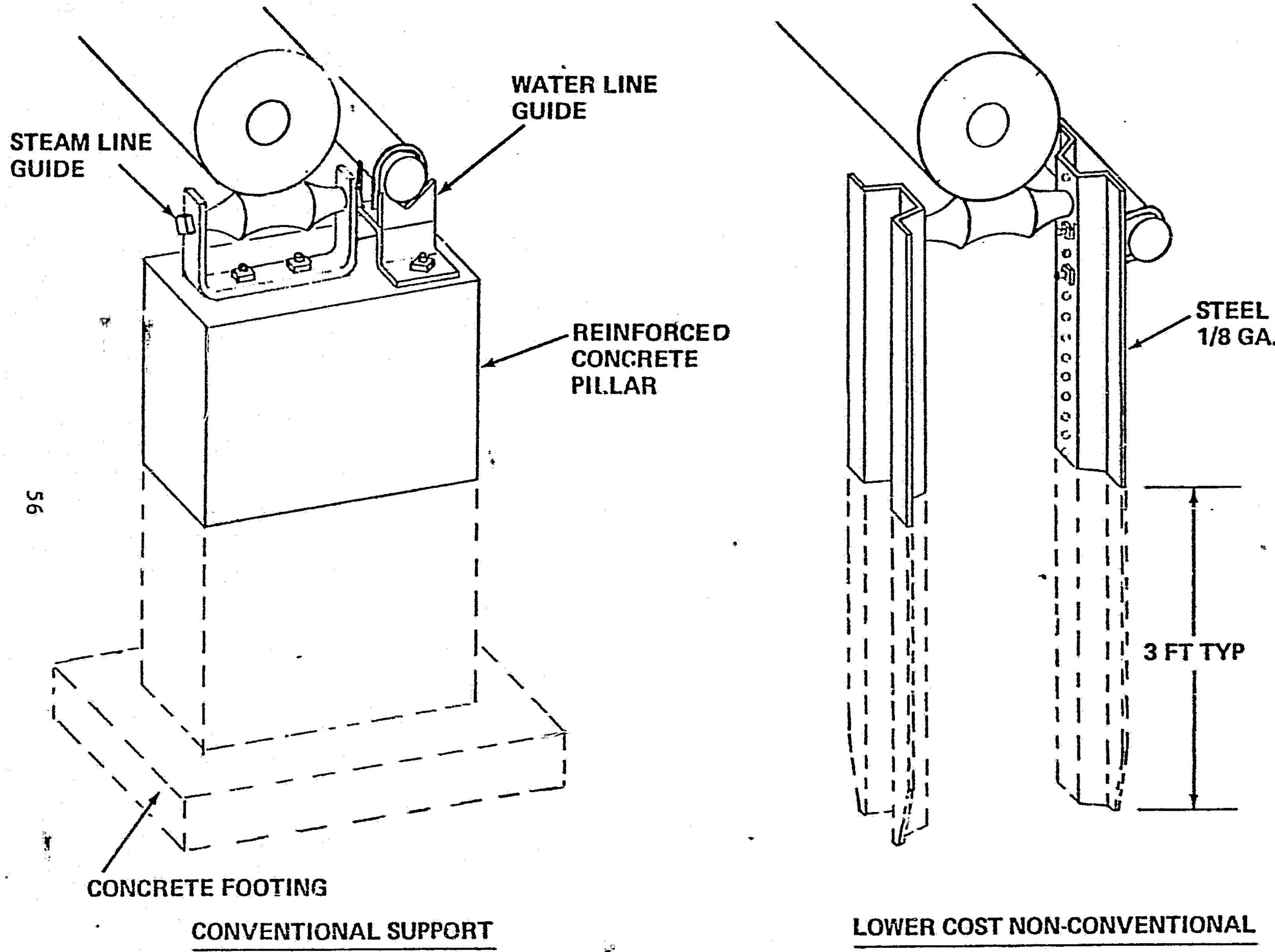


FIGURE 5-3. PIPE SUPPORTS

9950-663

allowance of $6.00 per piling was used in the cost estimating, plus additional labor for trimming, aligning, and mechanical attachment of fittings.

When the revised costs for pile or post driven supports were substituted for the costs of concrete supports (Appendix C, Figure C-4) a cost savings of 10 percent was obtained for the total labor plus material cost estimate.

5.4 AUTOMATED WELDING

The use of automated welding and field shop construction is considered as conventional technology by many people. Although the equipment for automated welding is available and well developed, its use is still primarily for factory environments and its introduction as a pipe network fabrication approach is just beginning.

As part of this investigation a meeting was held at Astro-Arc Co., Sun Valley, California. This company is a leading supplier of automated pipe welding equipment and recently provided equipment and services to the U.S. Navy for construction of a large pipe network on Diego Garcia Island.

Photographs of Astro-Arc automated welding heads are shown in Figure 5-4 and 5-5. The weld head shown in Figure 5-5 is used for smaller diameter tubes and pipes (1/8 to 2.0 inch pipe) and the head shown in Figure 5-4 is used on pipe sizes from 2.0 inches to 42 inches diameter. The weld heads use an identical power source and programmer, cabinet mounted and portable for field use. A portable control unit, attached by cable to the power source, can be used adjacent to the work to permit in-process adjustment of the weld control parameters.

In addition to the automated welding equipment, Astro-Arc demonstrated the use of portable field equipment manufactured by TRI TOOL INC., Placerville, California, which automatically self-aligns and bevels to precise shapes the pipe ends of small and large diameter pipes in a few minutes. The butt welding of a 4-inch diameter, schedule 40 pipe was demonstrated in a 17-minute period.

A schedule was generated using Astro-Arc assistance to estimate labor hours for performing automated butt welds on various pipe diameters. Reasonable times for setup and teardown were determined. A moderate weld speed of 4 inches/minute and three weld passes were used for each weld. Butt weld joints up to 1-inch diameter were assumed made under field shop conditions with minimum setup times. Subassemblies of pipe 1-inch and smaller would then be transported to the field adjacent to the shop and welded in place. Automated welds on larger diameter (greater than 1-inch diameter) were assumed to be made under field conditions and larger setup and teardown labor was estimated.

Applying the automated weld labor estimate to the field welded labor costs tabulated in the baseline cost matrix resulted in a 14 percent reduction in the total labor plus material cost for the network.

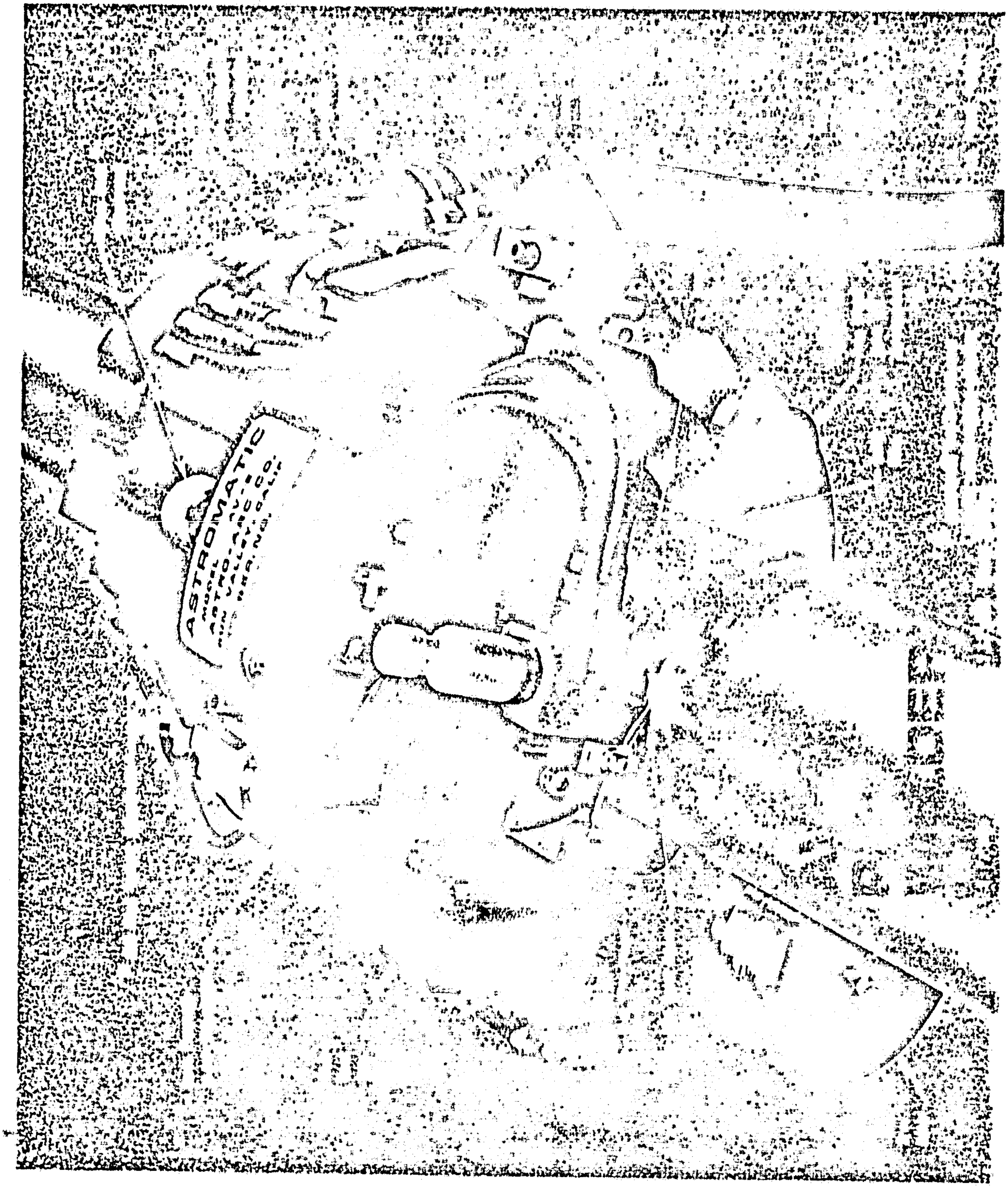


FIGURE 5-4. AV-2 PIPE WELDER

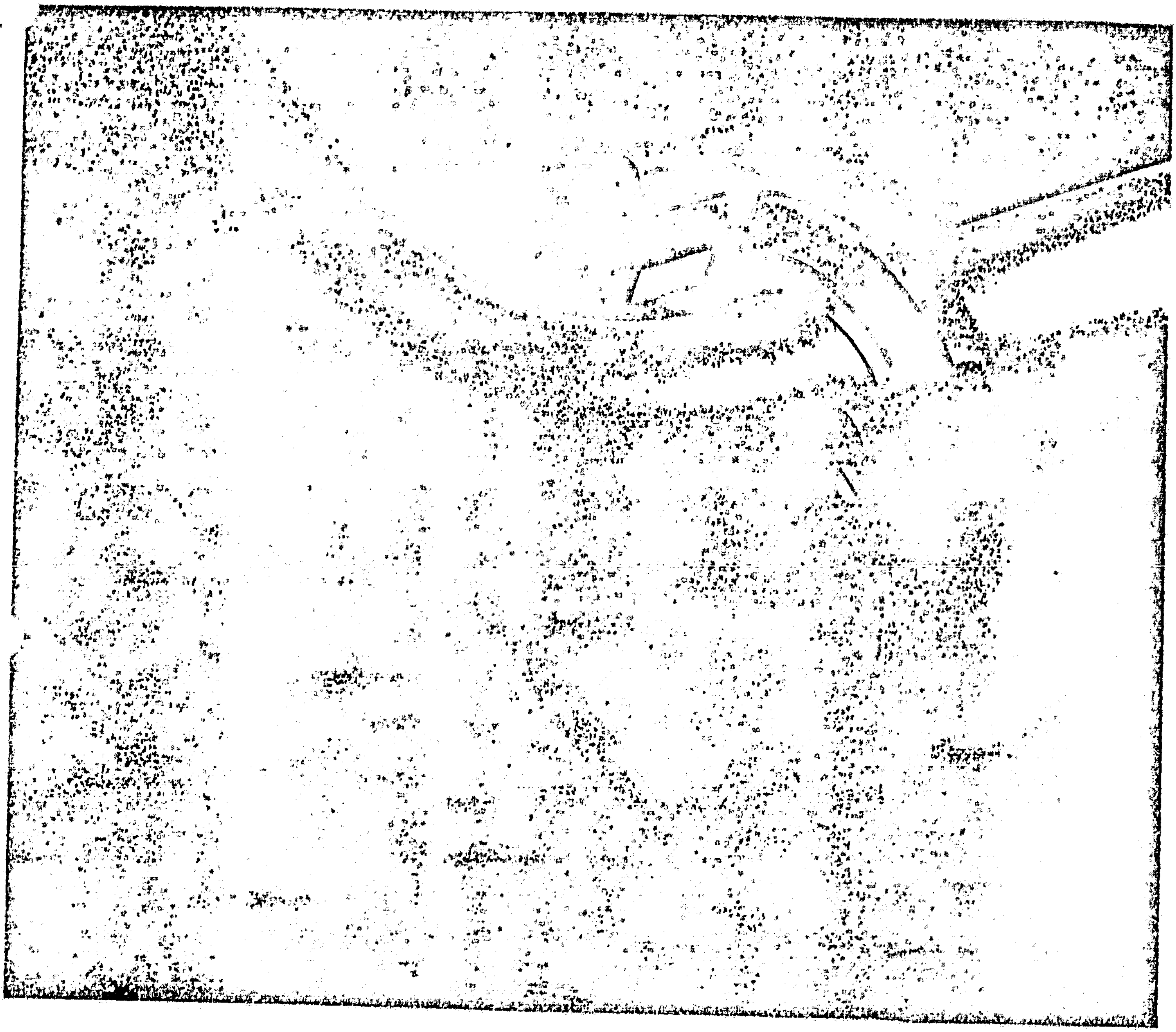


FIGURE 5-5. ASTROMATIC TUBE WELDING SYSTEM

5.5 BURIED PIPE

An unconventional pipe network construction approach identified by FACC is the buried pipe concept shown in Figure 5-6. In this approach the pipe is layed in a trench dug in the earth. This trench is sealed with a polyethylene plastic line. The pipe is suspended in the middle of the trench with simple wire hangars, and is coated on the outside diameter with a thick wax or organic mold release material. Foamed insulation is piped into the trench cavity around the pipe and cures to a rigid mass which supports the pipe within the trench. A possible insulating material is foamed slip-cast silica, commonly used as a refractory type insulator to temperatures up to 2200°F. After the insulation is cured, the pipe is released from the insulation by running hot water through the pipe to melt or degrade the mold release. The top of the cast insulation surface is moisture sealed by vacuum sealing the polyethylene liner or spraying a sealant coat of plastic or elastomeric material. The trench is then covered with earth.

This pipe concept should significantly reduce two major pipe network costs: 1) the cost of pipe supports (37 percent of total cost) and 2) the cost of insulation (26.3 percent of total cost). There is, of course, an offsetting disadvantage to this approach because of less accessibility for some of the field welds that must be performed in place. The installation expansion joints and valves may also present problems in an underground installation. Although a complete design and cost evaluation of this concept was not permitted by the funds and time available in this study, the concept has been identified as having potential merit and worthy of more complete investigation.

5.6 COST RESULTS

Figure 5-7 summarizes the cost reductions which may be available using some of the unconventional construction techniques described in this section. The cost reduction estimates were made by applying the estimated labor and material savings to the 72-dish STEOR pipe network cost matrix.

The bar on the left side of Figure 5-7 represents the labor plus material cost of the baseline STEOR network of $192K. The four bars to the right of the baseline cost show the reductions estimated for applying various cost reduction techniques to the baseline network. The remaining bars represent the pipe network costs obtained by applying combinations of the same techniques.

The cost reductions obtained by the various techniques are shown in the figure and have also been summarized in previous paragraphs. If the more promising techniques are combined the cost reductions become more attractive. Using flexible hose expansion joints in combination with post supports reduces cost by 23 percent (Appendix C, Figure C-5). If the automated welding is used in conjunction with the use of flexible hose and post supports, a total labor plus material cost reduction of 33 percent is predicted.

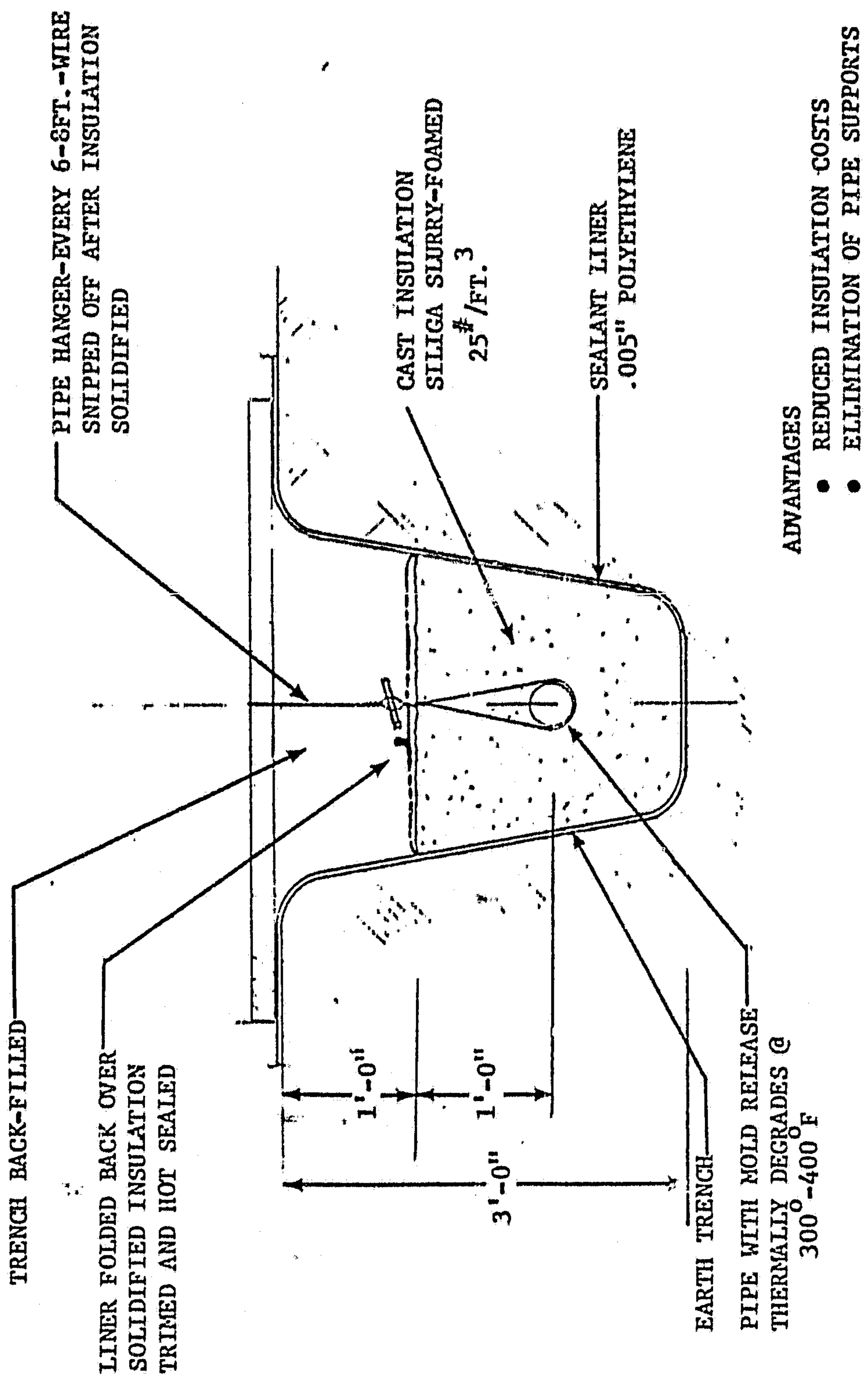


FIGURE 5-6. BURIED PIPE CONCEPT

ORIGINAL PAGE IS
OF POOR QUALITY

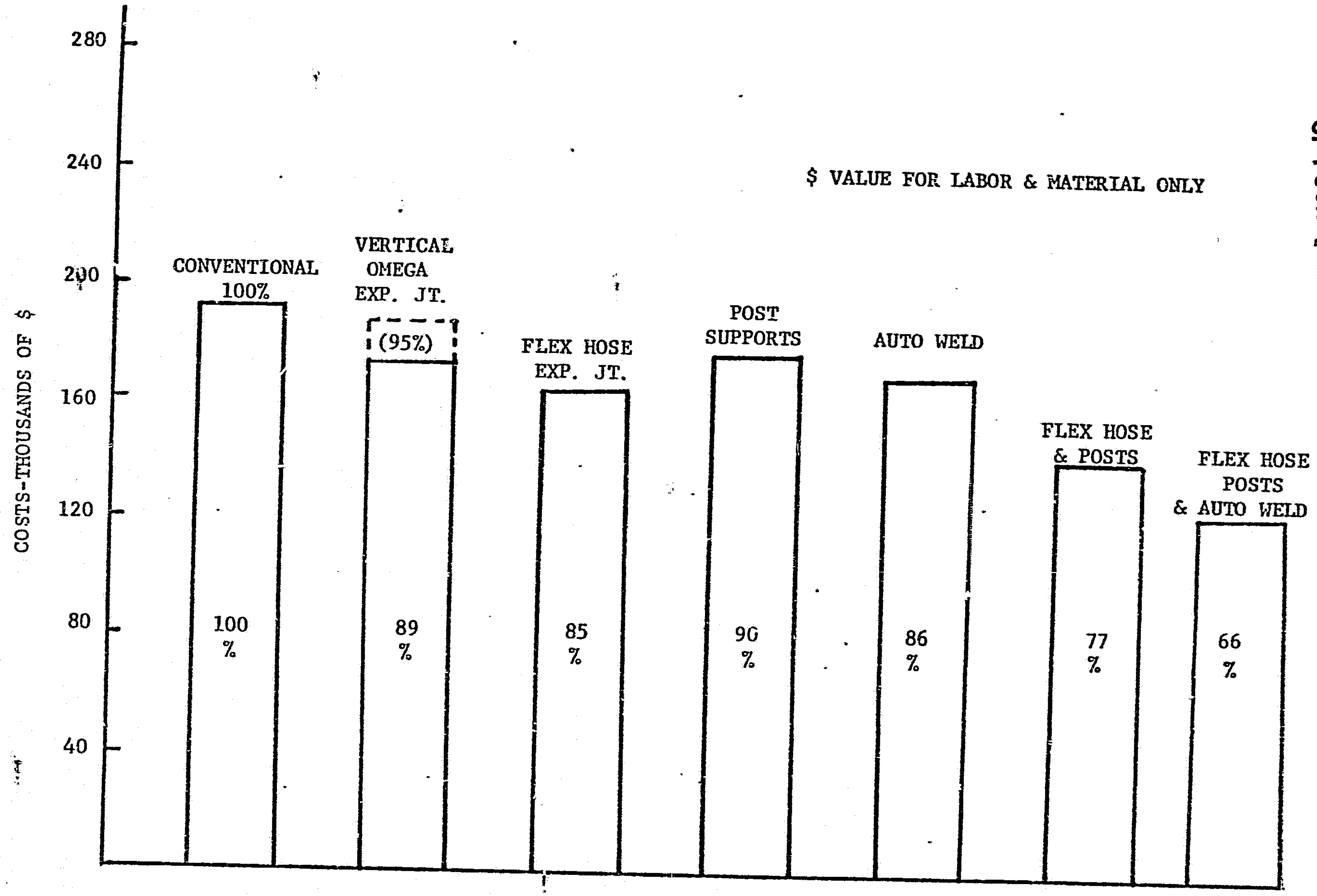


FIGURE 5-7. COST REDUCTIONS USING UNCONVENTIONAL CONSTRUCTION TECHNIQUES

SECTION 6

PARAMETRIC STUDY RESULTS

A pipe network optimization for two alternate IPH temperature applications and one additional plant size were part of Task B. The optimization was based on a cost model reflecting conventional construction technology. The JPL conventional cost model was used because the previous results of this study provided a reasonably good validation of its adequacy. In addition, FACC also reoptimized the baseline STEOR pipe network and recalculated the pipe network cost using the JPL advanced construction cost model. The JPL advanced cost model predicted cost savings that slightly exceed the 33 percent reduction identified by FACC in the previous section if this report.

The parametric optimizations were initially calculated using a cost of energy of $\$1500/kW_t$ for heat and frictional losses. At JPL's request the optimizations were also calculated for a cost of energy of $\$500/kW_t$. The results of both sets of calculations are presented in this section.

6.1 ALTERNATE TEMPERATURES

The selection of two alternate IPH temperatures was based on a rationale related to the baseline STEOR application. Figure 6-1 represents the distribution of required injection steam pressures for several California heavy oil fields where steam STEOR currently is used and can be expanded. The selected Edison Field has the second highest injection steam pressure requirement, with only the Cat Canyon-Sisquoc Field having a higher valve.

It was decided to select two lower injection pressures and the corresponding saturation temperatures for the alternate IPH temperature applications. Alternate injection pressures of 400 and 600 psi were selected which correspond to satisfying about 30 and 50 percent, respectively, of the potential STEOR steam applications. The corresponding injection temperatures are 355°F at 400 psi and 489°F at 600 psi. The pipe network optimization was recomputed using these alternate temperatures, but maintaining the baseline 72-dish field geometry.

6.2 ALTERNATE PLANT SIZE

The rationale for increasing the solar network size was to provide an annual thermal output equivalent to that of a single 25 MBTU/HR fossil fueled steam generator operating continuously. This translated to a 352 dish array containing 22 rows with 16 dishes each. Using a pipe network geometry similar to the baseline geometry, each 16-dish feeder row supplies a central header. The supply and steam discharge temperature and pressure are the same as for the baseline network.

71

ORIGINAL PAGE IS
OF POOR QUALITY

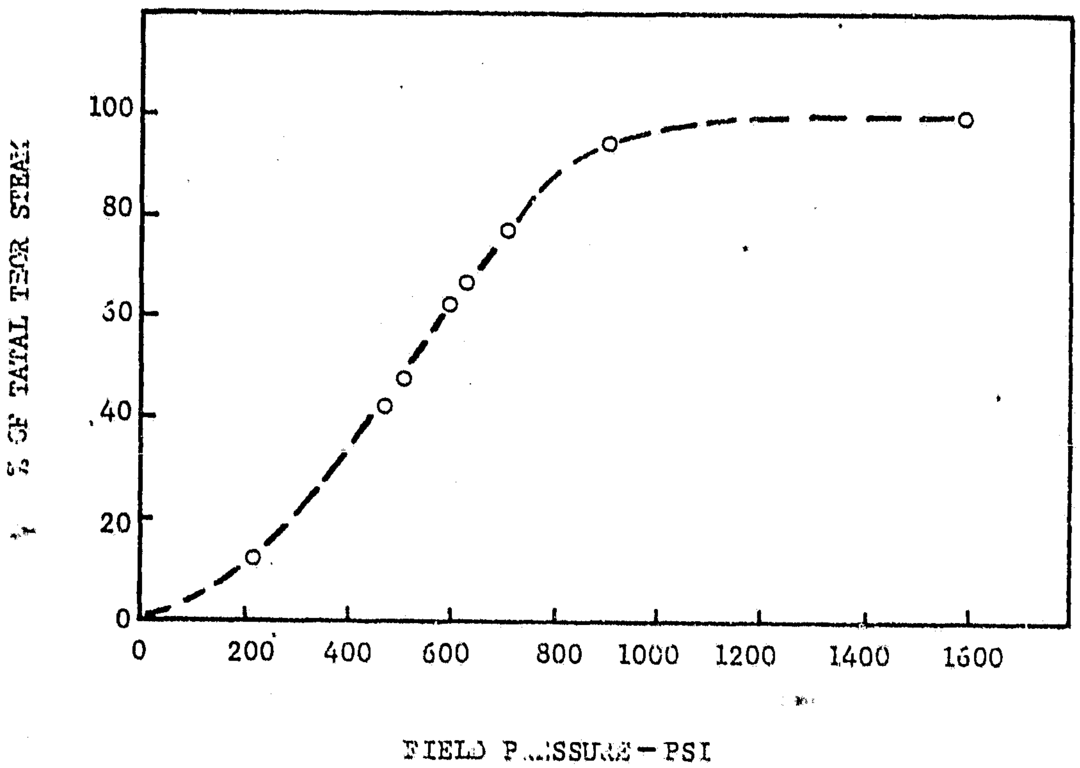


FIGURE 6-1. STEAM PRESSURE REQUIREMENTS FOR STEOR

6.3 RESULTS

Tables 6-1 and 6-2 tabulate the results of the optimization calculations made for the alternate STEOR network temperatures and plant size. Table 6-1 presents the results for $1500/kW$_t$ cost of energy and Table 6-2 presents the results for $500/kW$_t$ cost-of-energy.

The pipe network costs are expressed as both total system cost and capital cost. The total system cost is the capital cost plus the cost of the pipe network thermal and frictional losses evaluated at the appropriate cost-of-energy. The pipe network costs are expressed in terms of $/kW$_t$ and $/m^2 of concentrator, which are figures of merit commonly used to evaluate solar subsystems. The results presented in Tables 6-1 and 6-2 are reasonably compatible with results previously calculated by JPL. Total system cost increases about 14 percent ($/kW$_t$) as the process temperature increases from 355°F to 530°F (Table 6-1). The increase is primarily due to the increased heat loss, evaluated at $1500/kW$_t$. If a lower cost of energy is assumed, the effect of process temperature on total cost is less pronounced. As shown in Table 6-2, only a 5.1 percent increase in total system cost occurs as the process temperature increases over the same temperature range from 355°F to 530°F. Both tables show the capital cost (pipe plus insulation) is relatively insensitive to the influence of process temperature.

When the baseline STEOR network (corresponding to a 530°F process temperature) is reoptimized using the JPL Advanced Cost Model, the results shown in line 4 of Tables 6-1 and 6-2 are obtained. At a $1500/kW$_t$ cost-of-energy (Table 6-1) a 21 percent reduction is obtained in total system cost (capital plus energy) and a 38 percent reduction in capital cost. At a $500/kW$_t$ cost-of-energy the total system cost is reduced 31 percent and capital cost is reduced 42 percent.

The increased unit capital cost for larger plant sizes (6.3 percent in Table 6-1) results from the cost of additional larger feeders and additional headers to carry steam to the edge of the field. An improved arrangement of feeders and headers may reduce or eliminate this cost difference.

74

TABLE 6-1. RESULTS OF OPTIMIZATION ANALYSES FOR ALTERNATE STEOR PIPE NETWORKS

-1500 $\$/KW_t$ COST OF ENERGY-

- FACC OPTIMIZATION CODE
- JPL ESTIMATES FOR PIPELINE COSTS

NETWORK SIZE		COST MODEL	STEAM DELIVERY PARAMETERS		TOTAL SYSTEM COST		CAPITAL COST	
NO. DISHES	TRANSPORT CAPACITY KW_T		PRESSURE (PSIG)	TEMPERATURE (3) (^oF)	$\$/KW_T$	$\$/M^2$	$\$/KW_T$	$\$/M^2$
72	5318	CONVENTIONAL	400	355.0	68.93	44.77	44.69	29.18
72	5295	CONVENTIONAL	600	488.7	74.76	48.21	43.65	28.38
72 (1)	5284	CONVENTIONAL	850	529.6	78.53	50.45	43.88	28.48
72	5284	ADVANCED (4)	850	529.6	61.85	39.64	27.33	17.74
352 (2)	25766	CONVENTIONAL	850	527.8	84.67	54.23	46.67	30.22

(1) BASELINE STEOR NETWORK - ABOUT 20% OF FOSSIL FUELED TEOR STEAMER CAPACITY

(2) CAPACITY ABOUT EQUAL TO FOSSIL FUELED STEAMER CAPACITY

(3) TEMPERATURE AT FIELD DISCHARGE POINT

(4) JPL ADVANCED COST MODEL

ORIGINAL PAGE IS OF POOR QUALITY

TABLE 6-2. RESULTS OF OPTIMIZATION ANALYSES FOR ALTERNATE STEOR PIPE NETWORKS
-500 $\$/KW_t$ COST OF ENERGY-

- FACC OPTIMIZATION CODE
- JPL ESTIMATES FOR PIPELINE COSTS

NETWORK SIZE		COST MODEL	STEAM DELIVERY PARAMETERS		TOTAL SYSTEM COST		CAPITAL COST	
NO. DISHES	TRANSPORT CAPACITY KW_T		PRESSURE (PSIG)	TEMPERATURE (3) (^oF)	$\$/KW_T$	$\$/M^2$	$\$/KW_T$	$\$/M^2$
72	5318	CONVENTIONAL	400	349.9	51.14	33.09	40.41	26.26
72	5295	CONVENTIONAL	600	484.3	52.36	33.68	39.43	25.52
72 (1)	5284	CONVENTIONAL	850	525.4	53.76	34.44	39.32	25.38
72	5284	ADVANCED (4)	850	525.1	37.23	23.76	22.86	14.75
352 (2)	25766	CONVENTIONAL	850	523.1	57.38	36.60	41.26	26.55

(1) BASELINE STEOR NETWORK - ABOUT 20% OF FOSSIL FUELED TEOR STEAMER CAPACITY

(2) CAPACITY ABOUT EQUAL TO FOSSIL FUELED STEAMER CAPACITY

(3) TEMPERATURE AT FIELD DISCHARGE POINT

(4) JPL ADVANCED COST MODEL

ORIGINAL PAGE IS
OF POOR QUALITY

SECTION 7

RISER AND DOWNCOMER DESIGN

Task B of the Statement of Work includes a preliminary design study to define concepts for modifying the SCSE (EE-1) solar thermal electric system to incorporate IPH features. This task consists primarily of modifications to the dish installation to incorporate thermal transport riser and downcomer assemblies. The baseline parabolic dish for the SCSE system design is the LCC supplied by General Electric. The LCC was also designated by JPL as the baseline dish for the present IPH study. The remainder of this section describes the design and costing results of this effort.

7.1 DESIGN CONSIDERATIONS

The installation and kinematics of motion of the selected flexible coupling approach on the LCC are briefly summarized. Alternate design approaches are then addressed in light of the selected design.

It was recognized that the LCC posed a particularly difficult design problem to provide flexible thermal transport lines across the dish azimuth and elevation gimbals. The two gimbal points are separated by over twenty feet so that two completely different sets of flexible couplings are required. In addition the azimuth gimbal consists of the base truss structure mounted on ground level wheels which run on a 40-ft diameter track. The center of rotation is not very precise so that some design approaches, such as swiveled mechanical couplings, are difficult to incorporate.

The LCC is designed for field erection and adjustment. Virtually every truss member includes adjustable turnbuckles which are adjusted and pinned in place. There exists no opportunity to make an efficient integration of the riser/downcomer assemblies into the LCC without major redesign of the dish and base structures.

The flexible joint design eventually selected for the LCC is four separate flexible hose assemblies, two for the elevation gimbal and two for the azimuth gimbal. Pictorial drawings of the LCC base truss structure with the flexible hoses installed are shown in Figures 7-1 and 7-2. These hose assemblies are mounted on the opposed elevation trunnions of the LCC dish. Stationary lines clamped to vertical members of the base truss carry feed water up to one side of the dish trunnion and steam down the opposite side of the base truss. The elevation flexible hoses are shown in the dish-down position. As the dish rotates 180-degrees to the up position, thermal transport lines connected to the dish truss rotate the hose support "arms" and cause the hose to unwind to an hour-glass shape. Rigid lines attached to members of the dish truss carry the water and steam to and from the focal-point mounted receiver and the hose support arm.

As shown in Figure 7-1, hose assemblies are used to accommodate 300-degrees of azimuth rotation. Two sets of semi-circular tracks are used to cage the hose, one set for the water hose and an opposite set for the steam hose. In

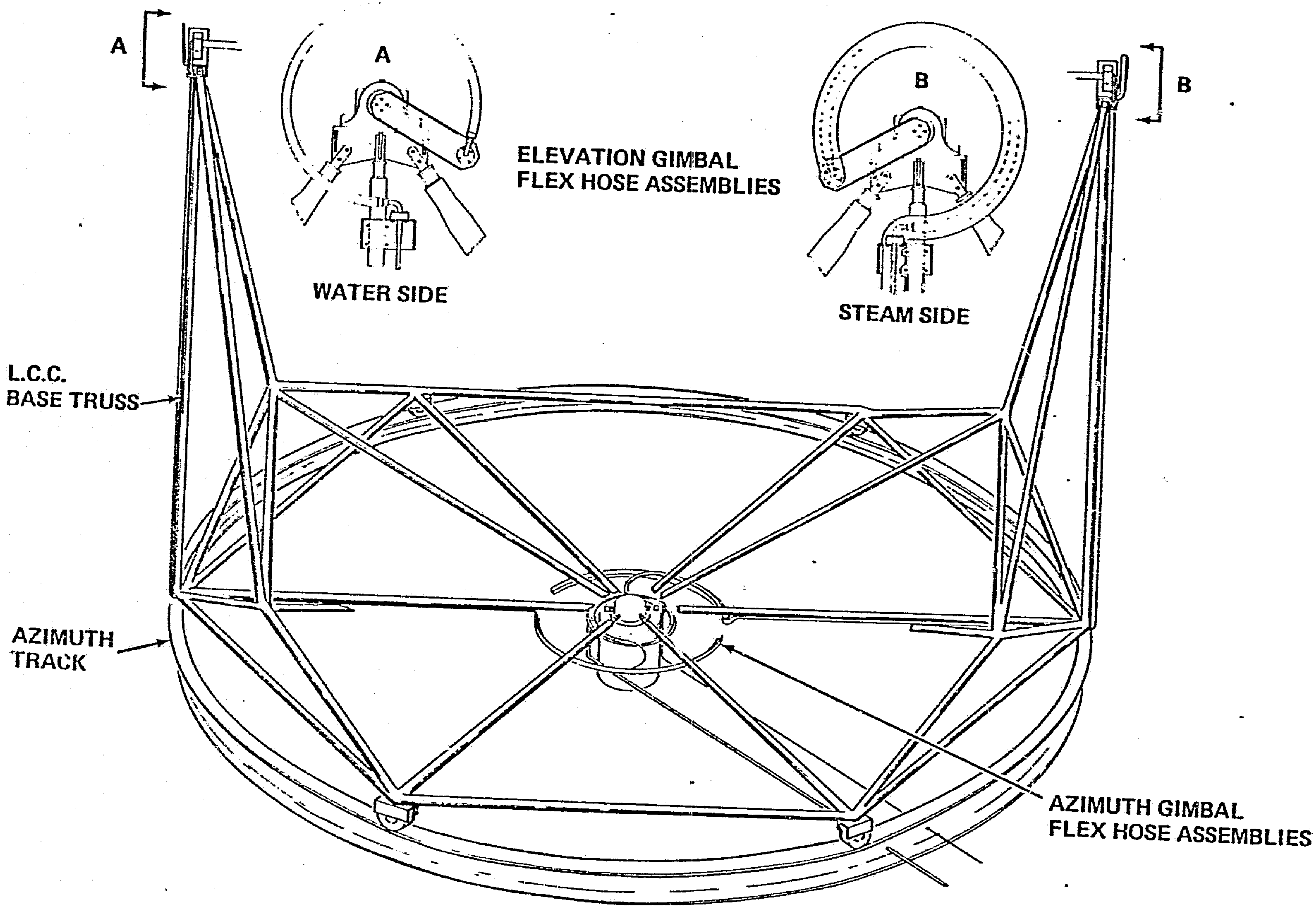


FIGURE 7-1. FLEXIBLE HOSE DESIGN ACROSS GIMBAL JOINTS

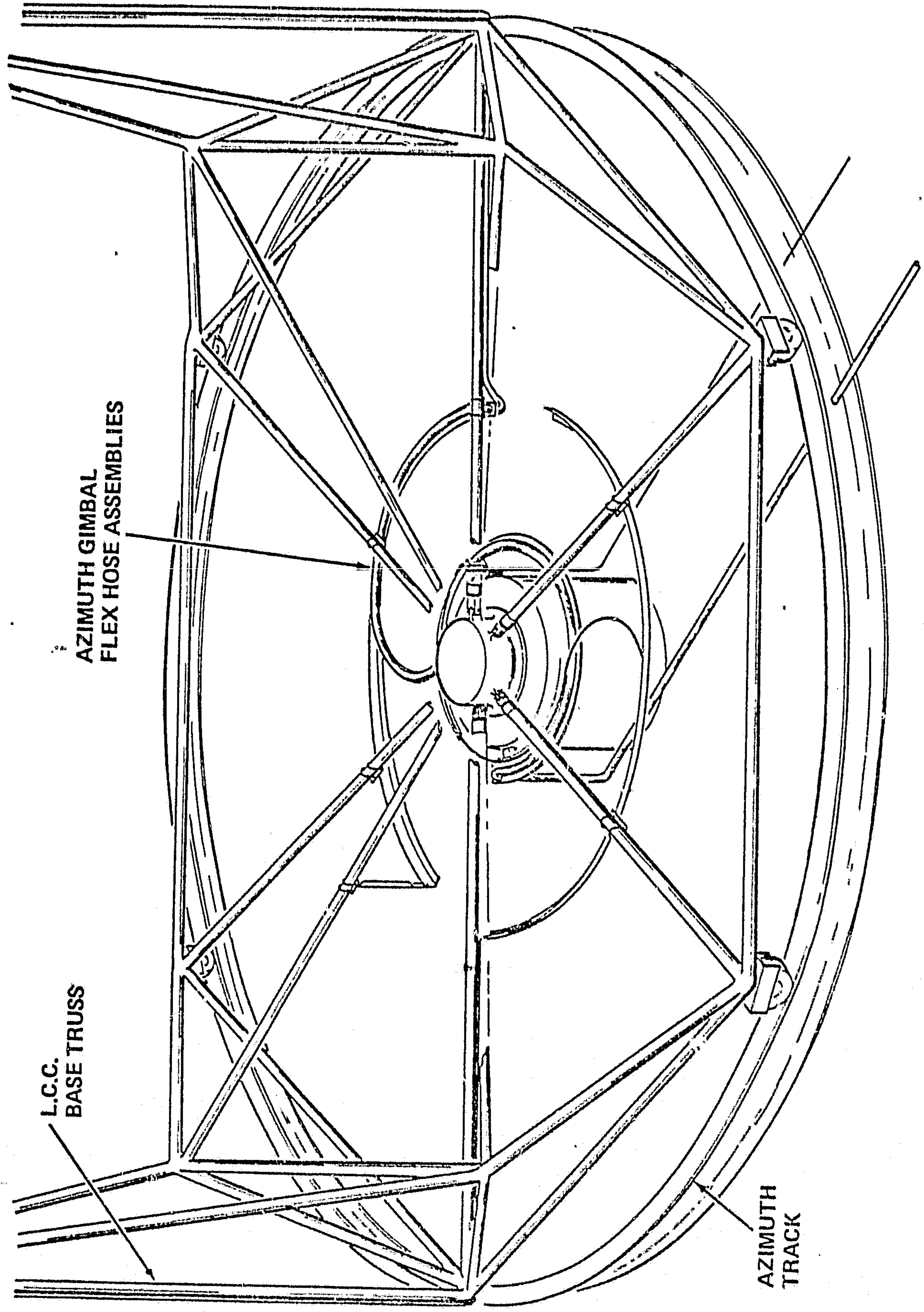


FIGURE 7-2. FLEXIBLE HOSE DESIGN ACROSS AZIMUTH GIMBAL

each set of tracks an inner track is attached to the fixed central pivot point of the dish and an outer track is suspended from the rotating base truss. As the base truss rotates from East to West, flexible hose is uncoiled from the outer track onto the inner track, and vice versa.

The selected design is described in greater detail in a later part of this section.

Alternative Design Approaches

Two alternative design approaches were considered: 1) the use of mechanical swivel joints, and 2) replacement of the hose assemblies with coiled tube assemblies which elastically deflect through the required motion.

The use of swivels such as the hydraulic swivel assemblies manufactured by Parker Hannifin were considered for the flexible coupling application, especially for the elevation gimbal water line. The following factors eliminated the possible use of this type of joint:

(1) The swivels employ both static and dynamic O-ring seals. Even the highest temperature-rated elastomers (fluorocarbons and silicones) are not rated for continuous service above 400°F, and seal life decreases rapidly at these high temperature conditions.

(2) The LCC gimbal joints do not have precise centers of rotation, especially the azimuth gimbal. To accommodate this condition would require two hydraulic swivels interconnected by flexible hose. This was considered a complicated design with a greatly increased number of potential leak points.

(3) The swivel type joints use dynamic O-ring seals to seal a mechanical interface against rotational motion. This type of dynamic O-ring application is demonstrated to be leak and failure prone, especially as the O-ring ages and swells and/or in the absence of a good lubricating agent.

The second alternate approach considered was a coil of stainless steel tubing to replace the hose assemblies. The tubing would be stressed to deflect elastically to provide the required total motion. A simplified stress/deflection analysis of this approach was performed for the 300-degree deflection of the azimuth gimbal. The results are shown in Figure 7-3. The tube size was the same as that used in the SCSE receiver and the maximum allowable stress, 15 ksi, was determined from ASME piping code. Figure 7-3 indicates that three turns of tubing mounted at the maximum allowable radius (20 feet) are required to accommodate the 300-degree deflection while not exceeding a 15 ksi stress level (bending plus pressure) within the tubing. This corresponds to an unacceptable of 339 feet of tubing. In the case of the azimuth steam coupling, both the cost of insulation (at about $3.00 per foot) and the frictional pressure drop imposed by this design eliminated it from additional consideration. The same negative reasons apply to the use of this design on the steam side of the elevation flexible coupling.

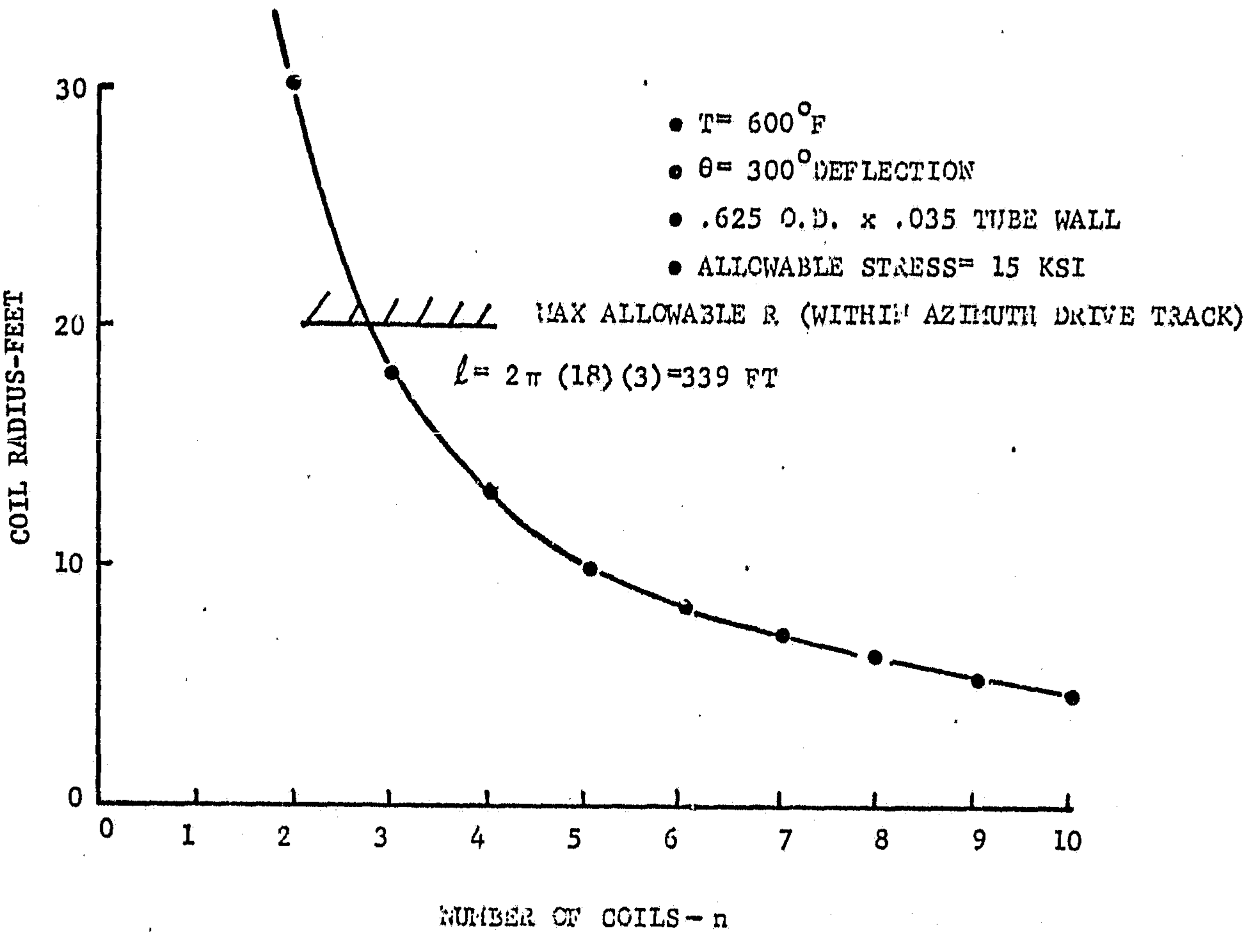


FIGURE 7-3. COIL RADIUS VS. NUMBER OF TURNS FOR COILED TUBE FLEXIBLE AZIMUTH JOINT

Although slightly more attractive for the water lines because of the absence of insulation, the coiled tube design is still expensive, poses a high friction loss, and is difficult to package.

7.2 SELECTED DESIGN

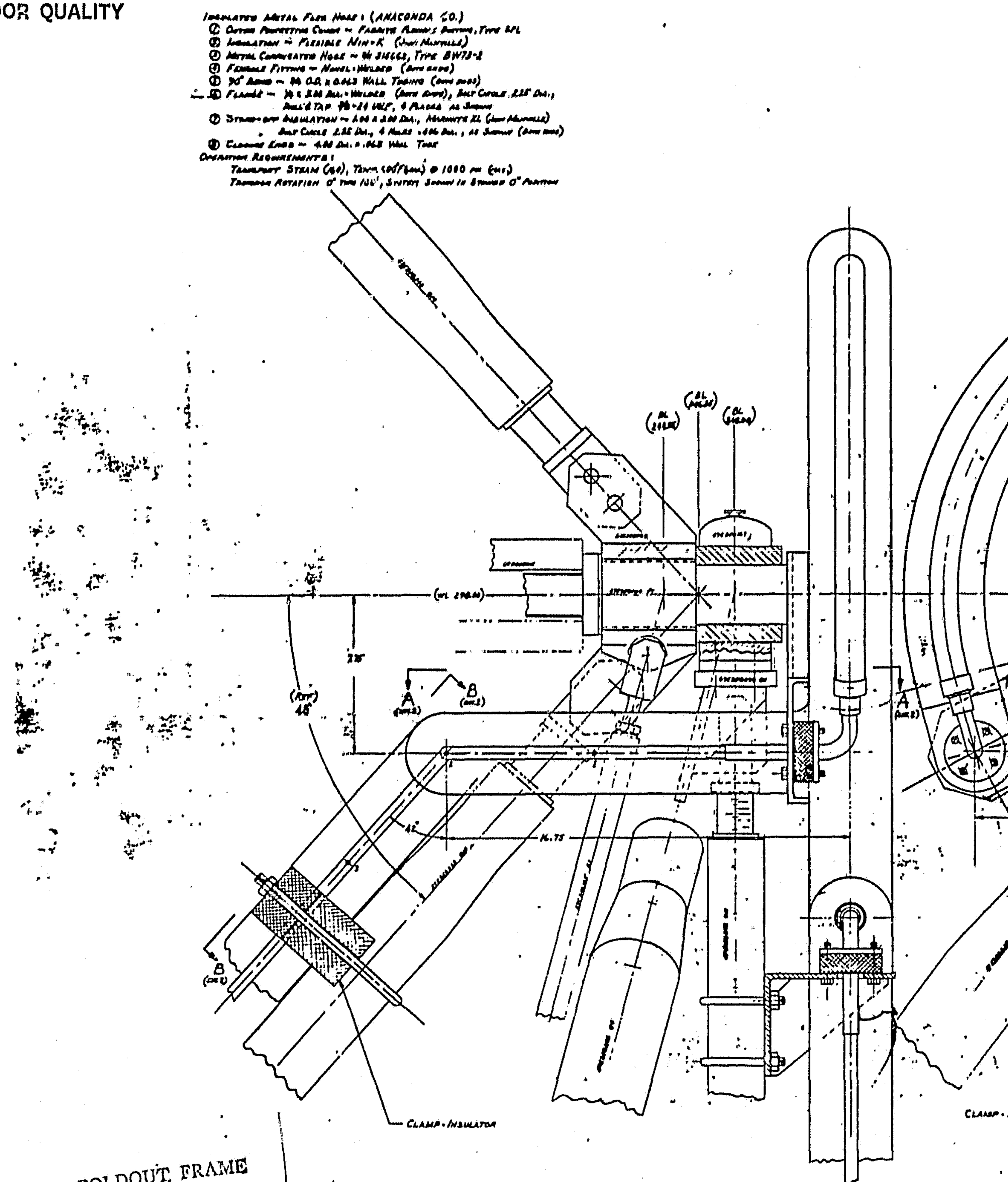
Details of the selected design are shown in Figures 7-4 and 7-5. The steam side flexible hose assembly for the elevation gimbal is shown in Figure 7-4. A rigid insulated steam tube is attached to a dish truss member and connects the receiver, located at the dish focal point, to a hose arm that swivels on the elevation trunnion. A flexible metal hose insulated on the outside diameter connects the rotating hose arm to a stationary downcomer line attached to the dish base truss. An identical, uninsulated assembly is used on the opposite side of the dish to carry feed water up to the trunnion-mounted hose arm, and then to the receiver.

At the base of the dish assembly, shown in Figure 7-5, the steam and water lines from the elevation trunnions are directed radially inward through rigid lines to the outer hose track attached to the rotating base truss. The steam and water flow are transported through the flexible hoses inward to the stationary mounted hose track attached to the central pivot. From hose termination points on the stationary track the flow is again transported radially outward at nearly grade level in rigid lines through perforations in the LCC azimuth track to discharge steam into or pick up water from the pipe network feeder lines.

The selected design consists primarily of rigid tube assemblies (0.625-inch diameter X 0.035-inch wall, 347 CRES) and brackets and fittings to attach the tube assemblies to the LCC dish and base truss structures. The steam lines are insulated with about three-inches of calcium silicate enclosed by an aluminum weather seal jacket. The elevation hose support arm and azimuth hose tracks are fabricated (cut, drilled, bent, and welded) from standard steel channel, as are all brackets and hangers.

Approximately 80 percent of the material cost is attributable to the flexible hose assemblies. These are manufactured by Anaconda Metal Hose and consist of an inner liner of deep convoluted (7.5 convolutions per inch) 321 stainless steel bellows, 0.75-inch internal diameter by 1.25-inch outer diameter. The outer diameter of the bellows is structurally supported by a stainless steel metal braid against internal fluid pressure loads. The steam line is insulated with one-inch thick Carborundum Durablanket insulation and sealed on the 3.25-inch outside diameter by a wire reinforced Hypalon polyester jacket to protect against weather and abrasion. The water line flexible hose has no insulation, but does have the polyester jacket. The elevation flexible hoses are 81-inches long and azimuth hoses are 186-inches long.

The flexible hoses have been conservatively designed to function at the minimum bend radii recommended by the manufacturer for maximum cyclic life. The reverse bending of the hose is accounted for in determining the minimum bend radii. The hose inside diameter was made intentionally large to account for the higher fluid friction caused by the internal corrugations, which is



FOLDOUT FRAME

2

FOLDOUT FRAME

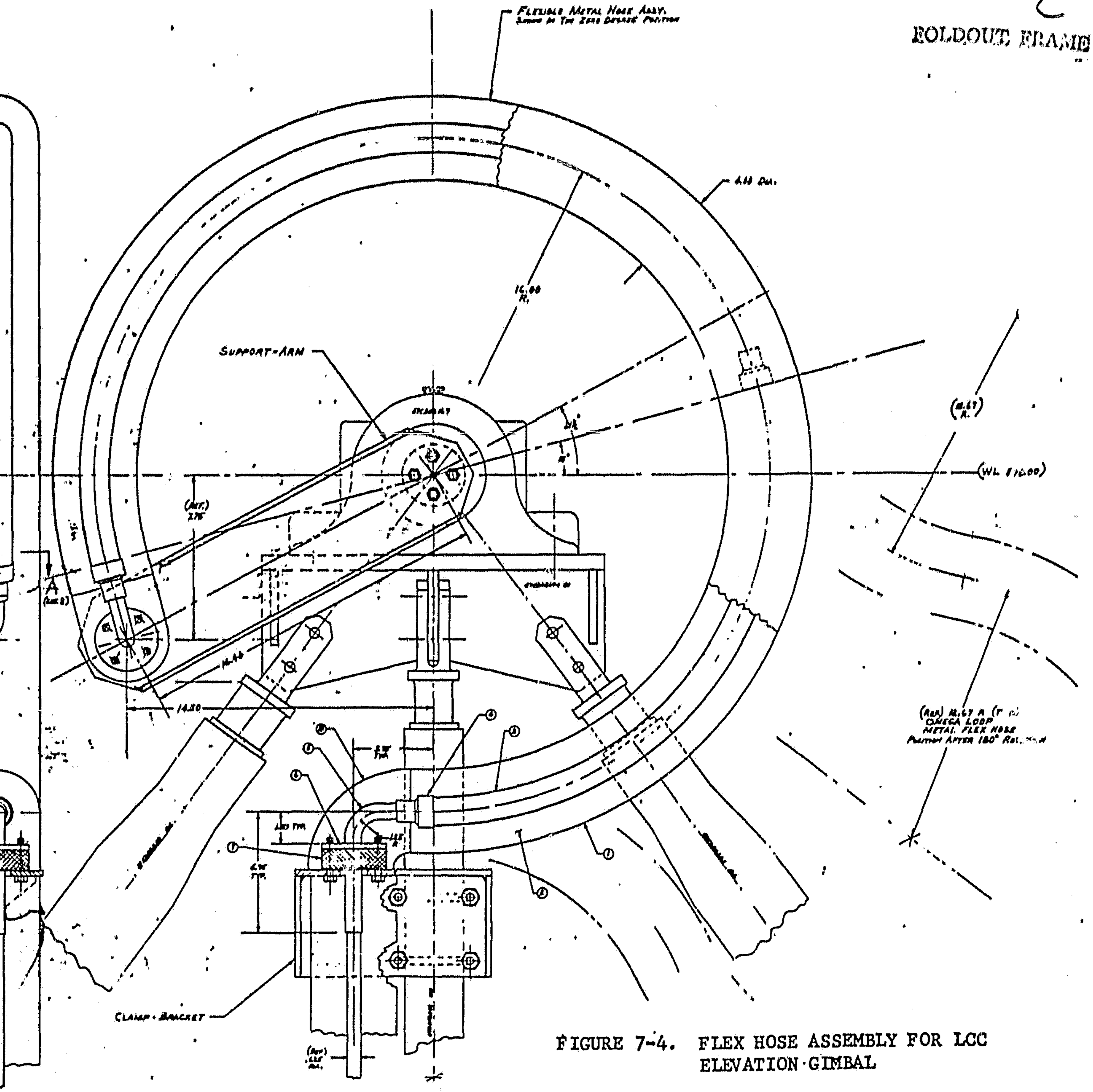
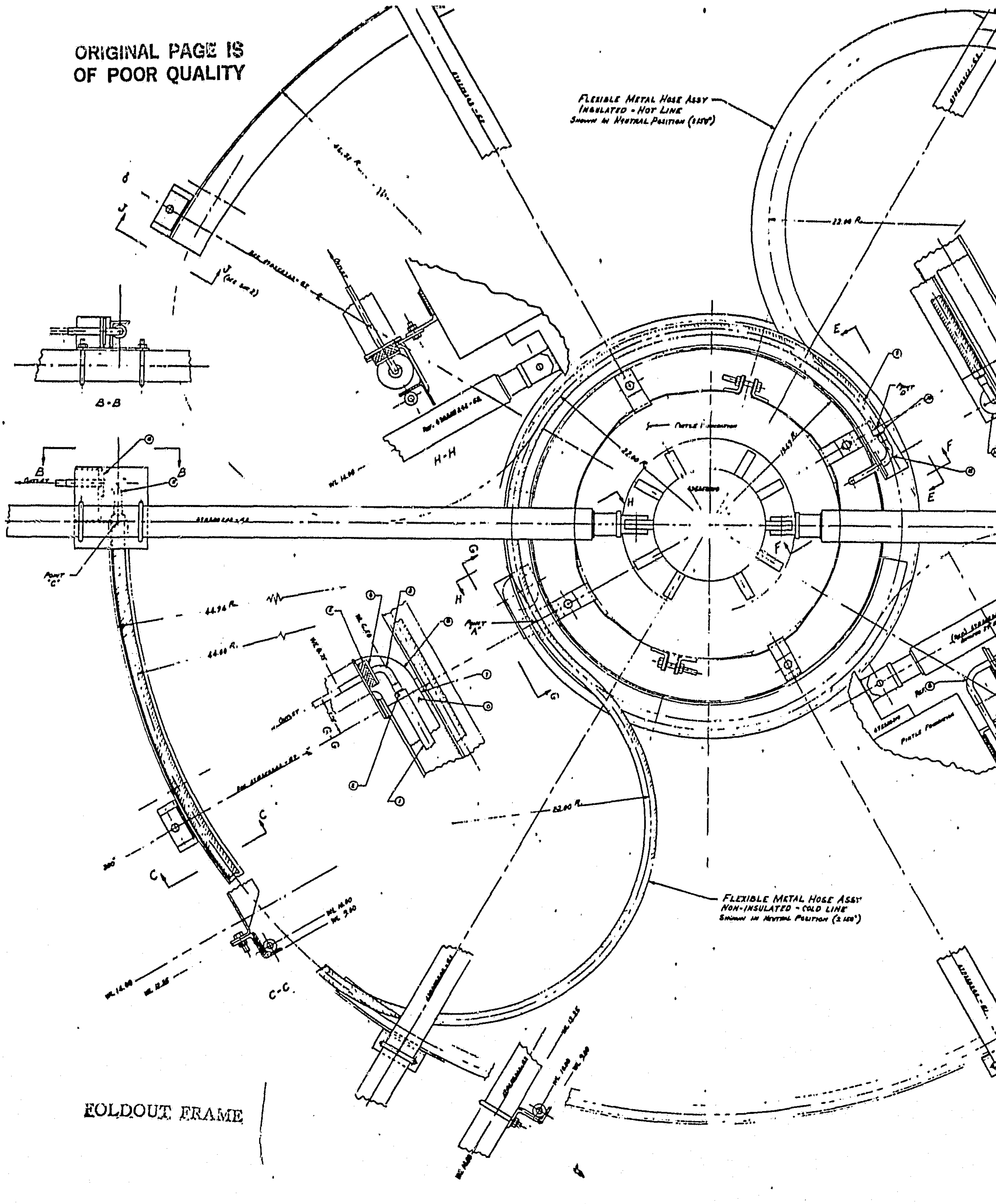


FIGURE 7-4. FLEX HOSE ASSEMBLY FOR LCC ELEVATION GIMBAL

ORIGINAL PAGE IS
OF POOR QUALITY



FOLDOUT FRAME

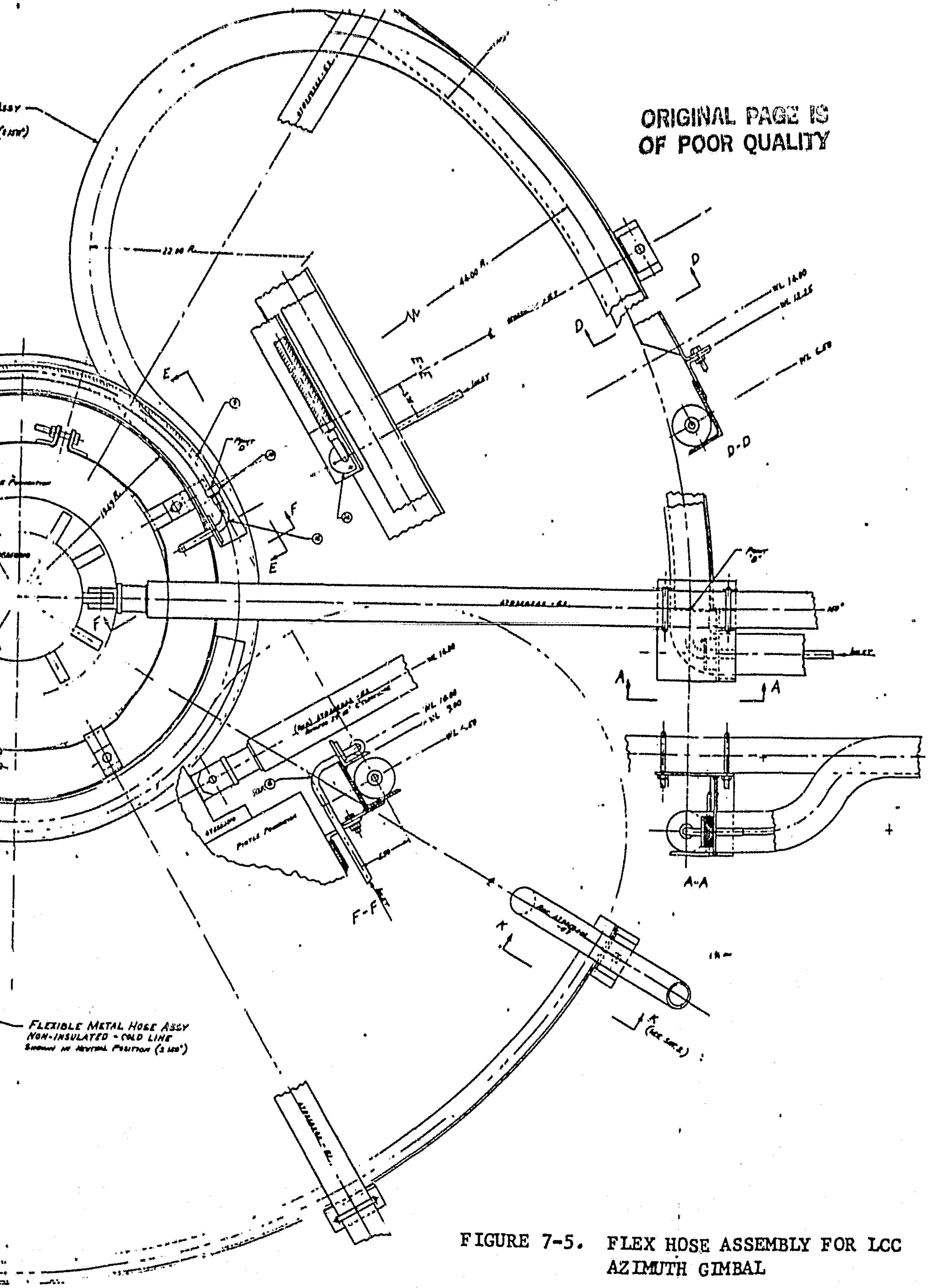


FIGURE 7-5. FLEX HOSE ASSEMBLY FOR LCC AZIMUTH GIMBAL

estimated to increase the friction factor (4fL/D) by 10 to 12 times compared to that for straight pipe. This design conservatism leads to higher cost. The impact of design conservatism on cost will be discussed in Paragraph 7.4.

7.3 COST ESTIMATES

A detailed cost estimate was performed for the LCC riser/downcomer assemblies for two quantities: a prototype quantity of 50-100 units and a production quantity of about 1000 units/year. The labor costs for the prototype quantity assemblies assumed field installation of the riser/downcomer assemblies to the dish. Labor costs for the production quantities assumed factory installation of the riser/downcomer assemblies to the truss members of the dish and its base.

A summary of the cost estimates is presented in Table 7-1. It is seen that even in production quantities the cost of incorporating riser/downcomer assemblies is \$3277 per dish, which is equivalent to about \$29/m^2. This value is comparable to the capital cost of the thermal transport field pipe network.

The very large cost to incorporate risers and downcomers is analyzed in Table 7-2 which gives a further breakdown on the production costs. Examination of this table shows that 65 percent of the total cost is due to flexible lines at the gimbal joints whereas the remaining 35 percent is for the rigid lines running from the ground to the focal point. The influence of the LCC dish design on high gimbal (flexible) line cost is also shown by the fact that the azimuth gimbal lines are more than double the cost of the elevation gimbal. This indicates that a short coupled azimuth gimbal alone would reduce total cost by 22 percent.

7.4 COST REDUCTION MODIFICATIONS

This section addresses the potential design modifications which could be employed to reduce the cost of riser/downcomer assemblies. The recommended modifications are divided into two classes: 1) modifications which could be incorporated into the basic LCC dish, and 2) modifications which would require a different dish structure.

7.4.1 MODIFICATIONS TO THE LCC DESIGN

a. Smaller Diameter Flexible Hose. The first modification recommended for the basic LCC design is the use of a reduced diameter flexible hose assembly. This will reduce the cost of the hose in two ways: 1) smaller diameter hose is less expensive, and 2) the smaller diameter hose can be coiled to a smaller radius resulting in shorter lengths being required (15 percent length reduction). The penalty of using smaller diameter hose would be a greater frictional loss. The proposed riser/downcomer flexible hoses use 0.75-inch internal diameter (I.D.) hose. If this hose was reduced to 0.50-inch I.D., the projected cost changes are those summarized in Table 7-3A. The negative impact of this design change would be to increase the estimated frictional energy loss through the hoses (primarily in the steam side) by a factor of five. The convoluted bellows frictional parameter is estimated to be twelve times

9950-663

TABLE 7-1. COST ESTIMATE, THERMAL TRANSPORT MODIFICATIONS TO LCC DISH

MATERIAL COSTS	PROTOTYPE QUANTITY (50-100 UNITS)	PRODUCTION QUANTITY (>1000 UNITS/YEAR)
STRUCTURE, FITTINGS, ETC.	$ 1318 EACH	$ 988 EACH
FLEXIBLE HOSE ASSEMBLIES		
ELEVATION GIMBAL		
STEAM SIDE	915	375
WATER SIDE	448	200
AZIMUTH GIMBAL		
STEAM SIDE	1405	703
WATER SIDE	639	328
TOTAL MATERIAL	4725	2594
LABOR COSTS	1,367	683
TOTAL COST*	$ 6092 EACH	$ 3277 EACH

*TOTAL COSTS EXCLUDE PROFIT, SALES TAX, CONTRACTOR INDIRECT CHARGES

9950-663

TABLE 7-2. BREAKDOWN OF PRODUCTION COST ESTIMATE TO INCORPORATE RISERS/DOWNCOMERS ON LCC DISH

	PERCENT OF TOTAL COST		
	MATERIAL	LABOR	TOTAL
AZIMUTH GIMBAL			
HOSES	31.3		
OTHER STRUCTURE	10.6		
TOTAL	41.9	2.4	44.3
ELEVATION GIMBAL			
HOSES	17.5		
OTHER STRUCTURE	1.2		
TOTAL	18.7	1.4	20.1
RIGID LINES	18.2	17.4	35.6
	78.8	21.2	100.0

PRODUCTION COST = 100% = $3277 EACH

TABLE 7-3. POTENTIAL RISER/DOWNCOMER COST REDUCTIONS FOR LCC

A. Use of Smaller Diameter (0.50-inch I.D.) Hose		B. Use of Smaller Diameter Hose and Less Conservative Bend Radii	
1. Baseline Total Cost	\$3277	1. Baseline Total Cost	\$3277
2. Cost Changes (\$)		2. Cost Changes (\$)	
• Reduced hose cost	-400	• Reduced hose cost(2)	-640
• Other hardware reductions(3)	-78	• Other hardware reductions(3)	-96
• Increased pumping (friction loss)	+242(1)	• Increased pumping (friction loss)	+145(1)
3. Net Cost Reduction	-\$236 or -7.2%	3. Net Cost Reduction	-18%

(1) Cost of Non-recoverable Frictional Pumping Energy = \$500/kW_t
(2) 40% reduction in azimuth and elevation hose costs
(3) 25% reduction in other hardware cost

higher than that for a straight pipe of equivalent I.D. In Table 7-3 the cost of pumping energy is assessed at \$500/kW_t. The increased frictional loss is offset by a 15 percent reduction in hose cost and 8 percent reduction in other related hardware cost. The net cost reduction is \$236 or 7.2 percent as shown in Table 7-3A.

b. Reduced Design Conservatism. The flexible hose assemblies for the LCC dish gimbals were designed with generous bend radii to provide maximum hose life under continuous cycling. The design conservatism stems in part from the use of double the manufacturer's recommended bend radii to account for the reverse bending the hoses undergo in the proposed design. The manufacturer's design recommendation applies to bending in one direction only. The reverse bending imposes a positive-to-negative bending stress on the hose bellows as opposed to only a zero-to-positive or zero-to-negative encountered in bending in only one direction.

Use of a smaller bend radius in the hose assemblies will also shorten the length of the hose assemblies to reduce cost. The potential to reduce cost by using 0.50-inch I.D. hoses shortened to one half the length used in the baseline design is shown in Table 7-3B. The net cost reduction is \$591 or 18 percent. It is likely that this cost reduction would be offset by increased replacement costs due to reduced cyclic life. However, the hose life/bending data to evaluate the life cycle cost was not available from the hose manufacturer.

7.4.2 HA/DEC DISH DESIGN

If alternate dish designs were considered for IPH applications, a conventional equatorial mount configuration (HA/DEC) of the type shown in Figure 7-6 would be an excellent candidate with respect to reduced cost of risers and downcomers. The lengths of the rigid lines from the ground to the receiver are less than required for the LCC, and only a single flexible joint assembly would be required to accommodate motion along the hour-angle drive axis. The flexible hose could be designed as a compact assembly located at the declination drive location shown in Figure 7-6. An inexpensive, short link of flexible hose could accommodate the small changes in declination drive angle which occur. The savings in riser/downcomer costs permitted by this alternate dish drive is probably in the range of 40 to 60 percent of the costs estimated for the baseline LCC modifications.

7.4.3 SINGLE POST DESIGN

Another dish design approach which would greatly reduce the costs of the IPH risers and downcomers compared to the LCC installation is a single post, pedestal type support such as shown in Figure 7-7. A close coupled azimuth/elevation drive at the interface of the dish/pedestal would permit the use of a single compact hose assembly capable of compound motion in both azimuth and elevation axes.

An alternative approach is to package the riser/downcomer rigid lines within the center post as a torsional spring. In this configuration the lines would be held fixed at the base of the post and undergo ±150 degrees of azimuth twist as they emerge at the post/dish interface. The two lines are preformed together in the form of a high lead angle torsional spring, 20 to 30 feet long. In this configuration the lines could undergo the required ±150 degrees of elastic deflection at low stress and low spring rate.

The elevation rotation is accommodated at the interface of the post with the dish with a short coupled flexible hose assembly similar to that described for the LCC installation.

Examination of Table 7-2 shows that the entire cost of the azimuth gimbal hose assembly could be eliminated with the design described, or a 44 percent reduction. The cost of the twisted torsion lines would be more than absorbed by reductions in the rigid line costs (35.6 percent) listed in Table 7-2 for the LCC, which include the cost of large amounts of extra line imposed by the LCC.

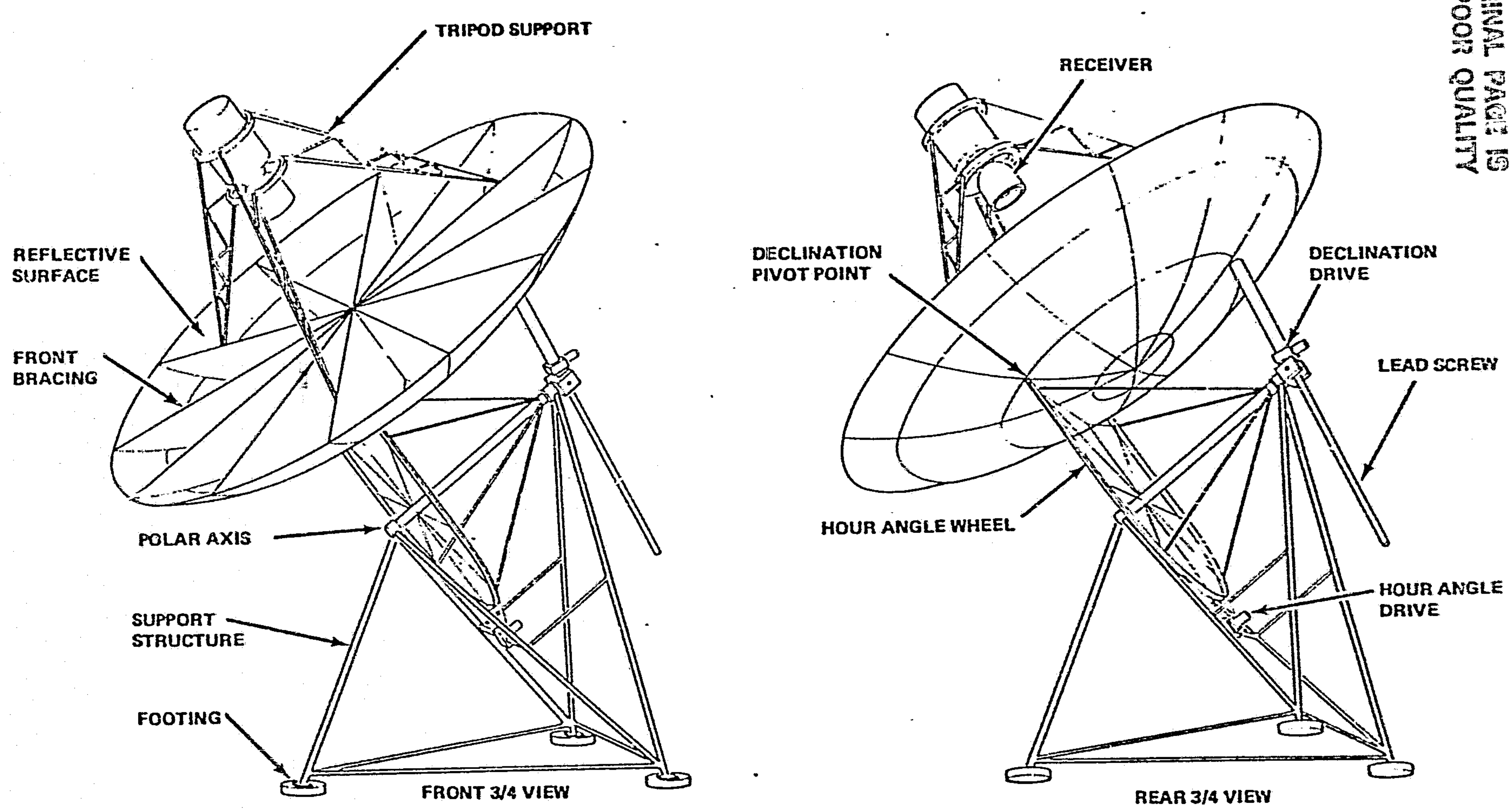


FIGURE 7-6. 12 METER DIAMETER COLLECTOR, EQUATORIAL MOUNT

9950-663

ORIGINAL PAGE IS
OF POOR QUALITY.

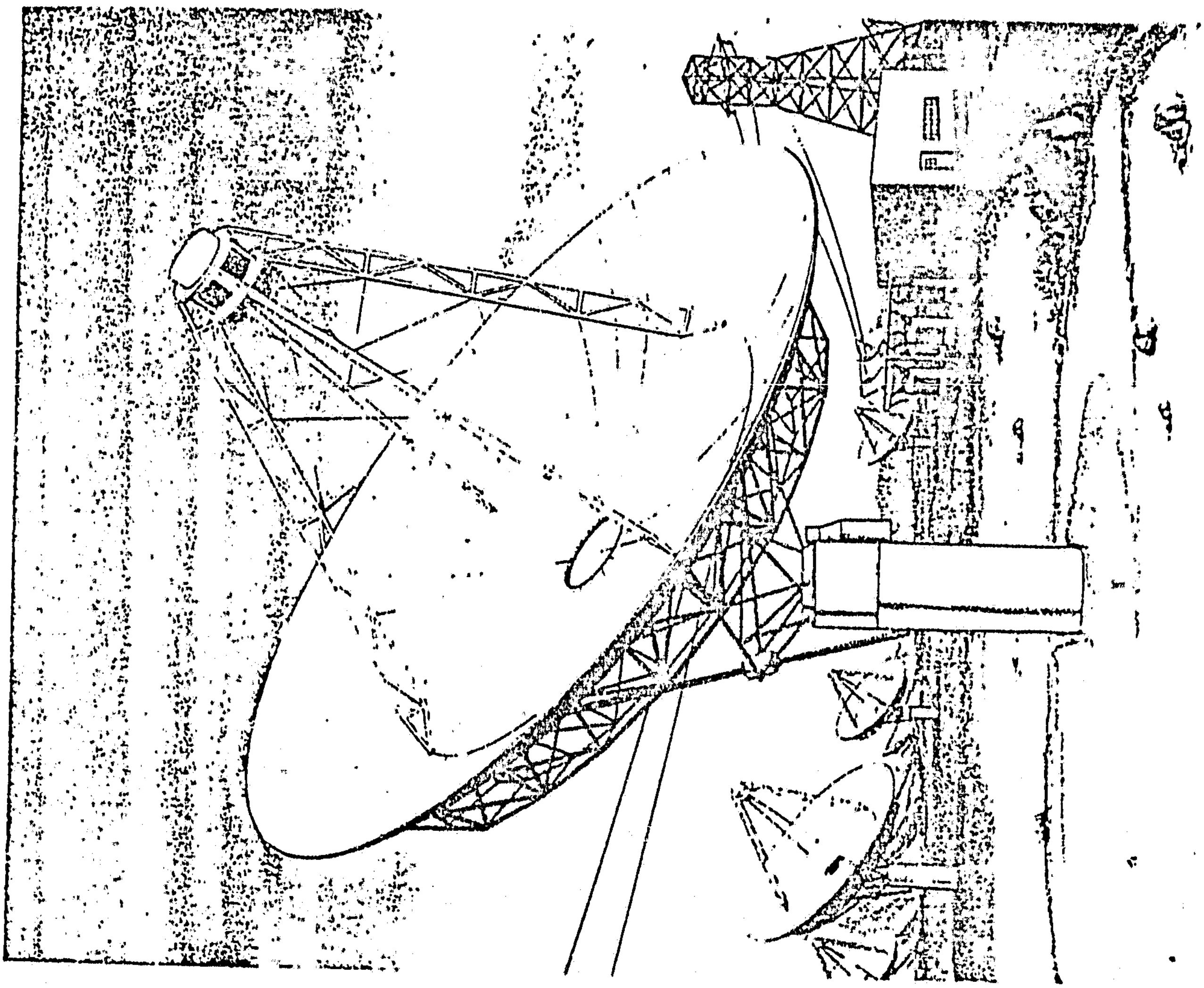


FIGURE 7-7. POST SUPPORTED DISH DESIGN

90

SECTION 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

The following conclusions summarize the main results of the IPH pipe network optimization studies documented in this report:

(1) The JPL pipe network optimization computer code gives results which are in good agreement with the FACC code when the JPL hot and cold side network optimizations are decoupled.

(2) The results obtained from two different cost models applied to the baseline STEOR application indicate the JPL conventional pipe network cost model yields costs which are approximately 20 percent higher than the FACC bottoms-up costs for comparable elements.

(3) Because the JPL cost model does not include indirect contractor costs, sales taxes, performance bonds (insurance), or profit, the total FACC cost is 18 percent <u>greater</u> than the JPL cost.

(4) Dominant elements of labor and material costs are the procurement and installation of insulation and supports; 63 percent of the total.

(5) Studies of potential cost reductions show:

A. The use of automated welding and field shop construction would yield a cost reduction of less than 36 percent.

B. A total labor and material cost reduction of 33 percent could be obtained from a combination of non-conventional construction techniques described herein.

C. Additional cost reduction could be obtained using a buried pipe concept.

(6) Over-the-gimbals thermal transport (piping) cost for the LCC is $3277 per dish ($\$29/m^2$) or $236,000 for the 72-dish field - approximately equal to the overall capital cost of the entire baseline pipe network system.

(7) Lower cost designs for over-the-gimbals thermal transport could be obtained with:

A. Lower pressure and/or lower temperature IPH applications.

B. An alternate post or pedestal mounted dish design with close-coupled elevation and azimuth gimbals. The estimated cost

91

reduction is between 40 and 50 percent of the cost to modify the LCC for installation of riser/downcomer assemblies.

(8) Conclusions from the parametric study are:

A. Total pipe network system cost (including cost of energy losses) increases with increased process temperature (e.g., 355°F to 530°F) because of:

- Greater thermal loss (5.1 percent increase in system cost at \$500/kW_t cost-of-energy)
- Greater insulation cost (1.6 percent increase)

B. Network capital costs are relatively insensitive to the influence of process temperature.

C. Increased unit capital cost (\$/m^2 or \$/kW_t) for larger plant size results from the use of additional larger feeders and additional headers to carry steam (and feedwater) to the edge of the field. An improved arrangement of headers and feeder lines may reduce or eliminate this cost difference.

8.2 RECOMMENDATIONS

The following recommendations are made based on the results of this study:

(1) The JPL pipe network optimization code and conventional cost model are substantially verified as a result of this study, except that the following modifications are suggested:

- The pipe network optimization code should be modified to decouple the hot/cold side solutions.
- The JPL conventional pipe network cost model should be revised to include indirect costs, taxes, bonds, and profit.
- The $\sqrt{2}$ approach used by JPL to calculate the cost of expansion joints should be re-examined.

APPENDIX A

SHADING LOSS ANALYSIS

9950-663

APPENDIX A
SHADING LOSS ANALYSIS

95

9950-

Inter Office

ORIGINAL PAGE IS OF POOR QUALITY

Ford Aerospace & Communications Corporation

18 February 1981
SCSE-81-21

To: D. A. Rodriguez

From: A. F. Dugan

Subject: Shading Losses for a 9x8 Collector Array

An evaluation of the shading loss for a 9x8 collector array arranged in a rectangular pattern was made. The technique used has been documented elsewhere[1], and will not be described here.

The results are summarized in the four figures included. In Figure 1, fractional energy available to mirrors is plotted as a function of ground cover ration (GCR) for various aspect ratios. GCR is defined as $\pi/(4\,LEW*LNS)$, where LEW and LNS are the north-south and east-west spacings expressed in dish diameters. Results obtained by JPL[2] for a 10x10 array are also shown. The GCR is the same as the packing fraction for an infinite field. The aspect ratio is LNS/LEW. The curves in Figure 1 are based on a reduced year, that is, the data base consists of twelve days, one from each month for Barstow 1976. The days chosen were free of dropouts. It is difficult to see from Figure 1 whether or not there is an optimum aspect ratio.

Shading calculations performed by different method from ours indicate an optimum aspect ratio of .71 for one particular GCR[2]. JPL[3] indicated that this optimum holds for all aspect ratios. This study does not corroborate this result.

In Figure 2, the fractional energy available to the dishes is plotted as a function of aspect ratio for various GCR. The solid curves are for the short year, while the dotted curves are for the full 366 day year. Each of the curves shows a maximum, but the maximum clearly varies with GCR. The maxima are very broad, which implies that little penalty is incurred if the field is off optimum.

In Figure 3, the fractional loss is plotted for the same conditions used in Figure 2. In Figure 4, the fractional loss for the full year only is plotted.

---

1 D. B. Osborn, "Generalized Shading Analysis for Paraboloidal Collector Fields". ASME 80-Pet-33.

2 W. J. Eppley, "Shade - A Computer Model for Evaluating the Optical Performance of Two Axis Tracking Parabolic Concentrators", ASME 79-WA/SOL-13.

3 J. R. Biddle (Memo to T. Fujita) 8/2/79.

96

The loss for the full year is less than that for the ideal year. The reason for this is that dropouts are more likely to occur early and late in the day than at mid-day. Early and late, the elevation of the sun is low, and the shading loss is high. At noon, the shading loss is small. Both the total energy collected and the energy lost due to shading are lower than on a perfectly clear day, but the ratio is smaller for the conditions of this study. The fractional loss is defined as the ratio of the lost energy to the collected energy.

A. F. Dugan

A. F. Dugan

C-2

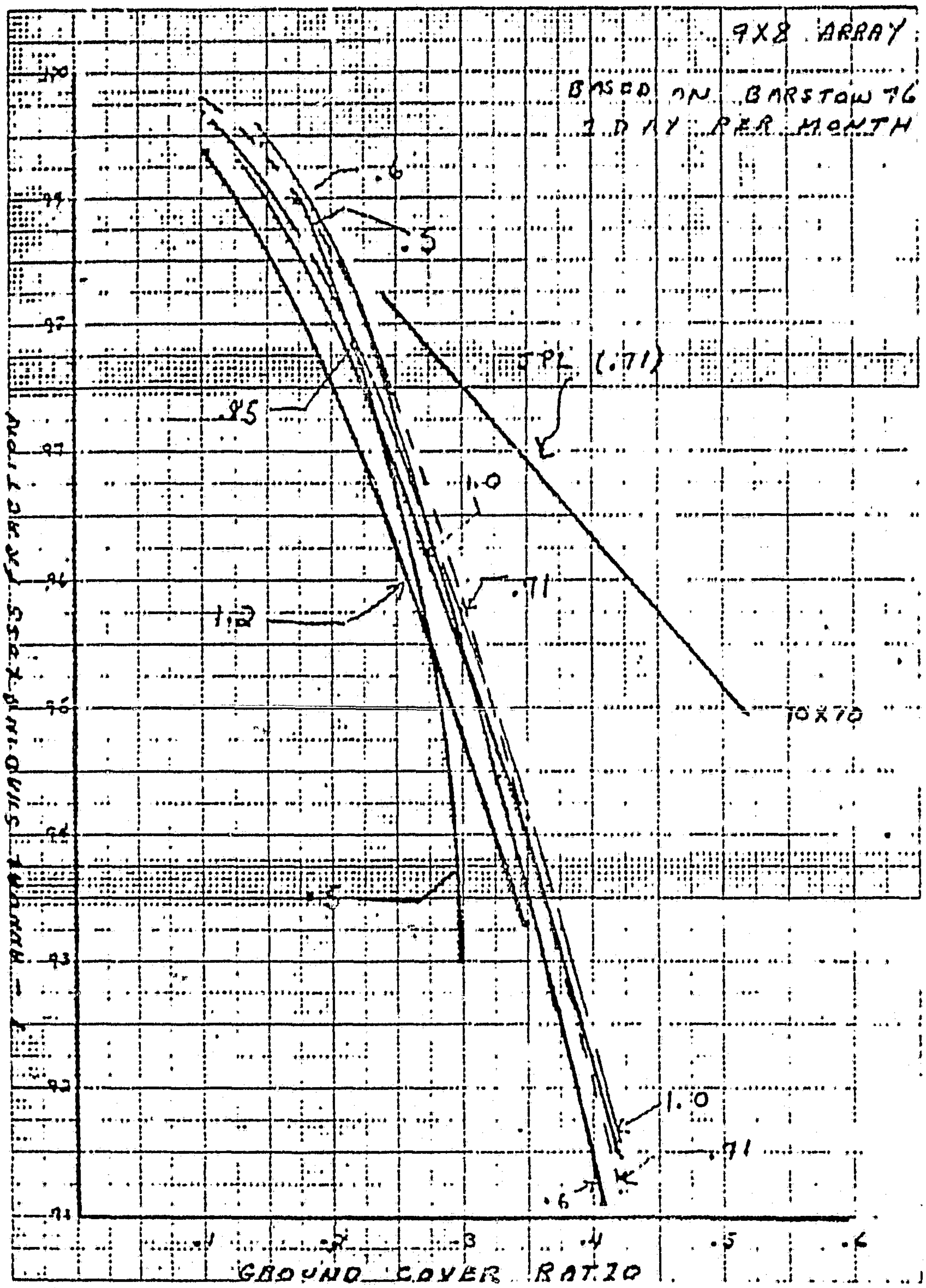


FIGURE 1. FRACTIONAL ENERGY COLLECTED VS. GROUND COVER RATIO

Parameters Indicate Aspect Ratio. Also Shown are JPL Results for a 10x10 Array.

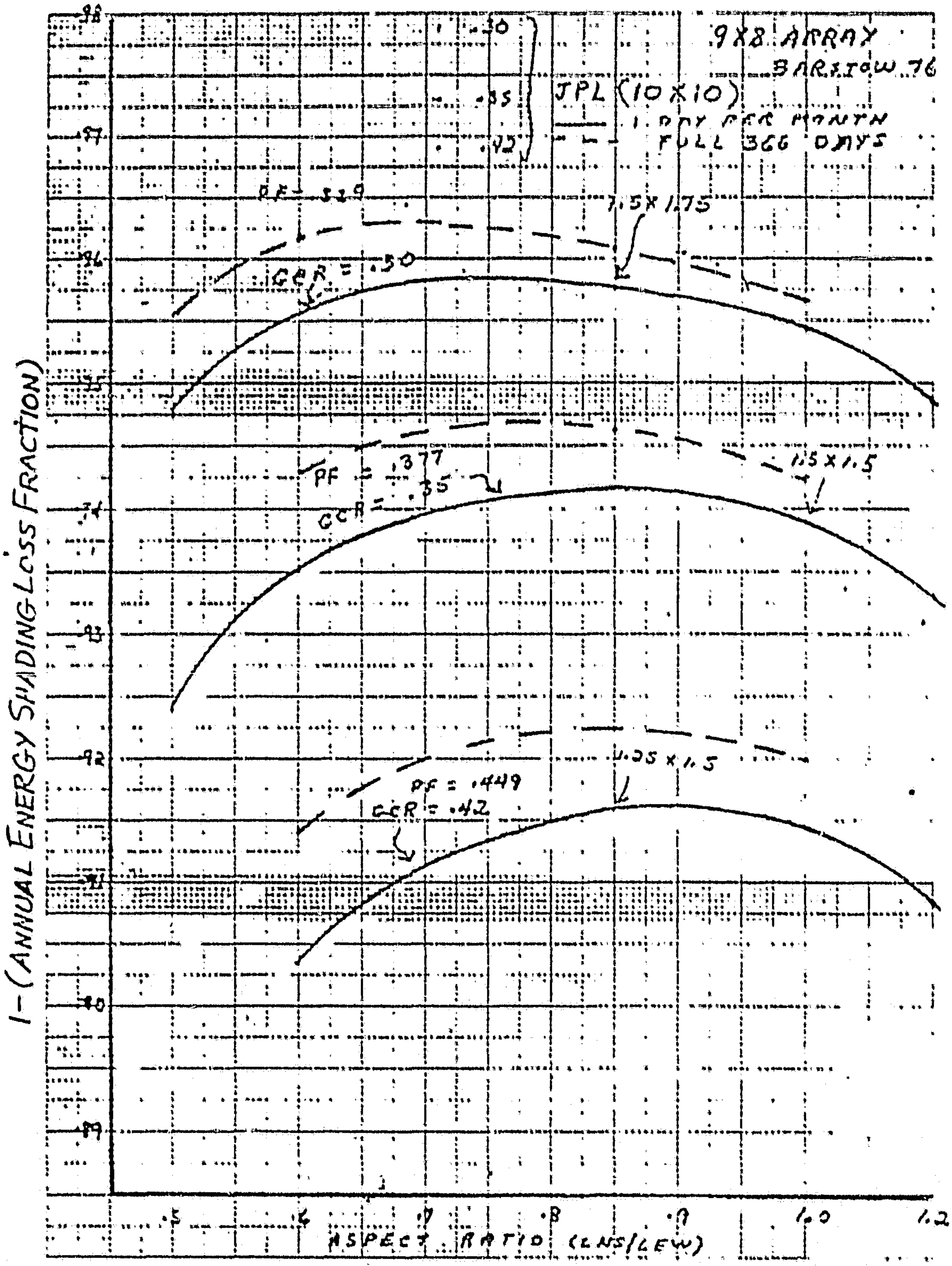


FIGURE 2. FRACTIONAL ENERGY COLLECTED VS. ASPECT RATIO FOR VARIOUS GCR

Solid Curves are Based on 1 Day Per Month, While Dotted Curves are Based on Full Year.

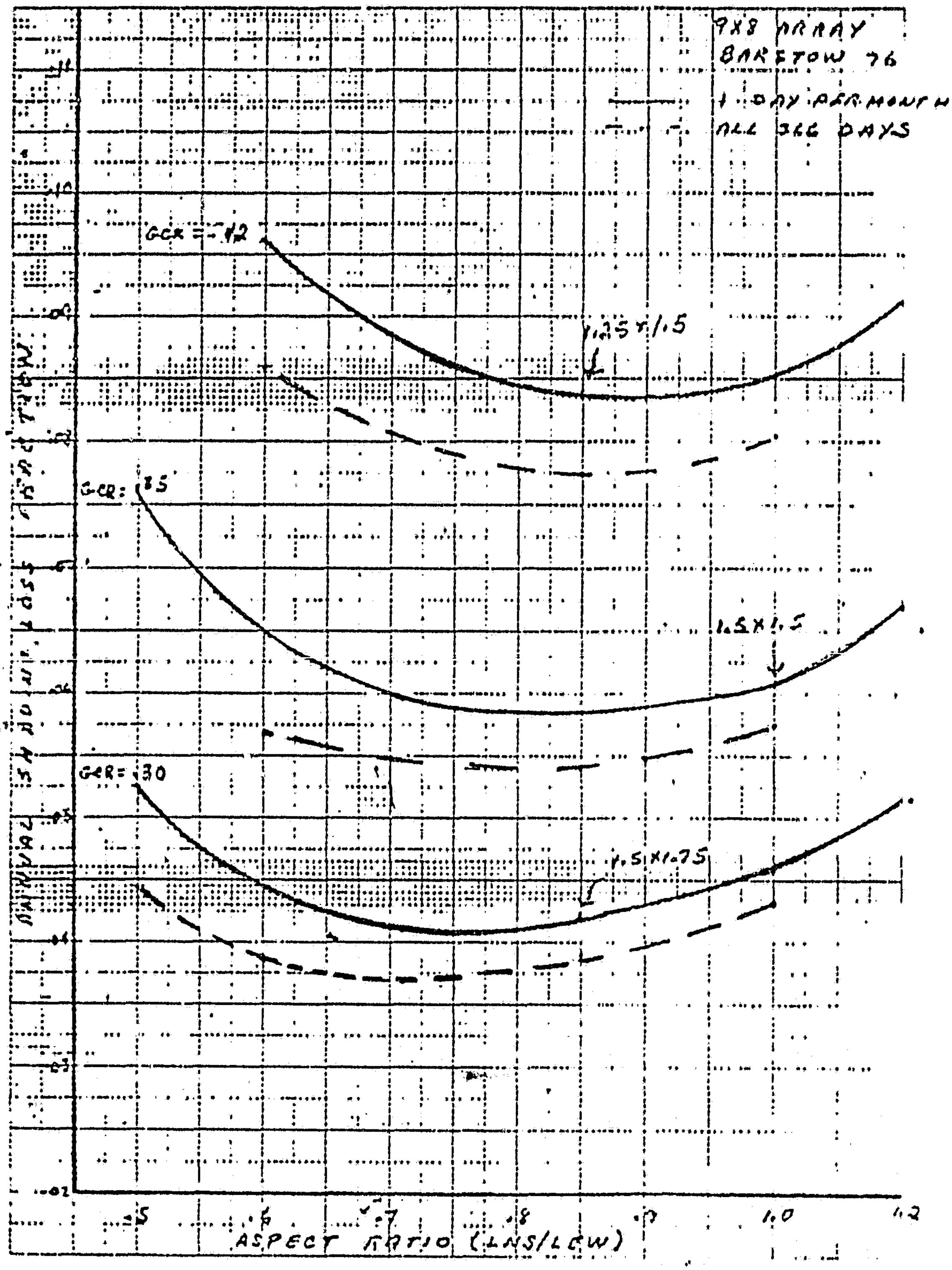


FIGURE 3., ANNUAL FRACTIONAL LOSS VS. ASPECT RATIO

One Day Per Month is Solid Curve, While Dotted Curve is Full Year.

ORIGINAL PAGE IS
OF POOR QUALITY

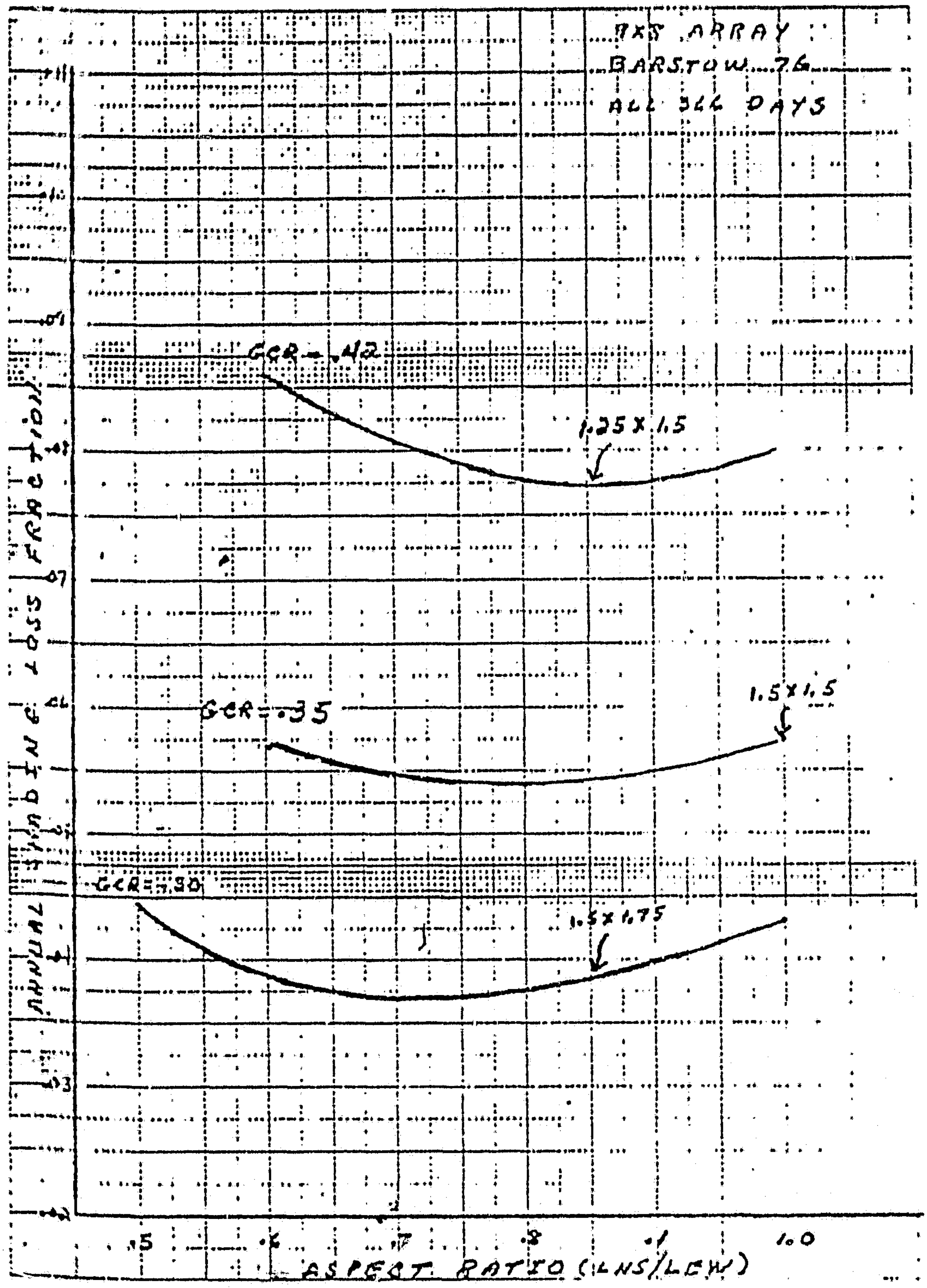


FIGURE 4. ANNUAL FRACTIONAL LOSS VS. ASPECT RATIO FOR FULL YEAR DATA

9930-663

APPENDIX B

OPTIMIZATION OF PIPE NETWORK COST

APPENDIX B

OPTIMIZATION OF PIPE NETWORK COST

ORIGINAL PAGE IS
OF POOR QUALITY

January 8, 1981

TO: D. A. Rodriguez

ROM: A. F. Dugan

SUBJECT: Optimization of Pipe Network Cost

cc: R. Pons
T. Clark
R. Polzien
H. Haskins
R. Irwin

I. Introduction

The problem of finding the minimum cost of a piping network has been studied by JPL and independently by FACC. The two approaches are different, but yield comparable results. In the following discussion, the JPL approach is briefly summarized, and the FACC approach is developed in more detail since the formulation used by JPL has been documented elsewhere[1].

II. Statement of the Problem

The problem is to find the optimum distribution of pipe sizes and insulation thicknesses to be used in a pipe network in which a hot fluid circulates. The total cost of the system is the sum of the following:

1) Cost of pipe.
2) Cost of insulation surrounding pipe.
3) Cost of energy (or power) lost by conduction.
4) Cost of energy required to pump the fluid.
5) Cost of the fluid which fills the network.

The cost of each item is assumed as follows:

1) Pipe Cost (for i th segment)

$$C_{Pi} = (A_i + B_i\, d_i)\, L_i \qquad (1)$$

L_i = pipe length

d_i = diameter

A_i and B_i are constants obtained from a pipe cost curve. Eq 1 assumes that pipe cost is a linear function of diameter. Actual pipe cost is a series of linear segments. For pipes of the different diameters, the constants A_i and B_i may be different.

2) Cost of insulation

$$C_I = C_{IV}\, \pi\, L_i \delta_i\, (d_i + \delta_i) \qquad (2)$$

Eq 2 states that insulation cost is proportional to the volume of material involved.

C_{IV} is the cost per unit volume of insulation

δ_i = insulation thickness

109

3) Energy lost by conduction:

$$C_{\theta i} = H_E \dot{M}_i C_p (T_1 - T_A) \left\{ 1 - \exp -\left(\frac{2\pi L_i k}{\dot{M}_i C_p \log\left(1 + \frac{2\delta i}{di}\right)} \right) \right\} \quad (3)$$

T_1 is the temperature of the fluid as it enters the pipe

$\dot{M}_i$ is the mass flow rate

C_p is the specific heat of the fluid

T_A is the ambient temperature

k is the thermal conductivity of the insulation

H_E is the assumed value of energy

Note that if the argument of the exponential is small, eq 3 reduces to

$$C_{\theta i} = \frac{H_E 2\pi L_i k (T_1 - T_A)}{\log\left(1 + \frac{2\delta}{d_i}\right)} \quad (3a)$$

This is the form used by JPL

4) Cost of energy to pump fluid

$$C_{f_i} = \frac{1 - \eta_e}{\eta_e \eta_p} L_i \frac{32 f_i L_i \dot{m}_i^3}{\pi^2 \rho_i^2 d_i^5} \quad (4)$$

ηe is the electrical conversion efficiency

ηp is the pump efficiency

f is the pipe friction factor (a function of Reynolds number)

ρ is the density of the fluid

5) Cost of fluid

$$C_{FL_i} = C_{FLM} \pi L_i \left(\frac{d_i}{2} \right)^2 \rho i \quad (5)$$

C_{FLM} is the cost per unit mass of the fluid.

The total cost is then

$$C_T = \sum_{i=1}^{N} \left\{ C_{P_i} + C_{I_i} + C_{\theta i} + C_{f_i} + C_{FL_i} \right\} \quad (6)$$

where N is the number of pipe segments in the network. The problem is then to find, for each i, the insulation thickness and pipe diameter which minimizes C_T.

105

III. JPL Approach

The JPL method is based on a Lagrange multiplier technique, and decouples the insulation thickness from the pipe diameter. Their procedure assumes a pump power level

$$W = \sum W_i = \frac{8}{\pi^2 \eta_p} \sum \frac{f_i L_i \dot{m}_i^3}{\rho_i^2 d_i^5} \tag{7}$$

It then seeks to minimize pipe cost (not overall system cost) using eq (6) as a constraint. The set equations to be solved is:

$$\frac{\partial C_p}{\partial d_i} + \lambda \frac{\partial W}{\partial d_i} = 0 \tag{8}$$

On carrying out the indicated differentiations, they obtain

$$L_i B_i - \lambda \frac{8 f_i L_i \dot{m}_i^3 \cdot 5}{\pi^2 \eta_p \rho_i^2 d_i^6} \tag{9}$$

$$\lambda = \frac{\pi^2 \eta_p B_i \rho_i^2 d_i^6}{40 f \dot{m}_i^3} \tag{10}$$

Equation 10 permits the determination of N-1 pipe diameters in terms of the other one. The method therefore requires that one pipe diameter (say the one with the smallest flow rate) be assumed. In terms of d_1,

$$d_i = d_1 \left[\frac{f_i \rho_1^2 B_i}{f_1 \rho_i^2 B_1} \right]^{1/6} \left(\frac{\dot{m}_i}{\dot{m}_1} \right)^{1/2} \tag{11}$$

A simplified version of eq 11 is used in the JPL computer code to determine the d_i. It will be shown in section V that the simplification used is unjustified.

For the pipe size distribution found above, the insulation thickness distribution is found next. The procedure used is identical to the one just described. The heat loss is

$$Q = \sum_{i=1}^{N} Q_i = \sum_{i=1}^{N} \frac{2\pi k L_i (T_i - T_A)}{\log\left(1 + \frac{2t}{d_i}\right)} \tag{12}$$

This is eq 3a. It assumes that the temperature of the fluid is the same everywhere. This, of course, is not true, but it is usually not that bad an assumption.

The cost of insulation is then minimized using eq 12 as the constraint.

$$\frac{\partial C_I}{\partial \delta_i} + \lambda \frac{\partial Q_B}{\partial \delta_i} = 0 \qquad (13)$$

is the set which must be solved. Explicitly,

$$\frac{\partial C_I}{\partial \delta_i} = \pi C_{IV} L_i (d_i + 2\delta_i) \qquad (14)$$

$$\frac{\partial Q_B}{\partial \delta_i} = \frac{4\pi k L_i (T_i - T_A)}{\left[\log_e\left(1 + \frac{2\delta_i}{d_i}\right)\right]^2} \frac{1}{d_i + 2\delta_i} \qquad (15)$$

In terms of δ_1, λ is

$$\lambda = \frac{C_{IV}\left[(d_1 + 2\delta_1)\log_e\left(1 + \frac{2\delta_1}{d_1}\right)\right]^2}{4\pi k L_1 (T_1 - T_A)} \qquad (16)$$

With equations 16, 14 and 15, eq 13 becomes a transcendental equation for δ_1. This equation is solved by the Newton-Raphson method. Having found the pipe diameter and insulation thicknesses as above, for assumed values of d_1 and δ_1, the capital cost is computed as

$$C_c = C_p + C_{FL} + C_I. \qquad (17)$$

Next, the power losses are computed from eqs 3a and 4. The cost per kW_t is determined by dividing C_c by the total power collected less the power losses. The following method is used to compute the adjusted cost per kwt:

Q_c = power collected

Q_L = power lost

$g = \frac{Q_L}{Q_C}$

$$\text{Adjusted Cost} = \frac{C_c}{Q_c - Q_L} + H_E\, Q_L\, g/(1-g). \qquad (18)$$

The whole procedure is then repeated with different values δ_1 and d_1 until a 2x2 matrix of adjusted cost is assembled. The optimum system is then taken to be the one with the minimum adjusted cost.

IV. FACC Approach

The FACC approach avoids the use of Lagrange multipliers and optimizes the overall system cost directly. No assumed values of any pipe diameters or insulation thicknesses, other than initial guesses, are required. The initial guesses are used to get an iteration loop started, and their exact values do not effect the final results.

The overall system cost is given by eq 6.

$$C_T = \sum_{i=1}^{N} \left(C_{Pi} + C_{Ii} + C_{\theta i} + C_{fi} + C_{FLi} \right) \tag{6}$$

The values of d_i and δ_i which minimize C_T are to be found from

$$\frac{\partial C_T}{\partial d_i} = 0 \tag{19}$$

$$\frac{\partial C_T}{\partial \delta_i} = 0 \tag{20}$$

Each segment is optimized indendently. For the i^{th} segment, eq (19) becomes,

$$\frac{\partial C_T}{\partial d_i} = B_i L_i + C_{IV} \pi L_i \delta_i - H_E \frac{1-\eta_E}{\eta_c \eta_P} \cdot \frac{5 \cdot 8 f_i L_i \dot{m}_i^3}{\pi^2 \rho_i^2 d_i^6} + \frac{4\pi H_E L_i k (T_i - T_a) \delta_i}{d_i (d_i + 2\delta_i) \left[\log\left(1 + \frac{2\delta_i}{d_i}\right)\right]^2} + 2 C_{FLV} \pi \rho_i \frac{d_i}{2} = 0 \tag{21}$$

It is convenient to express the terms in eq (21) as values relative to some reference diameter d_o.

$$\frac{\partial C_I}{\partial \delta_i} = C_{IV} \pi \frac{L_i \delta_i (\delta_i + d_o)}{\delta_i + d_o} = \frac{C_I}{\delta_i + d_o} \tag{22}$$

$$\frac{\partial C_\theta}{\partial d_i} = C_{\theta i} \frac{2\delta_i}{d_o (d_o + 2\delta_i) \log\left(1 + \frac{2\delta_i}{d_o}\right)} \tag{23}$$

$$\frac{\partial C_f}{\partial d_i} = -5 C_f \frac{d_o^5}{d_i^5} \tag{24}$$

$$\frac{\partial C_{FL}}{\partial d_i} = 2 C_{FL} / d_o \tag{25}$$

where the C's in eqs (22-25) are the values for d_o. When eq 12, is expressed in terms of these C's, the result is

$$\frac{\partial C_T}{\partial d_i} = B_i L_i + \frac{C_I}{d_o \delta_i} - 5 C_f \frac{d_o^5}{d_i^6} + \frac{2C_{FL}}{d_o} + C_\theta \frac{2\delta_i}{d_o(d_o+2\delta_i)\log\left(1+\frac{2\delta_i}{d_o}\right)} \quad (26)$$

on solving eq 26 for d_i, we obtain,

$$d_i = d_o \left\{ \frac{5 C_f}{B_i L_i d_o + C_I \frac{d_o}{d_o + d_i} + 2C_{FL} + \frac{2C_\theta \delta_i}{(d_o+2\delta_i)\log\left(1+\frac{2\delta_i}{d_o}\right)}} \right\}^{1/6} \quad (27)$$

In eq 27, C_θ is computed from eq 3 even though the derivative was computed from 3a.

The explicit form of eq 20 is

$$\frac{\partial C_T}{\partial \delta_i} = \pi C_{IV}(2\delta_i + d_i) - \frac{4 H_E \pi L_i k (T_i - T_A)}{(d_i + 2\delta_i)\left[\log\left(1+\frac{2\delta_i}{d_i}\right)\right]^2} e^{-\frac{\pi L_i k}{\dot{m} c_p \log\left(1+\frac{2\delta_i}{d_i}\right)}} \quad (28)$$

On setting eq 28 to zero and solving for δ_i, we obtain

$$\delta_i = \frac{1}{2}\left\{\left(\frac{4 H_E k (T_i - T_A)}{C_{IV}}\right)^{1/2} \frac{e^{-\frac{\pi L_i k}{\dot{m} c_p \log\left(1+\frac{2\delta_i}{d_i}\right)}}}{\log\left(1+\frac{2\delta_i}{d_i}\right)} - d_i\right\} \quad (29)$$

Equations 27 and 29, if they can be solved will yield the values of d_i and δ_i which minimize the overall cost of the i^{th} segment. The solution of this pair of equations turns out to be remarkably simple and rapid. The following algorithm has been implemented for their solution.

1) Assume values for d_o and δ_i. Compute d_i using these assumed values. Let the new d_o be the value just computed and repeat the process until two successive calculations of d_i yield the same result to within some specified tolerance (say .0001).

2) Using the value of d_i in eq 29, compute an improved value of δ_i by the same method.

3) Repeat step 1 using the value of δ_i obtained from step 2.

After an improved value of d_i has been obtained, repeat step 2. Continue this process until the convergence criterion is met. In actual practice, the procedure converges in four of five iterations.

To verify that this procedure indeed minimizes system cost, C_T was recalculated using slightly perturbed values of d_i & δ_i. In all cases, C_T was higher with the perturbed values.

9950-663

ORIGINAL PAGE IS
OF POOR QUALITY

V. Comparison of Test Case Results

In order to make a sensible comparison of the JPL and FACC approaches, test cases were run on each program. The FACC program was run using the inputs supplied by JPL. The input data is included in Section VI.

a) JPL Results

The JPL program generates a substantial amount of output. Input diameters for pipe number 1 ranged from .7" to .2". Insulation thickness on pipe 1 ranged from 1" to 6". A matrix of 6 x 6 points was generated. The optimum was found to lie between .4" and .5" diameter with an insulation thickness of about 3" on the first segment. At .4" and .5", the pipe diameter for the other segments increased as the square root of the mass flow rate for the hot side. For the cold side, pipe 1 was reduced by the cube root of the fluid density ratio as indicated by eq 11. As stated earlier, JPL used a simplified version of this equation. They neglected the variation of f. This factor cannot be neglected. The viscosity of the cold fluid is twice that of the hot fluid, so f for the cold side is about 20% higher on the cold side than on the hot side. This increase will offset the density ratio. (The FACC result showed the cold side diameters larger than the hot side).

The JPL code requires mass flow units to be input. In the test case, there were 19 different mass flow rates. These were 1, 2, 3, 4, 5, 6, 7, 8, 9, 16, 24, 25, 32, 36, 40, 48, 49, 56 and 64. The JPL input used 11 different flow rates. They lumped 5 and 6 into 6, 7, 8 and 9 into 9, 24 and 25 into 25, 32, 36 and 40 into 40 and 48, 49 and 56 into 56.

The fluid temperature is considered constant throughout the network (actually, two constants, one for the hot side and one for the cold side). The JPL code has an additional requirement built in. There is a maximum permitted pressure drop within a pipe. If the pressure drop exceeds this value, the pipe size is adjusted upward until the pressure drop criterion is satisfied. In the region of the minimum, this restriction was not invoked.

b) FACC Results

The FACC code was used to analyse the same network. The results were as follows. On the hot side, the optimum diameter was .44" with 3" of insulation. The pipes carrying more fluid were larger with more insulation. An examination of the diameters showed that they increased approximately as the square root of the mass flow rate, the maximum deviation being about 6%.

110

The cold side diameters were all about 7% higher than the hot side. They also followed the same approximate square root relationship, although there is nothing in the program which explicitly imposes this relationship.

In the FACC code, the number of flow units in each pipe is not an input. The program determines it from the geometry of the network. Furthermore in each segment, the temperature drop is determined. The thermal losses are computed from the more exact eq 3., and in each segment, T_1 is different.

The conclusion is that although the two programs approach the problem differently, they yield substantially the same result. The most glaring difference is that JPL finds smaller cold side pipes that hot. This discrepancy, however, would be eliminated by a proper treatment of the friction factor in eq 11.

V. Appendix - Data input

The test case considered a system with 512 collectors in which the heat transfer fluid was Therminol 66. The input data is tabulated below.

Variable	Value	
N_{COL}	512	number of collectors
A_{COL}	1017 ft^2	area of one collector
I_d, n	800 $watts/m^2$	insolation level
η_{COL}	.81	collector efficiency
T_A	100°F	ambient temperature
T_1^H	600°F	hot side temperature
T_1^C	400°F	cold side temperature
D	47 ft	spacing between collectors
η_p	.8	pump efficiency
η_e	.34	Rankine efficiency
H_E	\$1500/kWt	value of power
C_p^H	.628 BTU/lb°F	specific heat of hot fluid
C_{op}^C	.534 BTU/lb°F	specific heat of cold fluid
M	.499 lb/sec	mass flow rate in pipe 1
k_H	.516 BTU in/hr ft^2	thermal conductivity or hot side
k_c	.456 BTU in/hr ft^2	thermal conductivity cold side

ORIGINAL PAGE IS
OF POOR QUALITY

Variable	Value	
μ_H	.0049 stokes	viscosity of hot fluid
μ_c	.0098 stokes	viscosity of cold fluid
C_{IV}	$20/ft^3	insulation cost
C_{FL}	$.20/lb	cost of fluid

Pipe cost is given by

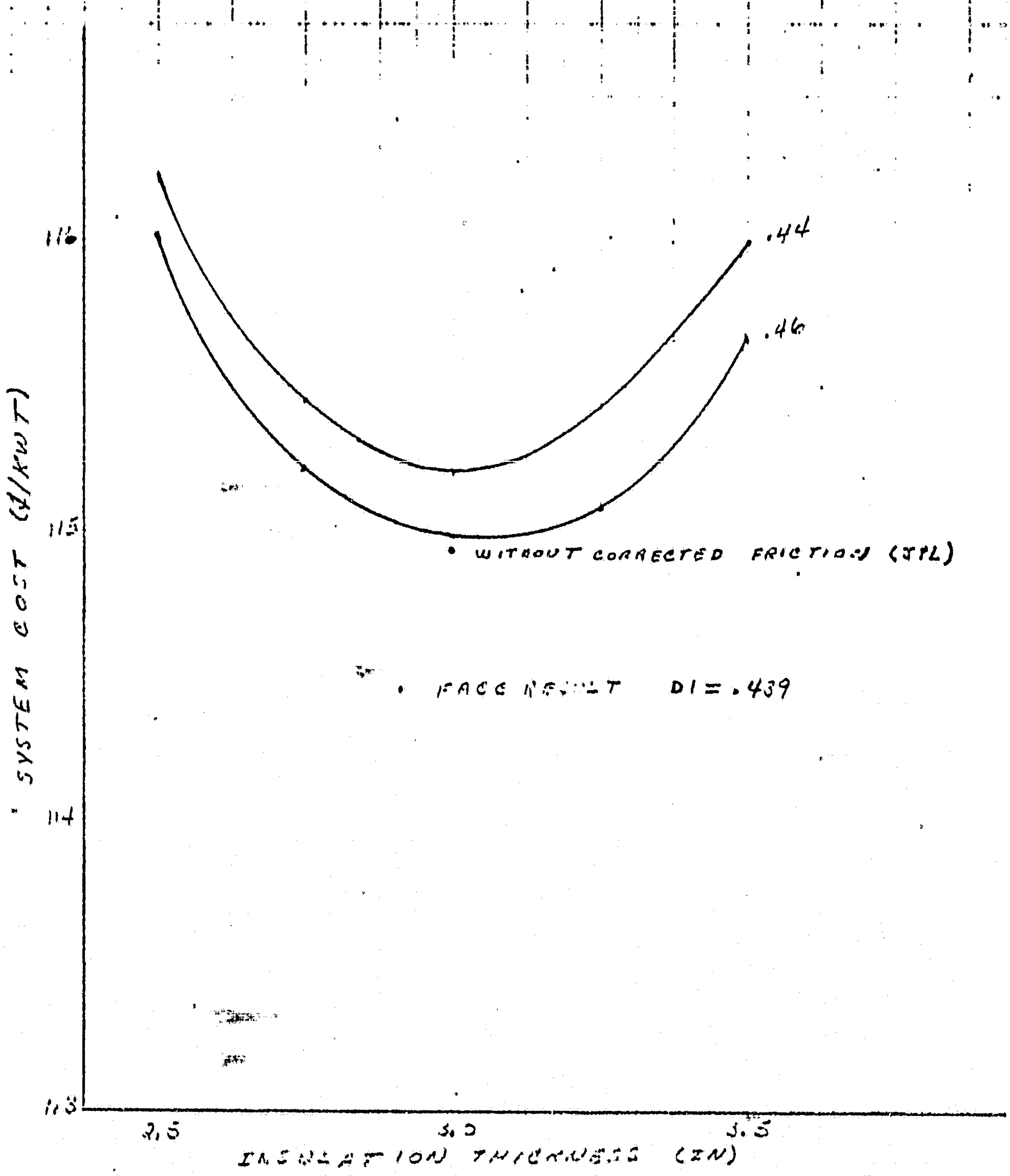
$$C_p = (10 + .625d)\ L \quad (\$) \quad d < 4''$$
$$= (5 + 1.9\ d)\ L \quad (\$) \quad d > 4''$$

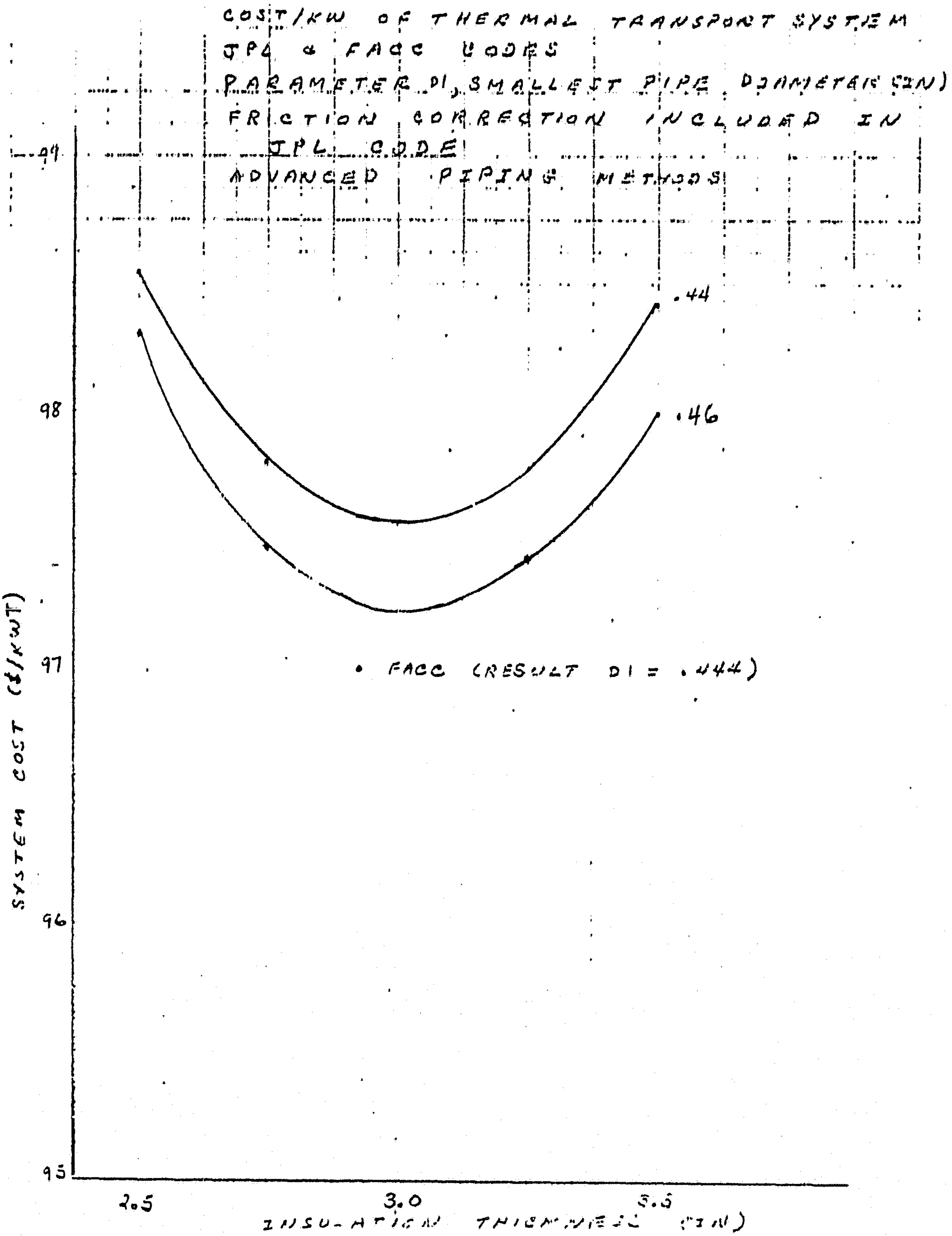
REFERENCES

1 R.H.Turner, "Economic Optimization of Energy Transport", 11th IECEC, p 1239

COST/KWT OF THERMAL TRANSPORT SYSTEM
JPL & FACC CODES
PARAMETER DI, SMALLEST PIPE DIAMETER (IN)
FRICTION CORRECTION INCLUDED IN JPL CODE

CONVENTIONAL PIPING METHODS




COST/KW OF THERMAL TRANSPORT SYSTEM
JPL & FACC CODES
PARAMETER DI, SMALLEST PIPE DIAMETER (IN)
FRICTION CORRECTION INCLUDED IN JPL CODE
ADVANCED PIPING METHODS
99
98
97
96
95
.44
.46
• FACC (RESULT DI = .444)
SYSTEM COST ($/KWT)
2.5
3.0
3.5
INSULATION THICKNESS (IN)

APPENDIX C

COMPUTER COST MATRIX PRINTOUTS

APPENDIX C

COMPUTER COST MATRIX PRINTOUTS

116

FIGURE C-1. COMPUTE[illegible]ST MATRIX FOR BASELINE STEOR PIPE NETWORK

ORIGINAL PAGE IS OF POOR QUALITY

TEOR PIPE NETWORK STEAM SIDE COST SUMMARY

NOM PIPE DIA	0.500	0.750	1.000	1.500	2.000	2.500	3.000	3.500	4.000	TOTAL
LENGTHS ST	882.	882.	1323.	60.	60.	60.	60.	120.	134.	
EXPANSION JOINTS	216.	216.	324.	12.	12.	12.	16.	32.	32.	
TOTAL	1098.	1098.	1647.	72.	72.	72.	76.	152.	166.	
PIPE COST										
LABOR HRS	39.8	39.8	61.5	3.5	3.8	4.7	8.3	19.1	23.9	204.4
LABOR $	675.	675.	1042.	59.	64.	80.	141.	324.	405.	3465.
MATERIAL $	1197.	1295.	2309.	157.	188.	267.	351.	860.	1136.	7760.
SALES TAX	72.	78.	139.	9.	11.	16.	21.	52.	68.	466.
INDIRECT	398.	398.	615.	35.	38.	47.	83.	191.	239.	2044.
PROFIT	238.	248.	417.	26.	31.	42.	61.	145.	188.	1394.
BONDS	35.	37.	62.	4.	5.	6.	9.	21.	28.	206.
TOTAL $	2615.	2731.	4583.	291.	336.	458.	666.	1593.	2063.	15335.
EXPANSION JOINTS #	18	18	27	1	1	1	1	2	2	71
LABOR HRS	106.5	117.8	193.2	8.0	8.6	25.1	29.0	67.8	77.9	633.9
LABOR $	1805.	1997.	3275.	136.	146.	425.	492.	1149.	1320.	10745.
MATERIAL $	480.	547.	449.	61.	86.	88.	127.	319.	384.	2541.
SALES TAX	29.	33.	27.	4.	5.	5.	8.	19.	23.	152.
INDIRECT	1065.	1178.	1932.	80.	86.	251.	290.	678.	779.	6339.
PROFIT	343.	381.	577.	28.	33.	78.	93.	220.	254.	2007.
BONDS	51.	56.	85.	4.	5.	12.	14.	32.	38.	297.
TOTAL $	3772.	4192.	6345.	313.	361.	859.	1023.	2417.	2798.	22082.
FIXTURES #	18	36	54	4	3	3	3	7	10	138
LABOR HRS	24.3	67.5	121.5	9.8	7.8	12.0	12.5	38.0	60.5	353.9
LABOR $	412.	1144.	2059.	166.	132.	203.	212.	644.	1025.	5997.
MATERIAL $	47.	106.	179.	13.	16.	17.	17.	43.	79.	517.
SALES TAX	3.	6.	11.	1.	1.	1.	1.	3.	5.	31.
INDIRECT	243.	675.	1215.	98.	78.	120.	125.	380.	605.	3539.
PROFIT	72.	196.	352.	28.	23.	35.	36.	109.	174.	1024.
BONDS	11.	29.	52.	4.	3.	5.	5.	16.	26.	151.
TOTAL $	787.	2156.	3867.	310.	253.	381.	396.	1194.	1913.	11259.
VALVES #	18	18	36	4	4	4	4	16	4	108
LABOR HRS	37.8	37.8	75.6	9.2	9.2	9.2	9.2	14.6	23.7	226.3
LABOR $	641.	641.	1282.	156.	156.	156.	156.	247.	402.	3837.
MATERIAL $	1544.	1544.	3088.	697.	697.	697.	697.	1394.	1988.	12346.
SALES TAX	93.	93.	185.	42.	42.	42.	42.	84.	119.	741.
INDIRECT	378.	378.	756.	92.	92.	92.	92.	146.	237.	2263.
PROFIT	270.	270.	539.	100.	100.	100.	100.	190.	279.	1947.
BONDS	40.	40.	80.	15.	15.	15.	15.	28.	41.	288.
TOTAL $	2965.	2965.	5930.	1102.	1102.	1102.	1102.	2089.	3066.	21422.
ANCHORS #	18	18	36	1	1	1	1	2	3	81
LABOR HRS	4.0	4.0	8.0	1.0	1.0	1.0	1.0	2.0	3.5	25.5
LABOR $	68.	68.	136.	17.	17.	17.	17.	34.	59.	433.
MATERIAL $	216.	2[illegible]6.	432.	22.	22.	22.	22.	45.	80.	1077.
SALES TAX	13.	13.	26.	1.	1.	1.	1.	3.	5.	65.
INDIRECT	40.	40.	80.	10.	10.	10.	10.	20.	35.	255.
PROFIT	34.	34.	68.	5.	5.	5.	5.	10.	18.	186.
BONDS	5.	5.	10.	1.	1.	1.	1.	2.	3.	27.
TOTAL $	376.	376.	752.	56.	56.	56.	56.	114.	200.	2043.
PIPE GUIDES #	54	54	81	3	3	3	3	6	7	214
LABOR HRS	167.4	167.4	299.7	11.1	13.8	13.8	16.8	33.6	44.8	768.4
LABOR $	2837.	2837.	5080.	188.	234.	234.	284.	570.	759.	13023.
MATERIAL $	3596.	3596.	5394.	200.	202.	212.	331.	992.	1167.	15690.
SALES TAX	216.	216.	324.	12.	12.	13.	20.	60.	70.	941.
INDIRECT	1674.	1674.	2997.	111.	138.	138.	168.	336.	448.	7684.
PROFIT	845.	845.	1400.	52.	59.	61.	81.	199.	248.	3790.
BONDS	125.	125.	207.	8.	9.	9.	12.	29.	37.	560.
TOTAL $	9292.	9292.	15402.	571.	654.	666.	896.	2166.	2729.	41680.
FOUNDATIONS & PILLA	72	72	117	4	4	4	4	8	10	295

FIGURE C-1. COMPUTER COST MATRIX FOR BASELINE STEOR PIPE NETWORK (CONTINUED)

LABOR	147.7	147.7	281.9	2.1	8.1	8.1	.7	13.6	10.5	633.4
LABOR $	1874.	1874.	3577.	26.	103.	103.	73.	172.	235.	8037.
MATERIAL $	1102.	1102.	2103.	15.	60.	60.	43.	101.	148.	4733.
SALES TAX	66.	66.	126.	1.	4.	4.	3.	6.	9.	284.
INDIRECT	872.	872.	1663.	12.	48.	48.	34.	80.	109.	3737.
PROFIT	397.	397.	758.	6.	22.	22.	15.	36.	51.	1704.
BONDS	59.	59.	112.	1.	3.	3.	2.	5.	8.	252.
TOTAL $	4370.	4370.	8340.	61.	239.	239.	170.	400.	558.	18747.
INSULATION										
LABOR HRS	144.9	144.9	217.4	9.5	15.8	16.3	16.7	33.4	36.5	635.4
LABOR $	1304.	1304.	1957.	85.	142.	146.	150.	301.	329.	5718.
MATERIAL $	5795.	9213.	18045.	885.	953.	1151.	1196.	2968.	4630.	44836.
SALES TAX	348.	553.	1083.	53.	57.	69.	72.	178.	278.	2690.
INDIRECT	782.	782.	1174.	51.	85.	88.	90.	180.	197.	3431.
PROFIT	835.	1203.	2259.	109.	126.	148.	153.	368.	552.	5753.
BONDS	123.	178.	334.	16.	19.	22.	23.	54.	82.	850.
TOTAL $	9188.	13233.	24852.	1200.	1382.	1623.	1684.	4050.	6067.	63278.
INSPECTION										
LABOR HRS	79.2	45.0	94.5	11.0	3.5	3.5	5.0	8.0	9.0	258.7
LABOR $	1342.	762.	1601.	186.	59.	59.	84.	136.	153.	4382.
MATERIAL $	134.	76.	160.	19.	6.	6.	8.	14.	15.	438.
SALES TAX	8.	5.	10.	1.	0.	0.	0.	1.	1.	26.
INDIRECT	792.	450.	945.	110.	35.	35.	50.	80.	90.	2587.
PROFIT	231.	131.	276.	32.	10.	10.	14.	23.	26.	754.
BONDS	34.	19.	41.	5.	2.	2.	2.	3.	4.	111.
TOTAL $	2541.	1443.	3032.	353.	112.	112.	159.	258.	289.	8299.

STEAM SIDE TOTALS

LABOR HRS	751.6	771.9	1353.3	65.2	71.6	93.7	104.2	230.1	298.3	3739.9
LABOR $	10958.	11302.	20009.	1019.	1053.	1423.	1609.	3577.	4687.	55637.
MATERIAL $	14111.	17695.	32159.	2069.	2230.	2520.	2792.	6736.	9627.	89938.
SALES TAX	847.	1062.	1930.	124.	134.	151.	167.	404.	578.	5396.
INDIRECT	6244.	6447.	11377.	600.	610.	829.	942.	2091.	2739.	31879.
PROFIT	3264.	3705.	6646.	387.	409.	500.	559.	1300.	1789.	18559.
BONDS	482.	548.	982.	57.	60.	74.	83.	192.	264.	2743.
TOTAL $	35907.	40759.	73103.	4257.	4495.	5496.	6152.	14300.	19684.	204152.

WATER SIDE SUMMARY

NOM PIPE DIA	0.125	0.250	0.375	0.500	0.750	1.000	1.250	1.500	2.000	
LENGTHS ST	882.	882.	882.	441.	60.	60.	120.	180.	74.	
PIPE COST										
LABOR HRS	39.8	39.8	39.8	19.8	2.7	2.9	6.3	10.4	4.5	166.0
LABOR $	675.	675.	675.	336.	46.	49.	107.	176.	81.	2820.
MATERIAL $	750.	828.	1013.	598.	88.	105.	261.	471.	232.	4346.
SALES TAX	45.	50.	61.	36.	5.	6.	16.	28.	14.	261.
INDIRECT	398.	398.	398.	198.	27.	29.	63.	104.	45.	1660.
PROFIT	190.	198.	218.	119.	17.	19.	45.	79.	38.	922.
BONDS	28.	29.	32.	18.	2.	3.	7.	12.	6.	136.
TOTAL $	2086.	2178.	2397.	1304.	186.	211.	499.	870.	415.	10145.
FIXTURES #	18	18	18	18	2	3	7	10	3	97
LABOR HRS	21.6	13.5	13.5	13.5	6.0	6.8	16.4	24.3	7.2	122.8
LABOR $	366.	229.	229.	229.	102.	115.	278.	412.	122.	2082.
MATERIAL $	29.	27.	28.	30.	7.	10.	22.	38.	11.	202.
SALES TAX	2.	2.	2.	2.	0.	1.	1.	2.	1.	12.
INDIRECT	216.	135.	135.	135.	60.	68.	164.	243.	72.	1228.
PROFIT	62.	40.	40.	40.	17.	20.	47.	71.	21.	358.
BONDS	9.	6.	6.	6.	3.	3.	7.	10.	3.	53.
TOTAL $	684.	438.	440.	442.	189.	216.	520.	776.	230.	3935.
VALVES #	18	18	18	18	2	2	4	6	4	90
LABOR HRS	32.4	32.4	32.4	32.4	4.2	4.2	8.4	12.6	9.9	168.9
LABOR $	549.	549.	549.	549.	71.	71.	142.	214.	168.	2862.
MATERIAL $	813.	813.	813.	813.	90.	90.	180.	270.	405.	4288.

ORIGINAL PAGE IS OF POOR QUALITY

FIGURE C-1. COMPUTER MATRIX FOR BASELINE STEOR PIPE NETWORK (CONCLUDED)

SALES TAX	49.	49.	49.	49.	5.	5.	11.	16.	14.	257.
INDIRECT	324.	324.	324.	324.	42.	42.	84.	126.	99.	1609.
PRO	176.	176.	176.	176.	21.	21.	42.	64.	71.	923.
BON	26.	26.	26.	26.	3.	3.	6.	9.	10.	136.
TOTAL $	1937.	1937.	1937.	1937.	233.	233.	465.	699.	779.	10156.
ANCHORS #	18	18	18	18	1	1	2	3	1	80
LABOR HRS	5.4	5.4	5.4	5.4	0.5	0.5	1.0	1.5	0.5	25.6
LABOR $	91.	91.	91.	91.	8.	8.	17.	25.	8.	430.
MATERIAL $	90.	90.	90.	90.	14.	14.	28.	42.	15.	473.
SALES TAX	5.	5.	5.	5.	1.	1.	2.	3.	1.	28.
INDIRECT	54.	54.	54.	54.	5.	5.	10.	15.	5.	256.
PROFIT	24.	24.	24.	24.	3.	3.	6.	9.	3.	121.
BONDS	4.	4.	4.	4.	0.	0.	1.	1.	0.	18.
TOTAL $	268.	268.	268.	268.	31.	31.	63.	94.	32.	1326.
PIPE GUIDES #	72	72	72	72	4	2	4	6	2	306
LABOR HRS	36.0	36.0	50.4	50.4	4.0	2.0	2.4	9.0	3.4	193.6
LABOR $	610.	610.	954.	954.	68.	34.	41.	152.	51.	3474.
MATERIAL $	632.	632.	632.	632.	36.	18.	56.	62.	22.	2722.
SALES TAX	38.	38.	38.	38.	2.	1.	3.	4.	1.	163.
INDIRECT	360.	360.	504.	504.	40.	20.	24.	90.	34.	1936.
PROFIT	166.	166.	216.	216.	15.	7.	13.	31.	11.	842.
BONDS.	25.	25.	32.	32.	2.	1.	2.	5.	2.	124.
TOTAL $	1831.	1831.	2376.	2376.	163.	82.	139.	344.	121.	9262.
FOUNDATIONS & PILLA	36	36	36	36	2	2	0	0	0	148
LABOR HRS	251.9	251.9	284.2	145.9	14.1	14.1	9.1	16.0	18.5	1005.7
LABOR $	3196.	3196.	3606.	1852.	177.	177.	115.	203.	235.	12756.
MATERIAL $	1878.	1878.	2119.	1088.	105.	105.	67.	119.	148.	7507.
SALES TAX	113.	113.	127.	65.	6.	6.	4.	7.	9.	450.
INDIRECT	1486.	1486.	1677.	861.	83.	83.	53.	95.	109.	5934.
PROFIT	677.	677.	764.	392.	38.	38.	24.	43.	51.	2705.
BONDS	100.	100.	113.	58.	6.	6.	4.	6.	8.	400.
TOTAL $	7450.	7450.	8406.	4316.	415.	415.	268.	474.	558.	29752.
INSPECTION										
LABOR HRS	37.8	5.4	7.2	28.8	45.0	1.0	1.0	1.3	2.8	130.3
LABOR $	640.	91.	122.	488.	762.	17.	17.	21.	48.	2206.
MATERIAL $	64.	9.	12.	49.	76.	2.	2.	2.	5.	221.
SALES TAX	4.	1.	1.	3.	5.	0.	0.	0.	0.	13.
INDIRECT	378.	54.	72.	288.	450.	10.	10.	13.	28.	1303.
PROFIT	110.	16.	21.	84.	131.	3.	3.	4.	8.	380.
BONDS	16.	2.	3.	12.	19.	0.	0.	1.	1.	56.
TOTAL $	1212.	173.	231.	924.	1443.	33.	33.	40.	91.	4179.

WATER SIDE TOTALS

LABOR HRS	424.9	384.4	432.9	296.2	76.5	31.5	44.6	75.1	46.8	1812.9
LABOR $	6127.	5441.	6226.	4499.	1234.	471.	717.	1203.	713.	26630.
MATERIAL $	4256.	4277.	4707.	3300.	416.	344.	616.	1004.	839.	19759.
SALES TAX	255.	257.	282.	198.	25.	21.	37.	60.	50.	1186.
INDIRECT	3216.	2811.	3164.	2364.	707.	257.	408.	686.	392.	14006.
PROFIT	1406.	1298.	1459.	1052.	242.	111.	181.	300.	202.	6250.
BONDS	208.	192.	216.	155.	36.	16.	27.	44.	30.	924.
TOTAL $	15468.	14275.	16054.	11567.	2660.	1221.	1986.	3298.	2226.	68755.

OVERAL TOTALS										
LABOR HRS	1176.5	1156.3	1786.2	361.4	148.1	125.2	148.8	305.2	345.1	5552.8
LABOR $	17085.	16743.	26235.	5518.	2287.	1894.	2326.	4700.	5399.	82267.
MATERIAL $	18367.	21972.	36866.	5369.	2646.	2864.	3408.	7740.	10465.	109697.
SALES TAX	1102.	1318.	2212.	322.	159.	172.	204.	464.	628.	6582.
INDIRECT	9460.	9258.	14541.	2964.	1317.	1086.	1351.	2777.	3131.	45885.
PROFIT	4670.	5003.	8105.	1439.	651.	611.	740.	1600.	1992.	24810.
BONDS	690.	739.	1198.	213.	96.	90.	109.	236.	294.	3636.
TOTAL $	51375.	55034.	89157.	15824.	7156.	6717.	8138.	17598.	21909.	272907.

ORIGINAL PAGE IS OF POOR QUALITY

9950-663

130

1

SW1315T 03/11/81 JJT PAGE 301

FIGURE C-2. COMPUTER COST MATRIX FOR BASELINE STEOR PIPE NETWORK-MODIFIED FOR FACTORY FABRICATED OMEGA EXPANSION JOINTS

TEOR PIPE NETWORK STEAM SIDE COST SUMMARY

NOM PIPE DIA	0.500	0.750	1.000	1.500	2.000	2.500	3.000	3.500	4.000	TOTAL
LENGTHS ST	882.	332.	1323.	60.	60.	60.	60.	120.	134.	
EXPANSION JOINTS	216.	216.	324.	12.	12.	12.	16.	32.	32.	
TOTAL	1098.	1078.	1647.	72.	72.	72.	76.	152.	166.	
PIPE COST										
LABOR HRS	39.8	39.8	61.5	3.5	3.8	4.7	8.3	19.1	23.9	204.4
LABOR $	675.	675.	1042.	59.	64.	80.	141.	324.	405.	3465.
MATERIAL $	1197.	1235.	2309.	157.	188.	257.	351.	860.	1135.	7760.
SALES TAX	72.	73.	139.	9.	11.	15.	21.	52.	68.	*466.
INDIRECT	398.	393.	615.	35.	38.	47.	83.	191.	239.	2044.
PROFIT	238.	243.	417.	26.	31.	42.	61.	145.	188.	1394.
BONDS	35.	37.	62.	4.	5.	6.	9.	21.	28.	206.
TOTAL $	2615.	2731.	4583.	291.	336.	458.	666.	1593.	2063.	15335.
EXPANSION JOINTS #	18	18	27	1	1	1	1	2	2	71
LABOR HRS	18.0	23.4	48.6	2.5	3.2	4.0	4.6	11.0	13.4	128.7
LABOR $	305.	396.	824.	42.	96.	154.	78.	186.	227.	2318.
MATERIAL $	828.	1236.	2295.	101.	149.	224.	318.	846.	1082.	7051.
SALES TAX	50.	72.	138.	6.	9.	13.	19.	51.	65.	423.
INDIRECT	180.	234.	486.	25.	32.	40.	46.	110.	134.	1287.
PROFIT	138.	194.	380.	18.	29.	45.	47.	121.	153.	1125.
BONDS	20.	29.	56.	3.	4.	7.	7.	13.	23.	165.
TOTAL $	1521.	2031.	4179.	194.	319.	493.	515.	1334.	1684.	12373.
FIXTURES #	18	36	54	4	3	3	3	7	10	138
LABOR HRS	24.3	67.5	121.5	9.8	7.8	12.0	12.5	38.0	60.5	353.9
LABOR $	412.	1144.	2059.	166.	132.	203.	212.	644.	1025.	5997.
MATERIAL $	47.	36.	179.	13.	16.	17.	17.	43.	79.	517.
SALES TAX	3.	6.	11.	1.	1.	1.	1.	3.	5.	31.
INDIRECT	243.	675.	1215.	98.	78.	120.	125.	380.	605.	3539.
PROFIT	72.	176.	352.	28.	23.	35.	36.	109.	174.	1024.
BONDS	11.	29.	52.	4.	3.	5.	5.	16.	26.	151.
TOTAL $	787.	2136.	3867.	310.	253.	381.	396.	1194.	1913.	11259.
VALVES #	18	18	36	4	4	4	4	16	4	108
LABOR HRS	37.8	37.8	75.6	9.2	9.2	9.2	9.2	14.6	23.7	226.3
LABOR $	641.	641.	1282.	156.	156.	156.	156.	247.	402.	3837.
MATERIAL $	1544.	1544.	3088.	697.	697.	697.	697.	1394.	1988.	12345.
SALES TAX	93.	93.	185.	42.	42.	42.	42.	84.	119.	741.
INDIRECT	378.	378.	756.	92.	92.	92.	92.	146.	237.	2263.
PROFIT	270.	270.	539.	100.	100.	100.	100.	190.	279.	1947.
BONDS	40.	40.	80.	15.	15.	15.	15.	23.	41.	288.
TOTAL $	2965.	2965.	5930.	1102.	1102.	1102.	1102.	2039.	3066.	21422.
ANCHORS #	18	18	36	1	1	1	1	2	3	81
LABOR HRS	4.0	4.0	8.0	1.0	1.0	1.0	1.0	2.0	3.5	25.5
LABOR $	68.	68.	136.	17.	17.	17.	17.	34.	59.	433.
MATERIAL $	216.	216.	432.	22.	22.	22.	22.	45.	80.	1077.
SALES TAX	13.	13.	26.	1.	1.	1.	1.	3.	5.	65.
INDIRECT	40.	40.	80.	10.	10.	10.	10.	20.	35.	255.
PROFIT	34.	34.	63.	5.	5.	5.	5.	10.	18.	185.
BONDS	5.	5.	10.	1.	1.	1.	1.	2.	3.	27.
TOTAL $	376.	376.	752.	56.	56.	56.	56.	114.	200.	2043.
PIPE GUIDES #	36	36	54	2	2	2	2	4	5	143
LABOR HRS	111.6	111.6	199.8	7.4	9.2	9.2	11.2	22.5	32.0	514.5
LABOR $	1892.	1892.	3387.	125.	156.	156.	190.	381.	542.	8721.
MATERIAL $	2397.	2397.	3596.	133.	135.	141.	221.	665.	668.	10353.
SALES TAX	144.	144.	216.	8.	8.	8.	13.	40.	40.	621.

ORIGINAL PAGE IS OF POOR QUALITY

9950-663

FIGURE C-2. COMPUTER COST MATRIX FOR BASELINE STEOR PIPE NETWORK–MODIFIED FOR FACTORY FABRICATED OMEGA EXPANSION JOINTS (CONTINUED)

ORIGINAL PAGE IS OF POOR QUALITY

INDIRECT	1116.	1116.	1998.	74.	92.	92.	112.	225.	320.	5145.
PROFIT	553.	555.	933.	35.	40.	40.	54.	133.	159.	2521.
BONDS	83.	83.	138.	5.	6.	6.	8.	20.	24.	373.
TOTAL $	6195.	6195.	10268.	383.	437.	444.	599.	1454.	1753.	27734.
FOUNDATIONS & PILLA	54	54	90	3	3	3	3	6	8	224
LABOR HRS	110.8	113.8	216.9	1.6	6.1	6.1	4.3	10.2	14.8	481.4
LABOR $	1405.	1435.	2749.	20.	77.	77.	55.	127.	188.	6133.
MATERIAL $	826.	826.	1618.	12.	45.	45.	32.	75.	110.	3593.
SALES TAX	50.	50.	97.	1.	3.	3.	2.	5.	7.	215.
INDIRECT	654.	654.	1280.	9.	36.	36.	25.	60.	87.	2840.
PROFIT	298.	298.	583.	4.	16.	16.	12.	27.	40.	1294.
BONDS	44.	44.	86.	1.	2.	2.	2.	4.	6.	191.
TOTAL $	3276.	3276.	6412.	46.	179.	179.	127.	300.	437.	14234.
INSULATION										
LABOR HRS	144.9	144.9	217.4	9.5	15.8	15.3	16.7	33.4	36.5	635.4
LABOR $	1304.	1334.	1957.	85.	142.	146.	150.	331.	329.	5718.
MATERIAL $	5795.	5215.	16045.	885.	953.	1151.	1196.	2933.	4630.	44835.
SALES TAX	348.	333.	1083.	53.	57.	69.	72.	173.	278.	2690.
INDIRECT	782.	732.	1174.	51.	85.	38.	90.	180.	197.	3431.
PROFIT	835.	1235.	2259.	109.	126.	148.	153.	368.	552.	5753.
BONDS	123.	178.	334.	16.	19.	22.	23.	54.	82.	853.
TOTAL $	9188.	13233.	24852.	1200.	1382.	1623.	1684.	4053.	6067.	63278.
INSPECTION										
LABOR HRS	79.2	43.0	94.5	11.0	3.5	3.5	5.0	8.0	9.0	258.7
LABOR $	1342.	732.	1601.	186.	59.	59.	84.	136.	153.	4382.
MATERIAL $	134.	76.	160.	19.	6.	6.	8.	14.	15.	438.
SALES TAX	8.	5.	10.	1.	0.	0.	0.	1.	1.	26.
INDIRECT	752.	430.	945.	110.	35.	35.	50.	80.	90.	2587.
PROFIT	231.	131.	276.	32.	10.	10.	14.	23.	26.	754.
BONDS	34.	19.	41.	5.	2.	2.	2.	3.	4.	111.
TOTAL $	2541.	1443.	3032.	353.	112.	112.	159.	253.	289.	8299.

STEAM SIDE TOTALS

LABOR HRS	570.4	534.8	1043.8	55.5	59.6	66.0	72.8	158.8	217.3	2828.8
LABOR $	8044.	8237.	15037.	856.	899.	1058.	1083.	2332.	3330.	40974.
MATERIAL $	12984.	16879.	31722.	2039.	2211.	2570.	2862.	6913.	9788.	87968.
SALES TAX	779.	1013.	1903.	122.	133.	154.	172.	415.	587.	5278.
INDIRECT	4583.	4727.	8543.	504.	498.	560.	634.	1392.	1944.	23391.
PROFIT	2679.	3137.	5807.	357.	380.	441.	482.	1127.	1588.	15998.
BONDS	396.	454.	858.	53.	56.	65.	71.	167.	235.	2364.
TOTAL $	29465.	34536.	63875.	3931.	4177.	4843.	5304.	12395.	17472.	175973.

WATER SIDE SUMMARY

NOM PIPE DIA	0.125	0.250	0.375	0.500	0.750	1.000	1.250	1.500	2.000	
LENGTHS ST	882.	332.	882.	441.	60.	60.	120.	180.	74.	
PIPE COST										
LABOR HRS	39.8	37.8	39.8	19.8	2.7	2.9	6.3	13.4	4.5	166.0
LABOR $	675.	675.	675.	335.	46.	49.	107.	176.	81.	2823.
MATERIAL $	750.	328.	1013.	598.	88.	135.	261.	471.	232.	4346.
SALES TAX	45.	30.	61.	36.	5.	6.	16.	23.	14.	261.
INDIRECT	398.	393.	398.	198.	27.	29.	63.	104.	45.	1660.
PROFIT	190.	178.	218.	119.	17.	19.	45.	79.	38.	922.
BONDS	28.	29.	32.	18.	2.	3.	7.	12.	6.	135.
TOTAL $	2086.	2178.	2397.	1304.	186.	211.	499.	870.	415.	10145.

9950-663

S#1315T 03/11/81 JJT PAGE 003

FIGURE C-2. COMPUTER COST MATRIX FOR BASELINE STEOR PIPE NETWORK-MODIFIED FOR FACTORY FABRICATED OMEGA EXPANSION JOINTS (CONTINUED)

ORIGINAL PAGE IS OF POOR QUALITY

FIXTURES #	18	18	18	18	2	3	7	10	3	97
LABOR HRS	21.6	13.5	13.5	13.5	6.0	6.8	16.4	24.3	7.2	122.8
LABOR $	366.	229.	229.	229.	102.	115.	278.	412.	122.	2032.
MATERIAL $	29.	27.	28.	33.	7.	10.	22.	33.	11.	232.
SALES TAX	2.	2.	2.	2.	0.	1.	1.	2.	1.	12.
INDIRECT	216.	135.	135.	135.	60.	58.	164.	243.	72.	1228.
PROFIT	62.	40.	40.	40.	17.	20.	47.	71.	21.	358.
BONDS	9.	6.	6.	6.	3.	3.	7.	10.	3.	53.
TOTAL $	684.	438.	440.	442.	189.	216.	520.	776.	230.	3935.
VALVES #	18	18	18	18	2	2	4	5	4	90
LABOR HRS	32.4	32.4	32.4	32.4	4.2	4.2	8.4	12.6	9.9	168.9
LABOR $	549.	549.	549.	549.	71.	71.	142.	214.	168.	2852.
MATERIAL $	813.	813.	813.	813.	90.	90.	180.	270.	406.	4288.
SALES TAX	49.	49.	49.	49.	5.	5.	11.	16.	24.	257.
INDIRECT	324.	324.	324.	324.	42.	42.	84.	126.	99.	1689.
PROFIT	176.	176.	176.	176.	21.	21.	42.	64.	71.	923.
BONDS	26.	26.	26.	26.	3.	3.	6.	9.	10.	136.
TOTAL $	1937.	1937.	1937.	1937.	233.	233.	465.	699.	779.	10156.
ANCHORS #	18	18	18	18	1	1	2	3	1	80
LABOR HRS	5.4	5.4	5.4	5.4	0.5	0.5	1.0	1.5	0.5	25.6
LABOR $	91.	91.	91.	91.	8.	8.	17.	25.	8.	430.
MATERIAL $	90.	90.	90.	90.	14.	14.	28.	42.	15.	473.
SALES TAX	5.	5.	5.	5.	1.	1.	2.	3.	1.	28.
INDIRECT	54.	54.	54.	54.	5.	5.	10.	15.	5.	256.
PROFIT	24.	24.	24.	24.	3.	3.	6.	9.	3.	121.
BONDS	4.	4.	4.	4.	0.	0.	1.	1.	0.	18.
TOTAL $	268.	268.	268.	268.	31.	31.	63.	94.	32.	1326.
PIPE GUIDES #	72	72	72	72	4	2	4	6	2	306
LABOR HRS	36.0	36.0	50.4	50.4	4.0	2.0	2.4	9.0	3.4	193.6
LABOR $	610.	610.	954.	954.	68.	34.	41.	152.	51.	3474.
MATERIAL $	632.	632.	632.	632.	36.	18.	56.	62.	22.	2722.
SALES TAX	38.	38.	38.	38.	2.	1.	3.	4.	1.	163.
INDIRECT	360.	360.	504.	504.	40.	20.	24.	90.	34.	1936.
PROFIT	166.	166.	216.	216.	15.	7.	13.	31.	11.	842.
BONDS	25.	25.	32.	32.	2.	1.	2.	5.	2.	124.
TOTAL $	1831.	1831.	2375.	2376.	163.	82.	139.	344.	121.	9262.
FOUNDATIONS & PILLA	36	36	35	35	2	2	0	0	0	148
LABOR HRS	222.2	222.2	249.3	142.7	12.4	12.4	6.8	12.0	14.8	895.0
LABOR $	2818.	2818.	3162.	1811.	156.	156.	86.	152.	188.	11348.
MATERIAL $	1657.	1657.	1859.	1064.	93.	93.	51.	33.	110.	6673.
SALES TAX	99.	99.	112.	64.	6.	6.	3.	5.	7.	400.
INDIRECT	1311.	1311.	1471.	842.	73.	73.	40.	71.	87.	5281.
PROFIT	597.	597.	670.	384.	33.	33.	13.	32.	40.	2405.
BONDS	88.	88.	99.	57.	5.	5.	3.	5.	6.	355.
TOTAL $	6571.	6571.	7373.	4222.	366.	366.	201.	355.	437.	26463.
INSPECTION										
LABOR HRS	37.8	5.4	7.2	28.8	45.0	1.0	1.0	1.3	2.8	130.3
LABOR $	640.	91.	122.	488.	762.	17.	17.	21.	48.	2205.
MATERIAL $	64.	9.	12.	49.	76.	2.	2.	2.	5.	221.
SALES TAX	4.	1.	1.	3.	5.	0.	0.	0.	0.	13.
INDIRECT	378.	54.	72.	288.	450.	10.	10.	13.	28.	1303.
PROFIT	110.	16.	21.	84.	131.	3.	3.	4.	8.	330.
BONDS	16.	2.	3.	12.	19.	0.	0.	1.	1.	56.
TOTAL $	1212.	173.	231.	924.	1443.	33.	33.	43.	91.	4179.

WATER SIDE TOTALS

9950-663

SW1315T 03/11/81 JJT PAGE 304

FIGURE C-2. COMPUTER COST MATRIX FOR BASELINE STEOR PIPE NETWORK-MODIFIED FOR FACTORY FABRICATED OMEGA EXPANSION JOINTS (CONCLUDED)

LABOR HRS	395.2	334.7	398.0	293.0	74.8	29.8	42.1	71.1	43.1	2702.2
LABOR $	5749.	5033.	5782.	4458.	1213.	450.	688.	1152.	666.	38222.
MATERIAL $	4035.	4336.	4447.	3276.	404.	332.	600.	974.	801.	15925.
SALES TAX	242.	243.	267.	197.	24.	20.	36.	53.	48.	1135.
INDIRECT	3041.	2636.	2958.	2345.	697.	247.	395.	662.	370.	13353.
PROFIT	1326.	1213.	1365.	1043.	237.	136.	175.	289.	191.	5951.
BONDS	196.	130.	202.	154.	35.	16.	26.	43.	28.	830.
TOTAL $	14589.	13376.	15022.	11474.	2611.	1171.	1920.	3179.	2104.	65466.
OVERAL TOTALS										
LABOR HRS	965.6	937.5	1441.8	348.5	134.6	95.8	115.1	229.9	260.4	4531.0
LABOR $	13793.	13350.	20819.	5314.	2112.	1538.	1771.	3534.	3995.	66195.
MATERIAL $	17019.	20735.	36169.	5315.	2615.	2932.	3462.	7387.	10589.	106393.
SALES TAX	1021.	1256.	2170.	319.	157.	174.	203.	473.	635.	6414.
INDIRECT	7624.	7353.	11507.	2850.	1195.	807.	1029.	2054.	2315.	36744.
PROFIT	4005.	4355.	7172.	1403.	617.	542.	657.	1415.	1780.	21949.
BONDS	592.	544.	1060.	207.	91.	31.	97.	209.	263.	3244.
TOTAL $	44054.	47703.	78897.	15405.	6788.	6019.	7223.	15574.	19577.	241439.

ORIGINAL PAGE IS OF POOR QUALITY

FIGURE C-3. COMPUTER COST MATRIX BASELINE STEOR PIPE NETWORK-MODIFIED FOR USE OF FLEXIBLE HOSE EXPANSION JOINTS

TEOR PIPE NETWORK
STEAM SIDE COST SUMMARY

NOM PIPE DIA	0.500	0.750	1.000	1.500	2.000	2.500	3.000	3.500	4.000	TOTAL
LENGTHS ST	882.	332.	1323.	60.	60.	60.	60.	120.	134.	
EXPANSION JOINTS	216.	216.	324.	12.	12.	12.	16.	32.	32.	
TOTAL	1098.	1078.	1647.	72.	72.	72.	76.	152.	166.	
PIPE COST										
LABOR HRS	39.8	37.8	61.5	3.5	3.8	4.7	8.3	19.1	23.9	204.4
LABOR $	675.	675.	1042.	59.	64.	80.	141.	324.	405.	3455.
MATERIAL $	1197.	1235.	2309.	157.	188.	267.	351.	860.	1136.	7760.
SALES TAX	72.	74.	139.	9.	11.	16.	21.	52.	68.	465.
INDIRECT	398.	338.	615.	35.	38.	47.	83.	191.	239.	2044.
PROFIT	238.	248.	417.	26.	31.	42.	61.	145.	188.	1394.
BONDS	35.	37.	62.	4.	5.	6.	9.	21.	28.	206.
TOTAL $	2615.	2731.	4583.	291.	336.	458.	666.	1593.	2063.	15335.
EXPANSION JOINTS #	18	18	36	2	2	3	2	4	5	90
LABOR HRS	12.0	12.0	27.0	3.0	3.0	6.0	3.0	6.0	7.0	79.0
LABOR $	203.	233.	458.	51.	51.	102.	51.	102.	118.	1339.
MATERIAL $	2340.	2770.	6552.	400.	400.	1096.	400.	1400.	1635.	17013.
SALES TAX	140.	137.	393.	24.	24.	66.	24.	84.	98.	1021.
INDIRECT	120.	120.	270.	30.	30.	60.	30.	60.	70.	790.
PROFIT	295.	333.	779.	51.	51.	134.	51.	167.	195.	2047.
BONDS	42.	39.	115.	8.	8.	20.	8.	25.	29.	302.
TOTAL $	5130.	3633.	8567.	564.	564.	1478.	564.	1838.	2145.	22512.
FIXTURES #	18	36	54	4	3	3	3	7	10	138
LABOR HRS	24.3	67.5	121.5	9.8	7.8	12.0	12.5	33.0	60.5	353.9
LABOR $	412.	1144.	2059.	166.	132.	203.	212.	644.	1025.	5997.
MATERIAL $	47.	136.	179.	13.	16.	17.	17.	43.	79.	517.
SALES TAX	3.	6.	11.	1.	1.	1.	1.	3.	5.	31.
INDIRECT	243.	675.	1215.	98.	78.	120.	125.	380.	605.	3539.
PROFIT	72.	196.	352.	28.	23.	35.	36.	109.	174.	1024.
BONDS	11.	29.	52.	4.	3.	5.	5.	16.	26.	151.
TOTAL $	787.	2136.	3867.	310.	253.	381.	396.	1194.	1913.	11259.
VALVES #	18	18	36	4	4	4	4	16	4	108
LABOR HRS	37.8	37.8	75.6	9.2	9.2	9.2	9.2	14.6	23.7	226.3
LABOR $	641.	641.	1282.	156.	156.	156.	156.	247.	402.	3837.
MATERIAL $	1544.	1544.	3088.	697.	697.	697.	697.	1394.	1988.	12346.
SALES TAX	93.	93.	185.	42.	42.	42.	42.	84.	119.	741.
INDIRECT	378.	378.	756.	92.	92.	92.	92.	146.	237.	2263.
PROFIT	270.	270.	539.	100.	100.	100.	100.	190.	279.	1947.
BONDS	40.	40.	80.	15.	15.	15.	15.	23.	41.	288.
TOTAL $	2965.	2965.	5930.	1102.	1102.	1102.	1102.	2089.	3066.	21422.
ANCHORS #	0	0	0	0	0	1	0	1	1	3
LABOR HRS	0.	0.	0.	0.	0.	1.0	0.	1.0	1.5	3.5
LABOR $	0.	0.	0.	0.	0.	17.	0.	17.	26.	60.
MATERIAL $	0.	0.	0.	0.	0.	22.	0.	22.	35.	79.
SALES TAX	0.	0.	0.	0.	0.	1.	0.	1.	2.	5.
INDIRECT	0.	0.	0.	0.	0.	10.	0.	10.	15.	35.
PROFIT	0.	0.	0.	0.	0.	5.	0.	5.	8.	18.
BONDS	0.	0.	0.	0.	0.	1.	0.	1.	1.	3.
TOTAL $	0.	0.	0.	0.	0.	56.	0.	56.	87.	203.
PIPE GUIDES #	36	36	72	2	2	2	2	3	4	159
LABOR HRS	112.0	112.0	168.0	7.4	9.2	9.2	11.2	16.8	22.3	468.6
LABOR $	1898.	1898.	2848.	125.	156.	156.	190.	285.	387.	7943.
MATERIAL $	2397.	2397.	4795.	134.	136.	141.	221.	495.	671.	11388.
SALES TAX	144.	144.	283.	8.	8.	8.	13.	30.	40.	683.

FLE OK

ORIGINAL PAGE IS OF POOR QUALITY

9950-663

FIGURE C-3. COMPUTER COST M X BASELINE STEOR PIPE NETWORK-MODIFIED FOR USE OF FLEXIBLE HOSE EXPANSION JOINTS (CONTINUED)

INDIRECT	1120.	1120.	1680.	74.	92.	92.	112.	153.	228.	4685.
PROFIT	564.	534.	975.	35.	40.	40.	54.	99.	135.	2507.
BONDS	83.	33.	144.	5.	6.	6.	3.	15.	20.	371.
TOTAL $	6206.	6235.	10730.	381.	438.	444.	599.	1093.	1481.	27578.
FOUNDATIONS & PILLA	36	36	72	2	2	3	2	4	5	162
LABOR HRS	73.9	73.9	173.5	1.3	4.0	6.1	2.9	7.8	10.1	353.2
LABOR $	937.	937.	2201.	13.	51.	77.	36.	99.	129.	4481.
MATERIAL $	551.	531.	1294.	8.	30.	45.	21.	50.	69.	2620.
SALES TAX	33.	33.	73.	0.	2.	3.	1.	3.	4.	157.
INDIRECT	436.	436.	1024.	6.	24.	36.	17.	46.	60.	2034.
PROFIT	199.	199.	467.	3.	11.	16.	8.	20.	27.	948.
BONDS	29.	29.	69.	0.	2.	2.	1.	3.	4.	143.
TOTAL $	2185.	2135.	5132.	31.	119.	179.	85.	221.	293.	10431.
INSULATION										
LABOR HRS	117.1	117.1	174.6	7.9	13.2	13.2	13.2	26.4	29.5	512.2
LABOR $	1054.	1054.	1572.	71.	118.	118.	113.	233.	265.	4608.
MATERIAL $	4684.	4634.	14495.	737.	794.	933.	944.	2344.	3611.	33226.
SALES TAX	281.	231.	870.	44.	48.	56.	57.	141.	217.	1994.
INDIRECT	632.	632.	943.	43.	71.	71.	71.	143.	159.	2765.
PROFIT	675.	675.	1815.	91.	105.	120.	121.	291.	432.	4323.
BONDS	100.	130.	268.	13.	15.	18.	18.	43.	64.	639.
TOTAL $	7426.	7426.	19963.	999.	1151.	1316.	1329.	3199.	4747.	47556.
INSPECTION										
LABOR HRS	79.2	43.0	94.5	11.0	3.5	3.5	5.0	3.0	9.0	258.7
LABOR $	1342.	732.	1601.	185.	59.	59.	84.	136.	153.	4382.
MATERIAL $	134.	76.	160.	19.	6.	6.	8.	14.	15.	438.
SALES TAX	8.	5.	10.	1.	0.	0.	0.	1.	1.	26.
INDIRECT	792.	430.	945.	110.	35.	35.	50.	80.	90.	2537.
PROFIT	231.	131.	276.	32.	10.	10.	14.	23.	26.	754.
BONDS	34.	19.	41.	5.	2.	2.	2.	3.	4.	111.
TOTAL $	2541.	1443.	3032.	353.	112.	112.	159.	253.	289.	8299.

STEAM SIDE TOTALS

LABOR HRS	496.1	535.1	896.2	52.3	53.7	64.9	65.3	137.7	188.0	2459.8
LABOR $	7162.	7314.	13063.	827.	787.	968.	983.	2092.	2910.	36112.
MATERIAL $	12894.	13443.	32872.	2165.	2267.	3224.	2659.	6623.	9239.	85387.
SALES TAX	774.	837.	1972.	130.	136.	193.	160.	397.	554.	5123.
INDIRECT	4119.	4239.	7447.	488.	460.	563.	580.	1223.	1703.	20793.
PROFIT	2532.	2616.	5619.	366.	371.	502.	445.	1049.	1462.	14963.
BONDS	374.	337.	830.	54.	55.	74.	66.	155.	216.	2211.
TOTAL $	27856.	28776.	61804.	4030.	4076.	5525.	4899.	11540.	16085.	164590.

WATER SIDE SUMMARY

NOM PIPE DIA	0.125	0.250	0.375	0.500	0.750	1.000	1.250	1.500	2.000	
LENGTHS ST	882.	332.	882.	441.	60.	60.	120.	180.	74.	
PIPE COST										
LABOR HRS	39.8	39.8	39.8	19.8	2.7	2.9	6.3	10.4	4.5	166.0
LABOR $	675.	675.	675.	336.	46.	49.	107.	176.	81.	2820.
MATERIAL $	750.	328.	1013.	598.	88.	105.	261.	471.	232.	4346.
SALES TAX	45.	30.	61.	36.	5.	6.	16.	28.	14.	261.
INDIRECT	398.	398.	398.	198.	27.	29.	63.	104.	45.	1660.
PROFIT	190.	178.	218.	119.	17.	19.	45.	79.	38.	923.
BONDS	28.	29.	32.	18.	2.	3.	7.	12.	6.	136.
TOTAL $	2086.	2178.	2397.	1304.	186.	211.	499.	870.	415.	10145.

ORIGINAL PAGE IS OF POOR QUALITY

9950-663

FIGURE C-3. COMPUTER COST MATRIX BASELINE STEOR PIPE NETWORK-MODIFIED FOR USE OF FLEXIBLE HOSE EXPANSION JOINTS (CONTINUED)

S#1314T 03/11/81 OUT PAGE 303

FIXTURES #	18	18	18	18	2	3	7	10	3	97
LABOR HRS	21.6	13.5	13.5	13.5	6.0	5.8	15.4	24.3	7.2	122.8
LABOR $	366.	229.	229.	229.	102.	115.	278.	412.	122.	2032.
MATERIAL $	29.	27.	28.	30.	7.	10.	22.	38.	11.	232.
SALES TAX	2.	2.	2.	2.	0.	1.	1.	2.	1.	12.
INDIRECT	216.	135.	135.	135.	60.	58.	164.	243.	72.	1228.
PROFIT	62.	40.	40.	40.	17.	20.	47.	71.	21.	358.
BONDS	9.	6.	6.	6.	3.	3.	7.	10.	3.	53.
TOTAL $	684.	438.	440.	442.	189.	216.	520.	776.	230.	3935.
VALVES #	18	18	18	18	2	2	4	6	4	90
LABOR HRS	32.4	32.4	32.4	32.4	4.2	4.2	8.4	12.6	9.9	168.9
LABOR $	549.	549.	549.	549.	71.	71.	142.	214.	168.	2862.
MATERIAL $	813.	813.	813.	813.	90.	90.	180.	270.	406.	4288.
SALES TAX	49.	49.	49.	49.	5.	5.	11.	16.	24.	257.
INDIRECT	324.	324.	324.	324.	42.	42.	84.	126.	99.	1639.
PROFIT	176.	176.	176.	176.	21.	21.	42.	64.	71.	923.
BONDS	26.	26.	26.	26.	3.	3.	6.	9.	10.	136.
TOTAL $	1937.	1937.	1937.	1937.	233.	233.	465.	699.	779.	10156.
ANCHORS #	18	18	18	18	1	1	2	3	1	80
LABOR HRS	5.4	5.4	5.4	5.4	0.5	0.5	1.0	1.5	0.5	25.6
LABOR $	91.	91.	91.	91.	8.	8.	17.	25.	6.	430.
MATERIAL $	90.	90.	90.	90.	14.	14.	28.	42.	15.	473.
SALES TAX	5.	5.	5.	5.	1.	1.	2.	3.	1.	28.
INDIRECT	54.	54.	54.	54.	5.	5.	10.	15.	5.	256.
PROFIT	24.	24.	24.	24.	3.	3.	6.	9.	3.	121.
BONDS	4.	4.	4.	4.	0.	0.	1.	1.	0.	18.
TOTAL $	268.	253.	268.	268.	31.	31.	63.	94.	32.	1326.
PIPE GUIDES #	72	72	72	72	4	2	4	6	2	336
LABOR HRS	36.0	36.0	50.4	50.4	4.0	2.0	2.4	9.0	3.4	193.6
LABOR $	610.	610.	954.	954.	68.	34.	41.	152.	51.	3474.
MATERIAL $	632.	632.	632.	632.	36.	18.	56.	62.	22.	2722.
SALES TAX	38.	38.	38.	38.	2.	1.	3.	4.	1.	163.
INDIRECT	360.	360.	504.	504.	40.	20.	24.	90.	34.	1936.
PROFIT	166.	166.	216.	216.	15.	7.	13.	31.	11.	842.
BONDS	25.	25.	32.	32.	2.	1.	2.	5.	2.	124.
TOTAL $	1831.	1831.	2376.	2376.	163.	82.	139.	344.	121.	9262.
FOUNDATIONS & PILLA	36	36	36	35	2	2	0	0	0	148
LABOR HRS	192.5	192.5	226.1	139.6	10.8	12.4	4.5	9.2	10.1	797.8
LABOR $	2443.	2443.	2869.	1771.	135.	156.	58.	117.	129.	10120.
MATERIAL $	1436.	1436.	1686.	1040.	80.	93.	34.	60.	69.	5933.
SALES TAX	86.	86.	101.	62.	5.	6.	2.	4.	4.	356.
INDIRECT	1136.	1136.	1334.	823.	64.	73.	27.	54.	60.	4707.
PROFIT	518.	518.	603.	375.	29.	33.	12.	24.	27.	2143.
BONDS	77.	77.	90.	55.	4.	5.	2.	4.	4.	317.
TOTAL $	5695.	5695.	6683.	4128.	316.	366.	134.	262.	293.	23575.
INSPECTION										
LABOR HRS	37.8	5.4	7.2	28.8	45.0	1.0	1.0	1.3	2.8	130.3
LABOR $	640.	91.	122.	488.	762.	17.	17.	21.	48.	2205.
MATERIAL $	64.	9.	12.	49.	76.	2.	2.	2.	5.	221.
SALES TAX	4.	1.	1.	3.	5.	0.	0.	0.	0.	13.
INDIRECT	378.	54.	72.	288.	450.	10.	10.	13.	28.	1303.
PROFIT	110.	16.	23.	84.	131.	3.	3.	4.	8.	380.
BONDS	16.	2.	3.	12.	19.	0.	0.	1.	1.	56.
TOTAL $	1212.	173.	231.	924.	1443.	33.	33.	40.	91.	4179.

WATER SIDE TOTALS

ORIGINAL PAGE IS OF POOR QUALITY

S#1314T 03/11/81 JJT PAGE 004

FIGURE C-3. COMPUTER COST MATRIX BASELINE STEOR PIPE NETWORK-MODIFIED FOR USE OF FLEXIBLE HOSE EXPANSION JOINTS (CONCLUDED)

LABOR HRS	365.5	325.0	374.8	289.9	73.2	29.8	40.0	63.3	38.4	1605.0
LABOR $	5374.	4938.	5489.	4418.	1192.	450.	660.	1117.	607.	23994.
MATERIAL $	3814.	3835.	4274.	3252.	391.	332.	585.	945.	760.	18185.
SALES TAX	229.	250.	256.	195.	23.	20.	35.	57.	46.	1091.
INDIRECT	2866.	2451.	2821.	2326.	688.	247.	382.	645.	343.	12779.
PROFIT	1247.	1133.	1303.	1034.	233.	136.	168.	281.	178.	5639.
BONDS	184.	163.	193.	153.	34.	16.	25.	41.	26.	841.
TOTAL $	13713.	12520.	14336.	11379.	2561.	1171.	1852.	3086.	1960.	62579.

OVERAL TOTALS

LABOR HRS	861.6	833.1	1271.0	342.7	126.9	94.7	105.3	206.0	226.5	4064.8
LABOR $	12536.	12032.	18552.	5245.	1979.	1418.	1648.	3209.	3517.	60106.
MATERIAL $	16708.	17278.	37146.	5417.	2658.	3556.	3242.	7563.	9999.	103572.
SALES TAX	1002.	1037.	2229.	325.	159.	213.	195.	454.	600.	6214.
INDIRECT	4985.	6570.	10268.	2814.	1148.	810.	962.	1869.	2046.	33573.
PROFIT	3729.	3734.	6922.	1401.	603.	609.	614.	1330.	1640.	20652.
BONDS	558.	535.	1023.	207.	89.	90.	91.	196.	242.	3052.
TOTAL $	41569.	41276.	76140.	15409.	6637.	6697.	6751.	14626.	18045.	227159.

ORIGINAL PAGE IS
OF POOR QUALITY

9950-663

129

S#1317T 03/11/81 JOT PAGE 301

FIGURE C-4. COMPUTER COST MATRIX BASELINE STEOR PIPE NETWORK-MODIFIED FOR PREFAB POST SUPPORTS

TEOR PIPE NETWORK
STEAM SIDE COST SUMMARY

NOM PIPE DIA	0.500	0.750	1.000	1.500	2.000	2.500	3.000	3.500	4.000	TOTAL
LENGTHS ST	882.	832.	1323.	60.	60.	60.	60.	120.	134.	
EXPANSION JOINTS	216.	216.	324.	12.	12.	12.	16.	32.	32.	
TOTAL	1098.	1098.	1647.	72.	72.	72.	76.	152.	166.	
PIPE COST										
LABOR HRS	39.8	37.8	61.5	3.5	3.8	4.7	8.3	19.1	23.9	204.4
LABOR $	675.	675.	1042.	59.	64.	80.	141.	324.	405.	3465.
MATERIAL $	1197.	1235.	2309.	157.	188.	267.	351.	863.	1136.	7760.
SALES TAX	72.	78.	139.	9.	11.	16.	21.	52.	68.	456.
INDIRECT	398.	398.	615.	35.	38.	47.	83.	191.	239.	2044.
PROFIT	238.	248.	417.	26.	31.	42.	61.	145.	188.	1394.
BONDS	35.	37.	62.	4.	5.	6.	9.	21.	28.	205.
TOTAL $	2615.	2731.	4583.	291.	336.	458.	666.	1593.	2063.	15335.
EXPANSION JOINTS #	18	18	27	1	1	1	1	2	2	71
LABOR HRS	106.5	117.8	193.2	8.0	8.6	25.1	29.0	67.8	77.9	633.9
LABOR $	1805.	1997.	3275.	136.	146.	425.	492.	1149.	1320.	10745.
MATERIAL $	480.	547.	449.	61.	86.	88.	127.	319.	384.	2541.
SALES TAX	29.	33.	27.	4.	5.	5.	8.	19.	23.	152.
INDIRECT	1065.	1178.	1932.	80.	86.	251.	290.	678.	779.	6339.
PROFIT	343.	331.	577.	28.	33.	78.	93.	220.	254.	2007.
BONDS	51.	56.	85.	4.	5.	12.	14.	32.	38.	297.
TOTAL $	3772.	4132.	6345.	313.	361.	859.	1023.	2417.	2798.	22082.
FIXTURES #	18	36	54	4	3	3	3	7	10	138
LABOR HRS	24.3	67.5	121.5	9.8	7.8	12.0	12.5	33.0	60.5	353.9
LABOR $	412.	1144.	2059.	166.	132.	203.	212.	644.	1025.	5997.
MATERIAL $	47.	136.	179.	13.	16.	17.	17.	43.	79.	517.
SALES TAX	3.	6.	11.	1.	1.	1.	1.	3.	5.	31.
INDIRECT	243.	675.	1215.	98.	78.	120.	125.	380.	605.	3539.
PROFIT	72.	176.	352.	28.	23.	35.	36.	109.	174.	1024.
BONDS	11.	29.	52.	4.	3.	5.	5.	16.	26.	151.
TOTAL $	787.	2136.	3867.	310.	253.	381.	396.	1194.	1913.	11259.
VALVES #	18	18	36	4	4	4	4	16	4	138
LABOR HRS	37.8	37.8	75.6	9.2	9.2	9.2	9.2	14.6	23.7	226.3
LABOR $	641.	641.	1282.	156.	156.	156.	156.	247.	402.	3837.
MATERIAL $	1544.	1544.	3088.	697.	697.	697.	697.	1394.	1988.	12346.
SALES TAX	93.	93.	185.	42.	42.	42.	42.	34.	119.	741.
INDIRECT	378.	378.	756.	92.	92.	92.	92.	146.	237.	2263.
PROFIT	270.	270.	539.	100.	100.	100.	100.	190.	279.	1947.
BONDS	40.	40.	80.	15.	15.	15.	15.	23.	41.	288.
TOTAL $	2965.	2755.	5930.	1102.	1102.	1102.	1102.	2083.	3066.	21422.
ANCHORS #	18	18	36	1	1	1	1	2	3	81
LABOR HRS	4.0	4.0	8.0	1.0	1.0	1.0	1.0	2.0	3.5	25.5
LABOR $	68.	68.	136.	17.	17.	17.	17.	34.	59.	433.
MATERIAL $	216.	216.	432.	22.	22.	22.	22.	45.	80.	1077.
SALES TAX	13.	13.	26.	1.	1.	1.	1.	3.	5.	65.
INDIRECT	40.	40.	80.	10.	10.	10.	10.	20.	35.	255.
PROFIT	34.	34.	68.	5.	5.	5.	5.	10.	18.	185.
BONDS	5.	5.	10.	1.	1.	1.	1.	2.	3.	27.
TOTAL $	376.	376.	752.	56.	56.	56.	56.	114.	200.	2043.
PIPE GUIDES #	54	54	81	3	3	3	3	6	7	214
LABOR HRS	167.4	167.4	299.7	11.1	13.8	13.8	16.8	33.6	44.8	768.4
LABOR $	2837.	2337.	5080.	186.	234.	234.	284.	570.	759.	13023.
MATERIAL $	3596.	3570.	5394.	200.	202.	212.	331.	992.	1167.	15693.
SALES TAX	216.	216.	324.	12.	12.	13.	20.	60.	70.	941.

ORIGINAL PAGE IS OF POOR QUALITY

9950-663

FIGURE C-4. COMPUTER COST MATRIX BASELINE STEOR PIPE NETWORK-MODIFIED FOR PREFAB POST SUPPORTS (CONTINUED)

ORIGINAL PAGE IS OF POOR QUALITY

INDIRECT	1674.	1674.	2997.	111.	138.	138.	168.	336.	448.	7684.
PROFIT	845.	845.	1400.	52.	59.	61.	81.	199.	248.	3790.
BONDS	125.	125.	207.	8.	9.	9.	12.	29.	37.	563.
TOTAL $	9292.	9292.	15402.	571.	654.	666.	896.	2186.	2729.	41633.
FOUNDATIONS & PILLA	72	72	117	6	4	4	4	8	10	295
LABOR HRS	39.9	39.9	76.2	0.5	2.5	2.5	1.7	4.1	5.8	173.2
LABOR $	677.	577.	1291.	11.	41.	41.	29.	70.	98.	2935.
MATERIAL $	1741.	1741.	3322.	24.	212.	212.	150.	356.	540.	8297.
SALES TAX	104.	104.	199.	1.	13.	13.	9.	21.	32.	498.
INDIRECT	236.	236.	450.	4.	14.	14.	10.	24.	34.	1022.
PROFIT	280.	230.	534.	4.	28.	28.	20.	43.	71.	1294.
BONDS	41.	41.	79.	1.	4.	4.	3.	7.	11.	191.
TOTAL $	3079.	3079.	5875.	45.	313.	313.	222.	527.	785.	14238.
INSULATION										
LABOR HRS	144.9	144.9	217.4	9.5	15.8	16.3	16.7	33.4	36.5	635.4
LABOR $	1304.	1334.	1957.	85.	142.	146.	150.	301.	329.	5718.
MATERIAL $	5795.	9213.	18045.	885.	953.	1151.	1196.	2968.	4630.	44835.
SALES TAX	348.	555.	1083.	53.	57.	59.	72.	173.	278.	2693.
INDIRECT	782.	732.	1174.	51.	85.	88.	90.	130.	197.	3431.
PROFIT	835.	1233.	2259.	109.	126.	148.	153.	368.	552.	5753.
BONDS	123.	173.	334.	16.	19.	22.	23.	54.	82.	850.
TOTAL $	9188.	13233.	24852.	1200.	1382.	1623.	1634.	4050.	6067.	63278.
INSPECTION										
LABOR HRS	79.2	43.0	94.5	11.0	3.5	3.5	5.0	8.0	9.0	258.7
LABOR $	1342.	732.	1601.	186.	59.	59.	84.	136.	153.	4382.
MATERIAL $	134.	76.	160.	19.	6.	6.	8.	14.	15.	438.
SALES TAX	8.	5.	10.	1.	0.	0.	0.	1.	1.	26.
INDIRECT	792.	430.	945.	110.	35.	35.	50.	80.	90.	2587.
PROFIT	231.	131.	276.	32.	10.	10.	14.	23.	26.	754.
BONDS	34.	19.	41.	5.	2.	2.	2.	3.	4.	111.
TOTAL $	2541.	1443.	3032.	353.	112.	112.	157.	258.	289.	8299.

STEAM SIDE TOTALS

LABOR HRS	643.8	664.1	1147.6	63.7	66.0	88.1	100.2	220.6	285.5	3279.7
LABOR $	9761.	10105.	17723.	1004.	991.	1361.	1565.	3475.	4550.	50535.
MATERIAL $	14750.	18334.	33378.	2078.	2382.	2672.	2899.	6991.	10019.	93502.
SALES TAX	885.	1100.	2003.	125.	143.	160.	174.	419.	601.	5610.
INDIRECT	5608.	5311.	10164.	591.	577.	796.	918.	2036.	2664.	29164.
PROFIT	3147.	3538.	6422.	385.	415.	506.	564.	1312.	1810.	18149.
BONDS	465.	530.	949.	57.	61.	75.	83.	194.	267.	2682.
TOTAL $	34615.	39438.	70638.	4240.	4570.	5570.	6205.	14427.	19911.	199643.

WATER SIDE SUMMARY

NOM PIPE DIA	0.125	0.250	0.375	0.500	0.750	1.000	1.250	1.500	2.000	
LENGTHS ST	882.	332.	882.	441.	60.	60.	120.	130.	74.	
PIPE COST										
LABOR HRS	39.8	39.8	39.8	19.8	2.7	2.9	6.3	10.4	4.5	166.0
LABOR $	675.	675.	675.	336.	46.	49.	107.	176.	81.	2820.
MATERIAL $	750.	323.	1013.	598.	88.	105.	261.	471.	232.	4346.
SALES TAX	45.	30.	61.	36.	5.	6.	16.	28.	14.	261.
INDIRECT	398.	373.	398.	193.	27.	29.	63.	104.	45.	1663.
PROFIT	190.	178.	218.	117.	17.	19.	45.	79.	38.	922.
BONDS	28.	27.	32.	18.	2.	3.	7.	12.	6.	136.
TOTAL $	2086.	2173.	2397.	1304.	186.	211.	499.	870.	415.	10145.

FIGURE C-4. COMPUTER COST MATRIX BASELINE STEOR PIPE NETWORK-MODIFIED FOR PREFAB POST SUPPORTS (CONTINUED)

S#1317T 03/11/81 JJT PAGE 305

FIXTURES #	18	18	18	18	2	3	7	10	3	97
LABOR HRS	21.6	13.5	13.5	13.5	6.0	6.8	16.4	24.3	7.2	122.8
LABOR $	366.	229.	229.	229.	102.	115.	273.	412.	122.	2082.
MATERIAL $	29.	27.	28.	30.	7.	10.	22.	33.	11.	202.
SALES TAX	2.	2.	2.	2.	0.	1.	1.	2.	1.	12.
INDIRECT	216.	135.	135.	135.	60.	68.	164.	243.	72.	1228.
PROFIT	62.	40.	40.	40.	17.	20.	47.	71.	21.	358.
BONDS	9.	6.	6.	6.	3.	3.	7.	10.	3.	53.
TOTAL $	684.	433.	440.	442.	189.	216.	520.	776.	230.	3935.
VALVES #	18	18	18	18	2	2	4	6	4	90
LABOR HRS	32.4	32.4	32.4	32.4	4.2	4.2	8.4	12.6	9.9	168.9
LABOR $	549.	549.	549.	549.	71.	71.	142.	214.	168.	2862.
MATERIAL $	813.	813.	813.	813.	90.	90.	180.	270.	406.	4288.
SALES TAX	49.	49.	49.	49.	5.	5.	11.	16.	24.	257.
INDIRECT	324.	324.	324.	324.	42.	42.	84.	126.	99.	1689.
PROFIT	176.	176.	176.	176.	21.	21.	42.	64.	71.	923.
BONDS	26.	26.	26.	26.	3.	3.	6.	9.	10.	136.
TOTAL $	1937.	1937.	1937.	1937.	233.	233.	465.	699.	779.	10156.
ANCHORS #	18	18	18	18	1	1	2	3	1	80
LABOR HRS	5.4	5.4	5.4	5.4	0.5	0.5	1.0	1.5	0.5	25.6
LABOR $	91.	91.	91.	91.	8.	8.	17.	25.	8.	430.
MATERIAL $	90.	90.	90.	90.	14.	14.	28.	42.	15.	473.
SALES TAX	5.	5.	5.	5.	1.	1.	2.	3.	1.	28.
INDIRECT	54.	54.	54.	54.	5.	5.	10.	15.	5.	256.
PROFIT	24.	24.	24.	24.	3.	3.	6.	9.	3.	121.
BONDS	4.	4.	4.	4.	0.	0.	1.	1.	0.	18.
TOTAL $	268.	233.	268.	268.	31.	31.	63.	94.	32.	1326.
PIPE GUIDES #	72	72	72	72	4	2	4	6	2	336
LABOR HRS	36.0	36.0	50.4	50.4	4.0	2.0	2.4	9.0	3.4	193.6
LABOR $	610.	610.	954.	954.	68.	34.	41.	152.	51.	3474.
MATERIAL $	632.	632.	632.	632.	36.	18.	56.	62.	22.	2722.
SALES TAX	38.	38.	38.	38.	2.	1.	3.	4.	1.	163.
INDIRECT	360.	350.	504.	504.	40.	20.	24.	90.	34.	1936.
PROFIT	166.	166.	216.	216.	15.	7.	13.	31.	11.	842.
BONDS	25.	25.	32.	32.	2.	1.	2.	5.	2.	124.
TOTAL $	1831.	1831.	2376.	2376.	163.	82.	139.	344.	121.	9262.
FOUNDATIONS & PILLA	36	36	36	36	2	2	0	0	0	148
LABOR HRS	50.1	53.1	58.8	21.9	3.0	3.0	2.8	4.9	5.8	200.3
LABOR $	848.	848.	997.	370.	52.	52.	47.	83.	98.	3394.
MATERIAL $	2506.	2506.	2887.	1258.	238.	238.	238.	422.	540.	10833.
SALES TAX	150.	150.	173.	75.	14.	14.	14.	25.	32.	650.
INDIRECT	295.	295.	347.	129.	18.	18.	16.	29.	34.	1182.
PROFIT	386.	336.	447.	186.	33.	33.	32.	57.	71.	1630.
BONDS	57.	57.	66.	27.	5.	5.	5.	3.	11.	241.
TOTAL $	4243.	4243.	4917.	2046.	360.	360.	351.	624.	785.	17929.
INSPECTION										
LABOR HRS	37.8	5.4	7.2	23.3	45.0	1.0	1.0	1.3	2.8	130.3
LABOR $	640.	91.	122.	488.	762.	17.	17.	21.	48.	2205.
MATERIAL $	64.	9.	12.	49.	76.	2.	2.	2.	5.	221.
SALES TAX	4.	1.	1.	3.	5.	0.	0.	0.	0.	13.
INDIRECT	378.	54.	72.	283.	450.	10.	10.	13.	28.	1303.
PROFIT	110.	16.	21.	84.	131.	3.	3.	4.	8.	380.
BONDS	16.	2.	3.	12.	19.	0.	0.	1.	1.	56.
TOTAL $	1212.	173.	231.	924.	1443.	33.	33.	43.	91.	4179.

WATER SIDE TOTALS

9950-663

FIGURE C-4. COMPUTER COST MATRIX
[illegible]
NETWORK-MODIFIED FOR
PREFAB POST SUPPORTS
(CONCLUDED)

LABOR HRS	225.1	322.5?	237.5	172.2	55.4?	23.4	33.5	56.3	34.1	[illegible]
LABOR $	3773.?	3305.?	3457.?	3037.?	1139.?	345.?	649.?	1055.?	576.	17253.?
MATERIAL $	4834.?	4735.?	5475.	3470.	549.	477.	787.	1307.	1231.	23035.
SALES TAX	293.	234.	328.	203.	33.	29.	47.	-78.	74.	1385.
INDIRECT	2025.	1620.	1834.	1632.-	642.	192.	371.	620.	317.	9254.
PROFIT	1115.	1036.	1142.	845.-	237.	136.	188.	313.	223.	5176.
BONDS	165.	149.	169.	125.	35.	16.	28.	46.	33.	765.
TOTAL $	12262.	11058.	12565.	9297.-	2605.	1165.	2069.	3448.	2453.	56932.

OVERAL TOTALS										
LABOR HRS	866.9	846.7	1355.1	235.9	131.4	108.5	138.5	284.6	319.6	4287.2
LABOR $	13540.	13173.	21340.	4021.-	2100.	1737.	2214.	4553.	5125.	67803.
MATERIAL $	19634.	23239.	38853.	5548.	2931.	3149.	3686.	8298.	11249.	116587.
SALES TAX	1178.	1374.	2331.	333.	176.	139.	221.	498.	675.	6995.
INDIRECT	7633.	7431.	11997.	2223.-	1219.	987.	1290.	2655.	2981.	38418.
PROFIT	4262.	4374.	7564.	1231.-	652.	612.	752.	1625.	2033.	23325.
BONDS	630.	679.	1118.	182.-	96.	90.	111.	240.	300.	3447.
TOTAL $	46877.	50536.	83203.	13537.-	7174.	6735.	8274.	17874.	22363.	256575.

ORIGINAL PAGE IS
OF POOR QUALITY

FIGURE C-5. COMPUTER COST MATRIX BASELINE

STEOR PIPE NETWORK MODIFIED FOR:

1. FLEXIBLE HOSE EXPANSION JOINTS
2. PREFABRICATED POST PIPE SUPPORTS

ORIGINAL PAGE IS OF POOR QUALITY

TEOR PIPE NETWORK STEAM SIDE COST SUMMARY.

NOM PIPE DIA	0.500	0.750	1.000	1.500	2.000	2.500	3.000	3.500	4.000	TOTAL
LENGTHS ST	882.	882.	1323.	60.	60.	60.	60.	120.	134.	
EXPANSION JOINTS	216.	216.	324.	12.	12.	12.	16.	32.	32.	
TOTAL	1098.	1098.	1647.	72.	72.	72.	76.	152.	166.	
PIPE COST										
LABOR HRS	39.8	39.8	61.5	3.5	3.8	4.7	8.3	19.1	23.9	204.4
LABOR $	675.	675.	1042.	59.	64.	80.	141.	324.	435.	3495.
MATERIAL $	1197.	1295.	2309.	157.	188.	267.	357.	860.	1136.	7760.
SALES TAX	72.	78.	139.	9.	11.	15.	21.	52.	68.	465.
INDIRECT	398.	398.	615.	35.	38.	47.	83.	191.	239.	2044.
PROFIT	238.	248.	417.	26.	31.	42.	61.	145.	188.	1396.
BONDS	35.	37.	62.	4.	5.	5.	9.	21.	28.	206.
TOTAL $	2615.	2731.	4583.	291.	336.	458.	666.	1593.	2053.	15335.
EXPANSION JOINTS #	18	18	27	1	1	1	1	2	2	71
LABOR HRS	18.0	18.0	27.0	1.5	1.5	1.5	1.5	2.0	2.0	73.0
LABOR $	305.	305.	458.	26.	26.	26.	26.	34.	34.	1240.
MATERIAL $	785.	785.	1177.	258.	258.	258.	258.	516.	516.	4811.
SALES TAX	47.	47.	71.	15.	15.	15.	15.	31.	31.	287.
INDIRECT	180.	180.	270.	15.	15.	15.	15.	20.	20.	730.
PROFIT	134.	134.	201.	32.	32.	32.	32.	61.	61.	718.
BONDS	20.	20.	30.	5.	5.	5.	5.	9.	9.	108.
TOTAL $	1471.	1471.	2206.	351.	351.	351.	351.	671.	671.	7893.
FIXTURES #	18	36	54	4	3	3	3	7	10	138
LABOR HRS	24.3	67.5	121.5	9.8	7.8	12.0	12.5	38.0	50.5	353.9
LABOR $	412.	1144.	2059.	165.	132.	203.	212.	644.	1325.	5997.
MATERIAL $	47.	106.	179.	13.	16.	17.	17.	43.	79.	517.
SALES TAX	3.	6.	11.	1.	1.	1.	1.	3.	5.	31.
INDIRECT	243.	675.	1215.	98.	78.	120.	125.	380.	535.	3539.
PROFIT	72.	196.	352.	28.	23.	35.	36.	109.	174.	1024.
BONDS	11.	29.	52.	4.	3.	5.	5.	16.	25.	151.
TOTAL $	787.	2156.	3867.	310.	253.	331.	395.	1194.	1913.	11259.
VALVES #	18	18	36	4	4	4	4	15	6	108
LABOR HRS	37.8	37.8	75.6	9.2	9.2	9.2	9.2	34.6	23.7	226.3
LABOR $	641.	641.	1282.	156.	156.	156.	156.	587.	432.	3837.
MATERIAL $	1544.	1544.	3088.	697.	697.	697.	697.	1394.	1938.	12346.
SALES TAX	93.	93.	185.	42.	42.	42.	42.	84.	119.	741.
INDIRECT	378.	378.	756.	92.	92.	92.	92.	166.	237.	2263.
PROFIT	270.	270.	539.	100.	100.	100.	100.	190.	279.	1967.
BONDS	40.	40.	80.	15.	15.	15.	15.	28.	41.	283.
TOTAL $	2965.	2965.	5930.	1102.	1102.	1102.	1102.	2089.	3056.	21422.
ANCHORS #	0	0	0	0	0	1	0	1	1	3
LABOR HRS	0.	0.	0.	0.	0.	1.0	0.	1.0	1.5	3.5
LABOR $	0.	0.	0.	0.	0.	17.	0.	17.	26.	60.
MATERIAL $	0.	0.	0.	0.	0.	22.	0.	22.	35.	79.
SALES TAX	0.	0.	0.	0.	0.	1.	0.	1.	2.	5.
INDIRECT	0.	0.	0.	0.	0.	10.	0.	10.	15.	35.
PROFIT	0.	0.	0.	0.	0.	5.	0.	5.	8.	18.
BONDS	0.	0.	0.	0.	0.	1.	0.	1.	1.	3.
TOTAL $	0.	0.	0.	0.	0.	56.	0.	56.	87.	200.
PIPE GUIDES #	36	36	72	2	2	2	2	3	4	159
LABOR HRS	112.0	112.0	168.0	7.6	9.2	9.2	11.2	15.8	22.8	458.6
LABOR $	1898.	1898.	2848.	125.	156.	156.	190.	285.	387.	7943.
MATERIAL $	2397.	2397.	4795.	134.	136.	141.	221.	496.	671.	11388.
SALES TAX	144.	144.	288.	8.	8.	8.	13.	30.	40.	683.

FIGURE C-5. COMPUTER COST MATR... BASELINE
STEOR PIPE NETWORK MODIFIED
FOR:

1. FLEXIBLE HOSE EXPANSION JOINTS
2. PREFABRICATED POST PIPE SUPPORTS

(CONTINUED)

SW11(04/01/81 OUT PAGE

INDIRECT	1120.	1120.	1680.	74.-	92.-	92.	112.	158.-	228.-	4585.
PROFIT	564.	564.	975.	35.-	40.	43.	54.	99.-	135.-	2537.
BONDS	83.	85.	144.	5.-	6.	5.	8.	15.-	20.-	371.-
TOTAL $	6206.	6206.	10730.	381.-	438.	444.	599.	1393.-	1481.-	27578.
FOUNDATIONS & FILLA	36	36	72	2	2	3	2	4	5	152
LABOR HRS	73.9	73.9	173.5	1.0	4.0	6.1	2.9	7.8	13.1	353.2
LABOR $	937.	937.	2201.	13.-	51.	77.	36.	99.-	129.-	4481.
MATERIAL $	551.	551.	1294.	3.-	30.	45.	21.	50.-	59.-	2523.
SALES TAX	33.	33.	78.	0.-	2.	3.	1.	3.-	4.-	157.
INDIRECT	436.	436.	1024.	6.-	24.	35.	17.	46.-	50.-	2084.
PROFIT	199.	199.	467.	3.-	11.	16.	8.	20.	27.	943.
BONDS	29.	29.	69.	0.-	2.	2.	1.	3.	4.-	140.
TOTAL $	2165.	2135.	5132.	31.-	119.	179.	85.	221.-	293.-	10431.
INSULATION										
LABOR HRS	117.1	117.1	174.6	7.9	13.2	13.2	13.2	26.4	29.5	512.2
LABOR $	1054.	1054.	1572.	71.-	118.	118.	118.	238.	255.-	4603.-
MATERIAL $	4684.	4684.	14495.	737.-	794.	933.	944.	2344.-	3511.-	33225.
SALES TAX	281.	281.	870.	44.-	48.	56.	57.	141.-	217.	1994.
INDIRECT	632.	632.	943.	43.-	71.	71.	71.	143.-	159.-	2765.
PROFIT	675.	675.	1815.	91.-	105.	120.	121.	291.-	432.	4323.-
BONDS	100.	100.	268.	13.-	15.	18.	18.	43.-	54.-	639.-
TOTAL $	7426.	7426.	19963.	999.-	1151.-	1315.	1329.	3199.-	4767.-	47555.-
INSPECTION										
LABOR HRS	79.2	45.0	94.5	11.0	3.5	3.5	5.0	8.0	9.0	258.7
LABOR $	1342.	762.	1601.	186.-	59.	59.	84.	136.-	153.-	4382.
MATERIAL $	134.	76.	160.	19.-	6.	6.	8.	14.-	15.-	433.-
SALES TAX	8.	5.	10.	1.-	0.	0.	0.	1.-	1.-	25.
INDIRECT	792.	450.	945.	110.-	35.-	35.	50.	80.-	90.-	2587.
PROFIT	231.	131.	276.	32.-	10.	10.	14.	23.-	26.-	754.-
BONDS	34.	19.	41.	5.-	2.	2.	2.	3.-	4.-	111.
TOTAL $	2541.	1443.	3032.	353.-	112.	112.	159.	258.-	289.-	8299.

STEAM SIDE TOTALS

LABOR HRS	502.1	511.1	896.2	51.3	52.2	60.4	63.8	133.7	133.3	2453.8
LABOR $	7204.	7416.	13063.	802.-	762.	892.	963.	2324.-	2326.-	36313.
MATERIAL $	11339.	11438.	27497.	2023.-	2125.	2335.	2517.	5739.-	8123.-	73185.
SALES TAX	680.	686.	1650.	121.-	128.	143.	151.	344.-	487.-	4391.
INDIRECT	4179.	4269.	7447.	473.-	445.	518.	565.	1183.-	1653.-	20733.
PROFIT	2381.	241[illegible]	5040.	347.-	351.	430.	426.	943.-	1328.-	13634.
BONDS	352.	357.	745.	51.-	52.	59.	63.	139.-	196.-	2015.
TOTAL $	26196.	26584.	55443.	3817.-	3863.	4393.	4686.	13374.-	14511.-	149972.-

WATER SIDE SUMMARY

NOM PIPE DIA	0.125	0.250	0.375	0.500	0.750	1.000	1.250	1.500	2.000	
LENGTHS ST	882.	832.	882.	441.-	60.	53.	120.	180.-	74.-	
PIPE COST										
LABOR HRS	39.8	39.8	39.8	19.8	2.7	2.9	6.3	10.4	4.5	156.0
LABOR $	675.	675.	675.	336.-	46.	49.	107.	176.-	31.	2820.
MATERIAL $	750.	828.	1013.	598.-	88.	135.	261.	471.-	232.-	4345.-
SALES TAX	45.	50.	61.	36.-	5.	5.	16.	28.-	14.-	261.
INDIRECT	398.	398.	398.	198.-	27.	29.	63.	104.	45.-	1660.
PROFIT	190.	198.	213.	119.-	17.	19.	45.	79.-	38.	922.
BONDS	28.	29.	32.	18.-	2.	3.	7.	12.-	6.	136.
TOTAL $	2086.	2178.	2397.	1304.-	186.	211.	499.	870.-	415.-	13145.

9950-663

133

S#116ST 04/01/81 OUT PAGE 333

FIGURE C-5. COMPUTER COST MATRIX

BASELINE STEOR PIPE

NETWORK MODIFIED FOR:

1. FLEXIBLE HOSE EXPANSION JOINTS
2. PREFABRICATED POST PIPE SUPPORTS

(CONTINUED)

FIXTURES #	18	18	18	18	2	3	7	13	3	97
LABOR HRS	21.6	13.5	13.5	13.5	6.0	6.8	16.4	24.3	7.2	122.8
LABOR $	366.	229.	229.	229.	102.	115.	278.	412.	122.	2382.
MATERIAL $	29.	27.	28.	30.	7.	13.	22.	38.	11.	202.
SALES TAX	2.	2.	2.	2.	0.	1.	1.	2.	1.	12.
INDIRECT	216.	135.	135.	135.	60.	58.	164.	243.	72.	1223.
PROFIT	62.	40.	40.	40.	17.	23.	47.	71.	21.	353.
BONDS	9.	6.	6.	6.	3.	3.	7.	10.	3.	53.
TOTAL $	684.	438.	440.	442.	189.	216.	520.	776.	230.	3935.
VALVES #	18	18	18	18	2	2	4	6	4	90
LABOR HRS	32.4	32.4	32.4	32.4	4.2	4.2	8.4	12.6	9.9	168.9
LABOR $	549.	549.	549.	549.	71.	71.	142.	214.	158.	2862.
MATERIAL $	813.	813.	813.	813.	90.	93.	180.	270.	435.	4233.
SALES TAX	49.	49.	49.	49.	5.	5.	11.	16.	24.	257.
INDIRECT	324.	324.	324.	324.	42.	42.	84.	126.	99.	1689.
PROFIT	176.	176.	176.	176.	21.	21.	42.	64.	71.	923.
BONDS	26.	26.	26.	26.	3.	3.	6.	9.	10.	136.
TOTAL $	1937.	1937.	1937.	1937.	233.	233.	465.	599.	779.	10155.
ANCHORS #	18	18	18	18	1	1	2	3	1	83
LABOR HRS	5.4	5.4	5.4	5.4	0.5	0.5	1.0	1.5	0.5	25.6
LABOR $	91.	91.	91.	91.	8.	8.	17.	25.	8.	433.
MATERIAL $	90.	90.	90.	90.	14.	14.	28.	42.	15.	473.
SALES TAX	5.	5.	5.	5.	1.	1.	2.	3.	1.	23.
INDIRECT	54.	54.	54.	54.	5.	5.	10.	15.	5.	256.
PROFIT	24.	24.	24.	24.	3.	3.	6.	9.	3.	121.
BONDS	4.	4.	4.	4.	0.	0.	1.	1.	0.	13.
TOTAL $	268.	268.	268.	268.	31.	31.	63.	94.	32.	1325.
PIPE GUIDES #	72	72	72	72	4	2	4	6	2	306
LABOR HRS	36.0	36.0	50.4	50.4	4.0	2.0	2.4	9.0	3.4	193.6
LABOR $	610.	610.	954.	954.	68.	34.	41.	152.	51.	3474.
MATERIAL $	632.	632.	632.	632.	36.	18.	56.	62.	22.	2722.
SALES TAX	38.	38.	38.	38.	2.	1.	3.	4.	1.	153.
INDIRECT	360.	360.	504.	504.	40.	20.	24.	90.	34.	1935.
PROFIT	166.	166.	216.	216.	15.	7.	13.	31.	11.	842.
BONDS	25.	25.	32.	32.	2.	1.	2.	5.	2.	124.
TOTAL $	1831.	1831.	2376.	2376.	163.	32.	139.	344.	121.	9262.
FOUNDATIONS & PILLA	36	36	36	36	2	2	0	0	0	148
LABOR HRS	77.3	77.3	110.9	24.4	4.4	5.0	4.5	9.2	10.1	324.2
LABOR $	1058.	1058.	1484.	386.	60.	81.	58.	117.	129.	4430.
MATERIAL $	1551.	1551.	1801.	1155.	87.	130.	34.	50.	59.	6437.
SALES TAX	93.	93.	108.	69.	5.	6.	2.	4.	4.	384.
INDIRECT	456.	456.	654.	144.	26.	36.	27.	54.	60.	1913.
PROFIT	321.	321.	411.	178.	18.	23.	12.	24.	27.	1333.
BONDS	47.	47.	61.	26.	3.	3.	2.	4.	4.	197.
TOTAL $	3526.	3526.	4519.	1958.	198.	243.	134.	262.	293.	14564.
INSPECTION										
LABOR HRS	37.8	5.4	7.2	28.3	45.0	1.0	1.0	1.3	2.8	130.3
LABOR $	640.	91.	122.	486.	762.	17.	17.	21.	48.	2205.
MATERIAL $	64.	9.	12.	49.	76.	2.	2.	2.	5.	221.
SALES TAX	4.	1.	1.	3.	5.	0.	0.	0.	0.	13.
INDIRECT	378.	54.	72.	288.	450.	13.	10.	13.	28.	1303.
PROFIT	110.	16.	21.	84.	131.	3.	3.	4.	8.	383.
BONDS	16.	2.	3.	12.	19.	0.	0.	1.	1.	55.
TOTAL $	1212.	173.	231.	924.	1443.	33.	33.	40.	91.	4179.

WATER SIDE TOTALS

4

S#11651 04/01/81 OUT PAGE 336

FIGURE C-5. COMPUTER COST MATRIX BASE-LINE STEOR PIPE NETWORK MODIFIED FOR:

1. FLEXIBLE HOSE EXPANSION JOINTS
2. PREFABRICATED POST PIPE SUPPORTS

(CONCLUDED)

LABOR HRS	250.3	209.8	259.6	174.7.	66.8	23.4	40.0	53.3	33.6	1131.6
LABOR $	3989.	3303.	4104.	3033.-	1117.	575.	660.	1117.-	537.-	18335.
MATERIAL $	3929.	3950.	4387.	3367.-	398.	339.	583.	945.	750.	18659.
SALES TAX	236.	237.	263.	202.-	24.	20.	35.	57.	46.-	1120.
INDIRECT	2186.	1731.	2141.	1647.-	650.	210.	382.	645.-	343.-	9985.
PROFIT	1049.	941.	1106.	837.-	222.	96.	168.	231.	178.-	4879.-
BONDS	155.	139.	163.	124.-	33.	14.	25.	41.	26.	721.-
TOTAL $	11544.	10351.	12167.	9210.-	2443.	1056.-	1852.	3336.-	1950.-	53557.-
OVERAL TOTALS										
LABOR HRS	752.4	720.9	1155.8	226.0	119.0	83.8	103.8	202.0	221.5	3585.2
LABOR $	11253.	10719.	17167.	3635.-	1879.	1257.	1623.	3141.-	3433.-	54317.
MATERIAL $	15268.	15338.	31886.	5390.-	2523.	2725.	3100.	6684.-	8330.	91844.
SALES TAX	916.	923.	1913.	323.-	151.	156.	186.	431.-	333.-	5511.
INDIRECT	6365.	6050.	9589.	2120.-	1095.	723.	947.	1329.-	1975.-	33719.
PROFIT	3431.	3358.	6146.	1184.-	573.	436.	594.	1224.-	1536.-	18515.
BONDS	507.	496.	908.	175.-	85.	73.	88.	181.	223.-	2735.
TOTAL $	37740.	36935.	67610.	13027.-	6306.	5452.	6538.	13459.-	16571.	203639.

ORIGINAL PAGE IS OF POOR QUALITY

135

9950-663

APPENDIX D

COST DATA

APPENDIX D

COST DATA

9950-663

PIPE COSTS

138

QUOTATION

TUBESALES 2211 TUBEWAY • LOS ANGELES • CALIFORNIA • 90040 PHONE 723-7781

Date 2-17-81

FORD AEROSPACE AND COMMUNICATIONS CORP.
AERONUTRONIC DIV.
FORD ROAD, BLDG. 10, ROOM 295

NEWPORT BEACH, CALIFORNIA 92660

F.O.B. NEWPORT BEACH, CA

Terms SEE BELOW

ATTENTION: MR. J.E. MAYER

REFERENCE: 083305

We are pleased to quote as follows:

ITEM NO.	QUANTITY	DESCRIPTION	PRICE PER 100 FT	
		CD SMLS BLK PE ASTM-A-106 GR B		
1	9200'	17'/24' RL 3/8 SCH 40 675 X 091	97.08	120 DAYS
2	8200'	17'/24' RL 1/2 SCH40 840 X 109	112.85	A.R.O.
3				
		HF SMLS BLK PE ASTM-A-106 GR B		
	13,000'	17'/24' RL 3/4 SCH 40 1.050 X 113	128.98	"
4	3,000'	17'/24' RL 1 SCH 40 1.315 X 133	153.86	"
5	13,000'	17'/24' RL 1 1/4 SCH 40 1.660 X 140	189.18	"
6	700'	17'/24' RL 1 1/2 SCH 40 1.900 X 145	214.47	"
		SMLS BLK PE ASTM-A-53 GR B		
7	700'	17'/24' RL 2" SCH 40 2 3/8 X 154	238.48	"
8	700'	17'/24' RL 2 1/2 SCH 40 2 7/8 X 203	296.96	"
9	1000'	17'/24' RL 3" SCH 40 3 1/2 X 216	399.93	"
		SMLS BLK PE ASTM-A-106 GR B		
10	1500'	17'/24' RL 3 1/2 SCH 40 4 X 226	864.08	"
		DELIVERY WOULD BE MADE VIA OUR TUBESALES TRUCKS.		
		TERMS ITEMS 1 THRU 6 AND ITEM 10 1/2% 10/25TH ITEMS 7,8,9, 2% 10TH PROX.		
		PRICES FIRM EXCEPT IN THE EVENT OF PRICE INCREASE AT PRODUCING MILL LEVEL AND INCREASES IN FREIGHT RATES.		
		STOCK LISTS AVAILABLE ON REQUEST		

Prices quoted may be increased or decreased by changes in mill prices and freight rates.
Shipping schedule is based upon immediate placement of your order.
All materials offered from stock are subject to prior sale.
...ation is made in accordance with trade customs and practices printed on the reverse side.

SALES COPY TO:

TUBESALES

By DON NEWTON

139

9950-663

QUOTATION

ORIGINAL PAGE IS OF POOR QUALITY

TUBESALES. 2211 TUBEWAY • LOS ANGELES • CALIFORNIA • 90040 PHONE 723-7781

Date 2-17-81

FORD AEROSPACE AND COMMUNICATIONS CORP.
AERONUTRONIC DIV.
FORD ROAD, BLDG. 10, ROOM 295

NEWPORT BEACH, CALIFORNIA 92660

F.O.B. NEWPORT BEACH, CA

Terms SEE BELOW

ATTENTION: MR. J.E. MAYER

REFERENCE: 083305

We are pleased to quote as follows:

ITEM NO.	QUANTITY	DESCRIPTION	PRICE PER 100 FT.	
		CD SMLS BLK PE ASTM-A-106 GR B		
1	9200'	17'/24' RL 3/8 SCH 40 675 X 091	97.08	120 DAYS
2	8200'	17'/24' RL 1/2 SCH40 840 X 109	112.85	A.R.O.
3				
		HF SMLS BLK PE ASTM-A-106 GR B		
	13,000'	17'/24' RL 3/4 SCH 40 1.050 X 113	128.98	"
	3,000'	17'/24' RL 1 SCH 40 1.315 X 133	153.86	"
5	13,000'	17'/24' RL 1 1/4 SCH 40 1.660 X 140	189.18	"
6	700'	17'/24' RL 1 1/2 SCH 40 1.900 X 145	214.47	"
		SMLS BLK PE ASTM-A-53 GR B		
7	700'	17'/24' RL 2" SCH 40 2 3/8 X 154	238.48	"
8	700'	17'/24' RL 2 1/2 SCH 40 2 7/8 X 203	296.96	"
9	1000'	17'/24' RL 3" SCH 40 3 1/2 X 216	399.93	"
		SMLS BLK PE ASTM-A-106 GR B		
10	1500'	17'/24' RL 3 1/2 SCH 40 4 X 226	864.08	"
		DELIVERY WOULD BE MADE VIA OUR TUBESALES TRUCKS.		
		TERMS ITEMS 1 THRU 6 AND ITEM 10 1/2% 10/25TH ITEMS 7,8,9, 2% 10TH PROX.		
		PRICES FIRM EXCEPT IN THE EVENT OF PRICE INCREASE AT PRODUCING MILL LEVEL AND INCREASES IN FREIGHT RATES.		
		STOCK LISTS AVAILABLE ON REQUEST		

Prices quoted may be increased or decreased by changes in mill prices and freight rates.
Shipping schedule is based upon immediate placement of your order.
All materials offered from stock are subject to prior sale.
[illegible]ation is made in accordance with trade customs and practices printed on the reverse side.

SA[illegible] COPY TO:

TUBESALES.

By DON NEWTON

Ford Aerospace & Communications Corporation

REQUEST FOR QUOTATION

KIL[illegible]Y TUBESUPPLY CO.
57[illegible] S. Capitol Av.
City of Industry, CA 91749

ORIGINAL PAGE IS
OF POOR QUALITY

RECEIVED
1981 FEB 25 AM 10 44
PURCHASING DEPARTMENT

GENTLEMEN
PLEASE QUOTE YOUR PRICE LESS TRADE DISCOUNTS AND TERMS OF PAYMENT ON ITEMS LISTED BELOW
OMIT SALES AND USE TAX FROM YOUR PRICE BUT INCLUDE ALL OTHER APPLICABLE TAXES. SALES AND USE TAX STATUS AND THE RESPONSIBILITY FOR PAYMENT THEREOF WILL BE INDICATED ON THE PURCHASE ORDER
IF UNABLE TO FURNISH QUANTITY SPECIFIED PLEASE SHOW HEREON THE QUANTITY YOU CAN SUPPLY AND YOUR GUARANTEED DELIVERIES
PLEASE INSERT UNIT PRICE OPPOSITE EACH ITEM AND MAIL COPY PROPERLY SIGNED TO THIS COMPANY RETAINING BIDDERS COPY FOR YOUR REFERENCE

WHEN CORRESPONDING PLEASE REFER TO NO 083302

REPLY TO FORD AEROSPACE AND COMMUNICATIONS CORPORATION
AERONUTRONIC DIVISION
FORD ROAD
NEWPORT BEACH, CA 92660

YOUR BID SHOULD REACH US NO LATER THAN	PHONE	WRITTEN	ATTENTION	PHONE
		2-19-81	J.E. Mayer, Buyer	714-759-6486

REQUEST FOR QUOTATION IS ALSO SUBJECT TO CONDITIONS ON THE LISTED ATTACHMENTS: NONE

Bldg. 10, Rm. 295 — FACC PYMT TERMS Net 20th Prox — ARD-7110A

QUANTITY	U/M	DESCRIPTION	UNIT PRICE
		Seamless Carbon Steel Pipe per ASTM 106B — NOTE: PRICES ARE IN CFT.	
9200	ft	Schedule 80 - 3/8 inch Dia	122.75
6200	ft	Schedule 80 - 1/2 inch Dia	138.20
1200[illegible]	ft	Schedule 80 - 3/4 inch Dia	138.09
3000	ft	Schedule 80 - 1.00 inch Dia	199.33
1300	ft	Schedule 80 - 1-1/4 inch Dia	258.25
700	ft	Schedule 80 - 1-1/2 inch Dia	295.53
700	ft	Schedule 80 - 2.00 inch Dia	456.40
700	ft	Schedule 80 - 2-1/2 inch Dia	624.21
1000	ft	Schedule 80 - 3.00 inch Dia	703.87
1500	ft	Schedule 80 - 3-1/2 inch Dia	735.75

PLEASE CONTACT DAN EATON WHEN PLACING YOUR ORDER.
"PRICE IN EFFECT AT TIME OF SHIPMENT TO APPLY."

SPECIFY MAX. LENGTHS AND IDENTIFY POINTS OF QUANTITY, LENGTH AND DELIVERY PRICE BREAKS.

REQ. DEL.	QUOTE MUST BE VALID UNTIL	FOR FORD AEROSPACE AND COMMUNICATIONS CORPORATION	DATE
1[illegible]0 days ARO	90 days	BY J.E. Mayer (BUYER'S NAME)	2/10/81

FOLLOWING INFORMATION MUST BE FILLED IN — lengths and identify points of quantity, length

F.O.B.	TRANSPORTATION TERMS	FIRM NAME	
Delivered	Our Truck	KILSBY TUBESUPPLY COMPANY	[X] LARGE BUSINESS / [ ] SMALL BUSINESS
City of Industry	PROPOSED METHOD OF SHIPMENT: Our Truck	SIGNATURE OF AUTHORIZED COMPANY REPRESENTATIVE	DATE 2/19/81
Net 30 Days	YOUR BEST DELIVERY ARO: 90 Days	(Dan Eaton, Inside Sales Supervisor)	

RETURN THIS COPY TO AERONUTRONIC

9950-663

Ford Aerospace & Communications Corporation

REQUEST FOR QUOTATION

ORIGINAL PAGE IS OF POOR QUALITY

KILSBY TUBE SUPPLY CO.
?00 S. Capitol Av.
City of Industry, CA 91749

RECEIVED

1981 FEB 25 AM 10:44

PURCHASING DEPARTMENT

GENTLEMEN: PLEASE QUOTE YOUR PRICES, DISCOUNTS AND TERMS OF PAYMENT ON MATERIALS OR SERVICES LISTED BELOW. OMIT SALES AND USE TAX FROM YOUR PRICE BUT INCLUDE ALL OTHER APPLICABLE TAXES. EXCISE TAX STATUS AND THE RESPONSIBILITY FOR PAYMENT THEREOF WILL BE INDICATED ON THE PURCHASE ORDER.

IF UNABLE TO SUPPLY AMOUNT SPECIFIED PLEASE SHOW HEREON THE QUANTITY YOU CAN SUPPLY AND YOUR GUARANTEED DELIVERIES.

PLEASE INSERT UNIT PRICE OPPOSITE EACH ITEM AND MAIL COPY PROPERLY SIGNED TO THIS COMPANY RETAINING BIDDERS COPY FOR YOUR REFERENCE.

WHEN CORRESPONDING PLEASE REFER TO NO **083303**

REPLY TO: FORD AEROSPACE AND COMMUNICATIONS CORPORATION
AERONUTRONIC DIVISION
FORD ROAD
NEWPORT BEACH, CA 92660

ATTENTION: J. E. Mayer, Buyer — Bldg. 10, Rm. 295
PHONE: 714-759-6486

YOUR BID SHOULD REACH US NO LATER THAN | PHONE | WRITTEN: 2-19-81

REQUEST FOR QUOTATION IS ALSO SUBJECT TO CONDITIONS ON THE LISTED ATTACHMENTS: NONE

ARD 7110A

FACC PYMT TERMS
~~Net 20th Prox~~

QUANTITY	U/M	DESCRIPTION	UNIT PRICE
		Seamless Carbon Steel Pipe per ASTM 106B	
?200	ft	Schedule 40 - 3/8 inch Dia	105.41
?200	ft	Schedule 40 - 1/2 inch Dia — NOTE: PRICED IN CFT.	125.40
13000	ft	Schedule 40 - 3/4 inch Dia	136.83
5000	ft	Schedule 40 - 1.00 inch Dia	177.21
1300	ft	Schedule 40 - 1-1/4 inch Dia	222.00
700	ft	Schedule 40 - 1-1/2 inch Dia	245.00
700	ft	Schedule 40 - 2.00 inch Dia	343.42
700	ft	Schedule 40 - 2-1/2 inch Dia	490.15
1000	ft	Schedule 40 - 3.00 inch Dia	617.29
1500	ft	Schedule 40 - 3-1/2 inch Dia	742.16

PLEASE CONTACT DAN EATON WHEN PLACING YOUR ORDER.
"PRICE IN EFFECT AT TIME OF SHIPMENT TO APPLY."
SPECIFY MAX. LENGTHS AND IDENTIFY POINTS OF QUANTITY, LENGTH AND DELIVERY PRICE BREAKS

REQUIRED DELIVERY: 120 days ARO
QUOTE MUST BE VALID UNTIL: 90 days
FOR FORD AEROSPACE AND COMMUNICATIONS CORPORATION BY: [signature] (BUYER'S NAME) DATE 2/10/81

FOLLOWING INFORMATION MUST BE FILLED IN: lengths and quantity points of quantity length

	TRANSPORTATION TERMS	FIRM NAME	
Delivered	Our Truck	KILSBY TUBESUPPLY COMPANY	[X] LARGE BUSINESS [ ] SMALL BUSINESS
F.O.B. POINT: City of Industry	PROPOSED METHOD OF SHIPMENT: Our Truck	SIGNATURE OF AUTHORIZED COMPANY REPRESENTATIVE	DATE
TERMS: Net 30 Days	YOUR BEST DELIVERY ARO: 90 Days	[signature] (Dan Eaton, Inside Sales Supv.)	2/19/81

RETURN THIS COPY TO AERONUTRONIC

182

9950-663

PREMOLDED CALCIUM SILICATE PIPE INSULATION

143

ORIGINAL PAGE IS OF POOR QUALITY

9950-663

(213) 723-8561

INDASCO INC.

11966 RIVERA ROAD • SANTA FE SPRINGS, CALIFORNIA 90670

QUOTATION

PROJECT Pipe Insulation

TO Ford Aerospace
Ford Rd.
Newport Beach, CA 92660

DATE 2-13-81

QUOTATION No. 1700

TERMS Net 30 Days, No Retention Allowed.

F.O.B. Our Warehouse

DELIVERY See Below

ATTENTION

Ron Polziun

GENTLEMEN: THANK YOU FOR YOUR INQUIRY, WE ARE PLEASED TO SUBMIT THIS PROPOSAL FOR YOUR CONSIDERATION.

Owens-Corning Kaylo 10 calcium silicate pipe insulation. All prices in 36" lenghts.

Inside Dia.	Wall Thickness	Price per lin. ft. 2000 lf. or less	Price per lin. ft. 2000 lf. or greater	Price per lf. Alum. Jacket
1/2"	3"	$ 3.88	$ 3.60	$ .92
1/2"	3-1/2"	$ 6.47	$ 6.01	$ .97
3/4"	3-1/2"	$ 6.62	$ 6.15	$1.01
1"	3-1/2"	$ 9.11	$ 8.46	$1.05
1-1/4"	4"	$ 9.32	$ 8.66	$1.18
1-1/2"	4"	$10.05	$ 9.33	$1.19
2"	4"	$10.78	$10.01	$1.26
2-1/2"	4-1/2"	$12.64	$11.64	$1.51
3"	4-1/2"	$12.81	$11.89	$1.51
3-1/2"	5"	$16.11	$14.96	$1.64

Delivery: 2 to 3 weeks from receipt of order.

NOTE: Prices quoted are those in effect at the date shown on this quotation. Cost increases incurred from material manufacturers between quotation date and date of delivery will necessitate an increase in the price shown on this quotation.

Quoted by: Michael P. O'Rourke

THE TERMS AND CONDITIONS ON THE REVERSE SIDE OF THIS PAGE ARE A PART OF THIS QUOTATION

This Quotation is hereby accepted and this will serve as your ... to proceed.

ACCEPTED BY:

TITLE:

DATE:

The above prices
☐ Include Sales Tax
☒ For Resale — Excludes Sales Taxes

INDASCO, INC.

BY

MICHAEL T. O'ROURKE President

9950-663

PREFABRICATED OMEGA EXPANSION JOINT

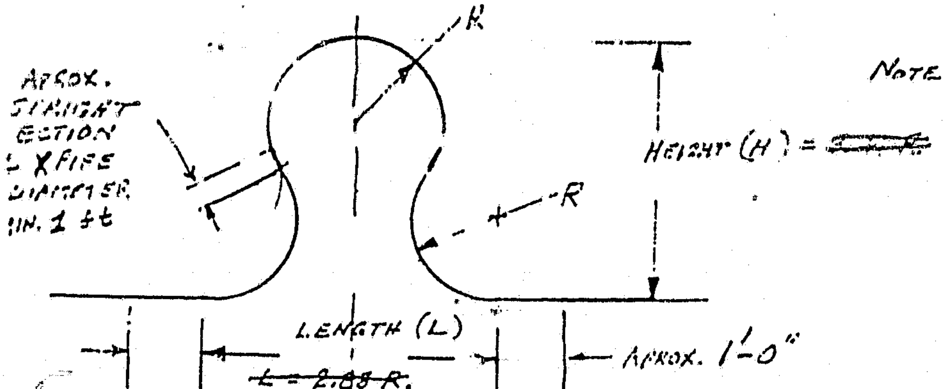
145

[illegible] 3/2/81

A[illegible] Pipe [illegible] & Fab. [illegible]
Huntington, [illegible]   Phone: [illegible] 531-8288
Mr Gary McCray

[illegible] Expansion Joint: (Carbon Stl. A106B; ASTM 106)
Cost for 100, 500, 1000 Joints ([illegible] Schedule 70 Pipe)

Nominal Pipe Size (inches)	Radius R (Ft.)	Length L (Ft.)	Height H (Ft.)	Pipe Length (Ft.)	Std. Length Pipe	Max Stress Ref. (PSI)	Load P (LBS)	Cost $/EA 100	Cost $/EA 500	Cost $/EA 1000
1/4	1.5			16.14	Assum can get lengths on order of mill runs	3108	1	$39 ea	$36 ea	$34
3/8	1.5			16.14		2500	1	48	39	37
1/2	2.0			20.95		2780	2.0	46	42	40
3/4	2.0			20.95		3477	4.6	67	62	60
1.0	2.25			24.00		3478	7.3	85	80	78
1 1/2	2.5			25.5		3434	19.9	101	95	92
2.0	2.75			28.0		3589	32.5	149	143	139
2 1/2	3.00			30.3		3691	56.8	224	215	211
3.0	3.25			33.4		3869	[illegible]	318	307	301
3 1/2	3.75			37.4		3389	172	424	411	400
4.0	4.00			40.8				541	525	516
5.0	4.50			46.0				880	862	853



Note: Prices based on current outlet suppliers prices per ft of pipe

~~L = 2.88 R.~~
L = 7.475 R, +2(4 x pipe dia)
(min of 1 ft on small sizes)

146

9950-663

PROTOTYPE INSTALLATION OF

RISER/DOWNCOMER ASSEMBLIES ON LCC

147

KFT

AZIMUTH: (FLEX HOSES)

FIELD LABOR $27/HR
SHOP LABOR $22.50/HR

INNER PINTLE:

		MATERIAL	LABOR
1.	CLAMP - BAND (2 HALVES)	2.00	4.75
2.	SUPPORT BRACKETS - BAND CLAMP ∠ 4×4×1/4×LG 6" (4 ea)	6.60	8.50
3.	∠ 4×6×5/16×LG. 120" (10.3#/FT.)	51.50	7.50
4	∠ 3×3×1/4×LG 120" (4.9#/FT.)	24.50	7.50
5	CLIP 2×4 1/2×1/4 (4 ea) $.32	1.28	1.00
6.	NUTS & BOLTS 3/8 DIA (13 ea) $.75 ea	9.75	~
7.	WELD ASSY	~	5.62
8	INSTALLATION	~	13.50
		$95.63	$48.37
	+10%	9.56	+20% 9.67
		$105.19	$58.00

OUTER SUPPORT RING:

		MATERIAL	LABOR
1.	∠ 4×6×5/16×LG. 122" (10.5#/FT.)	53.37	7.50
2.	∠ 3×4×1/4×LG. 122" (5.8#/FT.)	29.23	7.50
3.	∠ 2×3×1/4×LG 118" (4.1#/FT)	20.16	7.50
4	∠ CLIP 2 1/2×3×1/4×LG 5 1/2" (4.5#/FT) (8 ea)	9.00	5.60
5.	TEE HANGER (ST-3-B 4.25#/FT., LG. 23" (2 ea)	2.13	6.75
6.	TEE HANGER (ST-3-B 4.25#/FT.) LG 24" (2 ea)	2.13	6.75
7.	ANCHOR (POINT "C") WELDMENT	4.20	5.60
8.	ANCHOR (POINT "B") WELDMENT	4.20	5.60
9	NUTS & BOLTS 3/4 DIA (12 ea) $.75 ea	9.00	~
10.	"U" BOLTS 3/8 DIA (12 ea) $2.67 ea	32.00	~
11.	WELD ASSY	~	6.25
12.	INSTALLATION	~	15.60
		$165.67	$74.65
	+10%	16.56	+20% 14.93
		$182.23	$89.58

SUB TOTAL $287.42 $147.58

178

ORIGINAL PAGE IS
OF POOR QUALITY

3/17/81
NJT

ELEVATION: (FLEX HOSES)

FIELD LABOR $27.00/HR
SHOP LABOR $22.50/HR

TRUNNION - STEAM SIDE.

	MATERIAL	LABOR
1. ARM-CHANNEL 5 x 1 3/4 x 5/16 x LG 21" (6.7#/FT)	5.86	6.00
2. BRACKET-ANCHOR-WELDMENT	4.20	9.62
3. "U" BOLTS 3/8 DIA (2 ea) $2.67 ea	5.34	~
4 BOLTS 3/8 DIA (12 ea) $.75 ea	9.00	~
5. INSTALLATION	~	13.50
	$24.40	$29.12
TRUNNION - WATER SIDE (SAME AS ABOVE - STEAM SIDE)	$24.40	$29.12
	$48.80	$58.24
	+10% 4.88	+20% 16.65
SUB TOTAL	$53.68	$74.89

179

ORIGINAL PAGE IS
OF POOR QUALITY

3/17/81
R.G.

INTERMEDIATE LINES & CONNECTIONS:

STEAM LINE:

		MATERIAL	LABOR
1.	5/8 DIA TUBING FROM RECEIVER (LG. 369") $1.95/FT. TO ELEVATION TRUNNION	$ 59.96	135.00
2.	5/8 DIA TUBING FROM ELEVATION (LG. 284 + 203" = 487") TO AZIMUTH CENTER PINTLE	79.14	135.00
3.	WELD JOINTS (5 JOINTS)	~	67.50

WATER LINE:

4.	(SAME AS ABOVE STEAM LINE)	139.10	337.50
5.	CLAMP - INSULATION (STEAMLINE)		
	INSULATION BLOCK (EVERY 10 FT., 7 ea	$ 84.00	$ 38.94
	"U" BOLT (7 ea) $2.67 ea	18.69	37.20
6	"U" BOLT (WATER LINE) (7 ea)	18.69	39.20
	INSULATION (STEAM LINE, 71 FT @ 4.60/FT)	326.60	162.00
		$ 726.18	954.34
		+10% 72.61	+20% 190.87
	SUB TOTAL	$ 798.79	$ 1145.21
	TOTAL OF SUB TOTALS:	~~$ 1179.89~~ $ 1318 (1)	$ 1367.68
	FLEX HOSE ELEVATION (STEAM LINE)	915	
	FLEX HOSE ELEVATION (WATER LINE)	448	
	FLEX HOSE AZIMUTH (STEAM LINE)	1405.00	
	FLEX HOSE AZIMUTH (WATER LINE)	639.00	
	SUBTOTAL FLEX HOSE	3407	
	GRAND TOTAL	$ 4725	1367.68

TOTAL 6092

(1) CORRECTION:
21' 5/8 DIA INSULATED TUBING
BETWEEN PINTLE & OUTER RAIL
WATER SIDE #41
STEAM SIDE 138
179

D-14

150

9950-663

INSULATED FLEXIBLE HOSE ASSEMBLIES

FOR EXPANSION JOINT APPLICATION

151

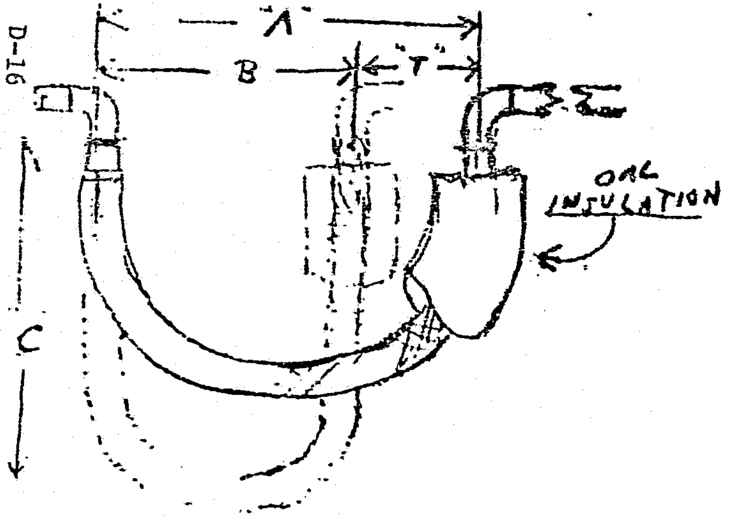
FORD AEROSPACE, AERONUTRONIC DIV. — ANACONDA — 12/81

TPR FIELD GEOMETRY, FLEXIBLE CONNECTIONS, STAINLESS STEEL WITH "DURABLANKET" INSULATION TAPED + CASED, WITH STEEL WELD NIPPLES EA END TO YOUR PIPE SIZES. 950 PSIG AT 600°F EXCEPT WHERE NOTED. PIPE RUNS = 60' BETWEEN ANCHORS

HOT SIDE

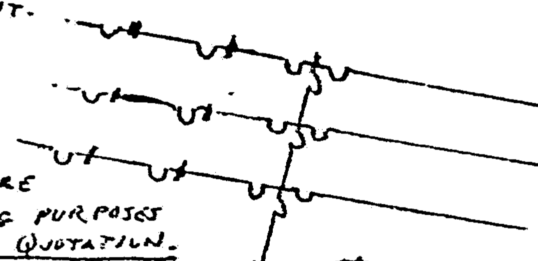
PIPE SIZE	HOSE ID & TYPE	OAL	PIPE GAP "A" COLD	TRAVEL "T"	PIPE GAP "B" HOT	LOOP HGT "C" HOT	EST. COST NET
FOR 1/2"	3/4" BW21-1H	44"	20.6"	3.6"	17"	15"	$122.50 EA (SUB STAINLESS NIPS, ADD $14.00)
FOR 3/4"	1" BW21-1H	46"	21.6"	3.6"	18"	16"	$144.60 EA (SUB STAINLESS NIPPLES ADD $16.00)
FOR 1"	1 1/4" BW21-2H	50"	23.6"	3.6"	20"	17.5"	$192.00 EA (SUB STAINLESS NIPPLES ADD $17.00)
HDR 1 1/2"	2" BWH-21-2	69"	32.6"	3.6"	29"	24"	$390.50 EA (SUB STAINLESS NIPPLES ADD $22.00)
HDR 2"	2 1/2" BWH21-2	76"	36"	3.6"	32.4"	27"	$497.40 EA (SUB STAINLESS NIPPLES ADD $46.00)
HDR 2 1/2"	3" BWH21-2	101"	49"	3.6"	45.4"	35"	$696.75 EA (SUB STAINLESS NIPPLES ADD $65.00)
HDR 3 1/2"	4" BWF W/SPEC. BR.*	116"	61"	3.6"	57.4"	44"	$1319.00 EA (SUB STAINLESS NIPPLES ADD $104.00)

* 850 PSI AT 600°F



NOTES: 1. HOSE ID'S JUMP ONE SIZE TO OFFSET PRESSURE DROP THROUGH LOOP.

2. LOOPS SHOULD BE LOCATED CLOSE TO AN ANCHOR POINT.



★ 3. ABOVE COSTS ARE FOR ESTIMATING PURPOSES AND ARE NOT A QUOTATION.

John [signature]

9950-663

153

2 of 2

: RD AEROSPACE, AERONUTRONIC ... ANACONDA 12/81

IPH FIELD GEOMETRY, COLD SIDE

FLEXIBLE CONNECTIONS, STAINLESS STEEL, NO INSULATION, STEEL WELD NIPPLES EACH END TO YOUR PIPE SIZES, 1000 PSIG AT 70°F EXCEPT WHERE NOTED. PIPE RUNS = 60' BETWEEN ANCHORS. HOSE IDs JUMPED ONE SIZE TO OFFSET ANY PRESSURE DROP THROUGH LOOP.

PIPE SIZE	HOSE ID & TYPE	OAL	PIPE GAP "A" COLD	TRAVEL "T" AT 140°F	PIPE GAP "B" HOT	LOOP HGT "C" HOT	EST. COST NET
FDR 1/4"	1/4" BW21-1	20"	8.5"	.5"	8"	6 1/4"	$34.20 EA
					(SUB STAINLESS NIPPLES, ADD $7.09)		
FDR 1/4"	3/8" BW21-1H	28"	12.5"	.5"	12"	9"	$43.70 EA
					(SUB STAINLESS NIPPLES, ADD $8.[illegible])		
FDR 3/8"	1/2" BW21-1H	35"	16.5"	.5"	16"	12"	$51.[illegible] EA
					(SUB STAINLESS NIPPLES, ADD $10.[illegible])		
FDR 1/2"	3/4" BW21-1H	38"	17.5"	.5"	17"	13"	$63.15 EA
					(SUB STAINLESS NIPPLES, ADD $12.[illegible])		
HDR 3/4"	1" BW21-1H	41"	18.5"	.5"	18"	14"	$74.30 EA
					(SUB STAINLESS NIPPLES, ADD $14.[illegible])		
HDR 1"	1 1/4" BW21-2H	45"	20.5"	.5"	20"	15"	$114.95 EA
					(SUB STAINLESS NIPPLES, ADD $16.[illegible])		
HDR 1 1/4"	1 1/2" BW21-2H	51"	22.5"	.5"	22"	16"	$154.80 EA
					(SUB STAINLESS NIPPLES, ADD $18.[illegible])		
HDR 1 1/2"	2" BWH21-2	64"	29.5"	.5"	29"	21"	$291.70 EA
					(SUB STAINLESS NIPPLES, ADD $20.[illegible])		
HDR 2"	2 1/2" BWH21-2*	71"	33"	.5"	32.5"	24"	$381.60 EA
					(SUB STAINLESS NIPPLES, ADD $45.[illegible])		

* 750 PSIG MAX OPERATING PRESSURE.

ORIGINAL PAGE IS OF POOR QUALITY

NOTES: 1. REFER TO SKETCH ON PG. #1

2. ABOVE COSTS ARE FOR ESTIMATING PURPOSES ONLY, AND ARE NOT A QUOTATION.

John Mitt[illegible]

9950-663

9950-663

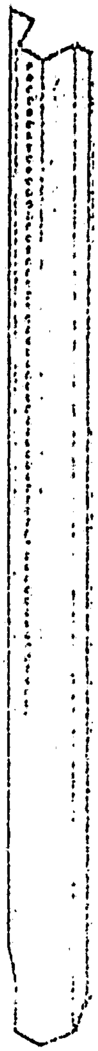
POSTS FOR PIPE SUPPORTS

154

ORIGINAL PAGE IS OF POOR QUALITY

SIGN POSTS AND ACCESSORIES

TRAFFIC SIGN POSTS



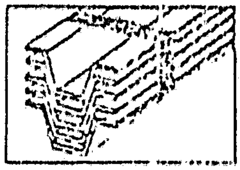
68-34-080

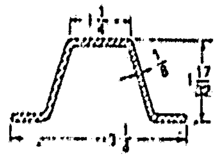
Sign Posts are manufactured from a rail steel flanged channel section. The design of this section makes it one of the strongest possible for use as Route Marker Posts and Highway Sign Posts. The use of rail steel in rolling this section gives it the high tensile strength desirable for this use.

Each of these posts is punched with sixty 3/8" hole on 1" centers beginning 1" from the top of the post.

In erecting — sign post should be driven 18" to 24" into ground for rigidity and stability.

Mounting of Traffic Signs — for commercial and business districts — The distance from the bottom of the sign to the ground should be 7 feet.

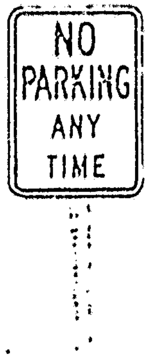




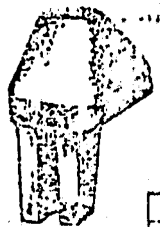
Sign Posts are to be used with Traffic Signs Pages 103-107.

Code No.	Length Feet	Weight Per Foot	*Price Ea., Per Post 5 Post	10 Over
68-34-080	8' 0"	2 lbs.	$13.75 ea.	$13.30 ea.
69-34-090	9' 0"	2 lbs.	15.10 ea.	14.65 ea.
70-34-100	10' 0"	2 lbs.	16.35 ea.	16.70 ea.

five



— Extra Heavy



51-85-012

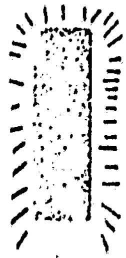
Speeds Up Installation
Prevents Marring the Post Ends. For Traffic Sign Series Posts, 68-34-080 thru 70-34-100 (Not for 66-34-006 posts)

Code No.	Price
51-85-012	$17.25 ea.

Code No.	Length Feet	*Price Ea., Per Post 5-Post	10-Over
66-34-006	6'	$8.75 ea.	$8.30 ea.

five

WT. PER FT. 1.12 Lbs.



Delineator Not Included With Post

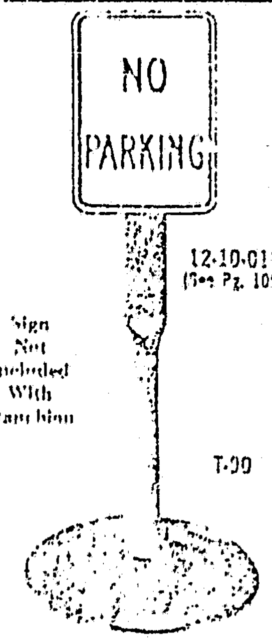
66-34-006

PORTABLE STANDARD

T-90 (Portable Traffic Stanchion)

No Rusting, Made of lifetime cast iron. (Not stamped metal) Overall height is 42", diameter of base is 15", approximate weight is 32 pounds. 12 x 18", 18 x 24" and Square 24" x 24" Traffic Signs Fit the T-90

Code No.	Description	Price Ea.
T-90	Portable Traffic Stanchion (without sign)	$73.95 ea.



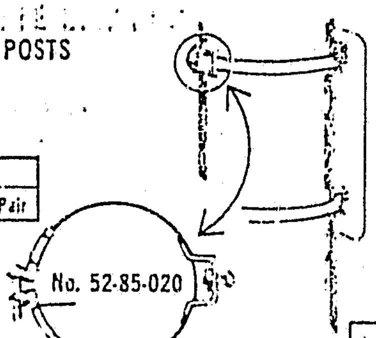
12-10-019 (See Pg. 105)

Sign Not Included With Stanchion

T-90

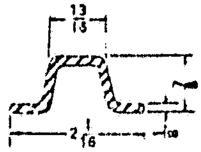
FOR WOOD OR STEEL POSTS

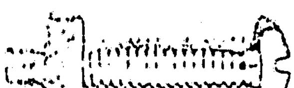
Code No.	Price
[illegible]	$12.55 Per Pair



No. 52-85-020

For Mounting of ... Listed ... Pages 103 to 107.





57-65-002

... of traffic signs on pages 103 thru 109 to Traffic Sign Posts 68-34-080 thru 70-34-100, also 66-34-006 Delineator posts. Each sign takes two bolts.

Code No.	Size	Material	Box of 50 Bolts and Nuts
[illegible]	[illegible] x 16"	Aluminum Bolts and Nuts	$22.35 Per Box

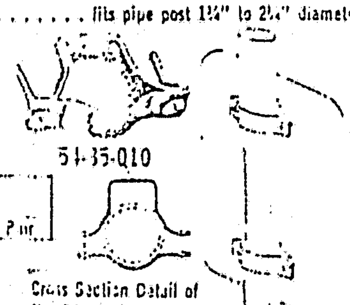
... fits pipe post 1¼" to 2¼" diameter

These pipe post brackets are designed to give a wide bearing surface for signs that are to be mounted on pipe posts.

No drilling is necessary and signs can be easily adjusted to desired position. Cadmium plated bolts are furnished with each bracket.

Code No.	Bracket Size	Outside Dia. of Post	Price
54-35-010	2"	1¼" x 2¼"	$12.75 Per Pair

54-35-010 Bracket is to be used for mounting of Traffic Signs Pages 103 to 107. Two Brackets required for each sign.



51-35-010

Cross Section Detail of No. 54-35-010 Bracket

Safety Sign Company
1055 WILSHIRE BLVD
LOS ANGELES, CALIFORNIA 90017
(213) 335 5522

155

9950-663

APPENDIX E

FACC NETWORK OPTIMIZATION COMPUTER

OUTPUT SHEETS AND INPUT DATA

156

APPENDIX E

FACC NETWORK OPTIMIZATION COMPUTER OUTPUT SHEETS AND INPUT DATA

9950-663

CONFIGURATION #7 - CH

E-1 FACC NETWORK OPTIMIZATION
BASELINE STEOR NETWORK 72 DISH FIELD
STEAM TEMPERATURE = 530°F
JPL CONVENTIONAL SCHEDULE 80 COST MODEL
COST OF ENERGY = 1500 $/$KW_T$


```
        H2O/STEAM      0.     $/LB
 SPACING     49.0     60.0 FT
 HEIGHT TO COLLECTOR      0.5 FT
# OF COLLECTORS  N-S   8 E-W   9
INSULATION COST 20.00 $/LB
MASS FLOW RATE PER UNIT  0.06 LB/SEC
SPECIFIC HEAT HOT 1.1500 COOL 1.0000 BTU/LB-DEG F
CONDUCTIVITY 0.6000 HOT 0.3100 COOL BTU IN/(FT**2-DEG F-HR)
SOURCE TEMPERATURE  550.0 DEG F   AMBIENT TEMP  100.0 DEG F
RETURN TEMPERATURE   70.0 DEG F
DENSITY   HOT 0.031  COOL 1.000  GM/CM3
VISCOSITY  HOT 0.011  COOL 0.010 STKS
CONVENTIONAL PIPING METHODS  SCHED80;
INSULATION 1.000 KW/M**2
COLLECTOR DIAM   12. M
COLLECTOR EFFICIENCY  0.6635
```

	INS	NUM	D IN	LENG FT	MASS UNITS	PCOST $	QTH KW	CQTH $	QF KW	CQF $	TOTAL KW	TOTAL E$	GRAND TOTAL $
COLLECTOR	3.40	72	0.500	51.	1	1309.42	0.95	1431.66	0.02	66.61	0.98	1498.27	2887.69
FDER S 1	3.35	18	0.500	1247.	1	33030.51	23.07	34603.97	0.56	1631.88	23.63	36235.85	70666.36
FDER S 2	3.52	18	0.750	1247.	2	35583.67	24.53	36795.77	0.88	2556.28	25.41	39352.04	74935.71
FDER S 3	3.71	18	1.000	1247.	3	37572.29	26.35	39530.64	0.77	2248.67	27.13	41779.31	79351.60
FDER S 4	3.71	18	1.000	624.	4	18003.07	13.17	19752.88	0.91	2644.93	14.08	22397.81	41200.88
HDER S 1	4.04	1	1.500	85.	8	2839.27	2.04	3066.66	0.09	269.57	2.14	3336.23	6175.50
HDER S 2	4.24	1	2.000	85.	16	3076.50	2.22	3327.41	0.19	555.22	2.41	3882.63	6959.12
HDER S 3	4.43	1	2.500	85.	24	3319.08	2.39	3589.16	0.25	723.62	2.64	4312.78	7631.86
HDER S 4	4.63	1	3.000	85.	32	3598.45	2.60	3898.43	0.18	536.76	2.78	4435.19	8033.64
HDER S 5	4.76	1	3.500	85.	40	3837.24	2.76	4133.62	0.17	482.05	2.92	4615.67	8452.91
HDER S 6	4.76	1	3.500	85.	48	3836.88	2.75	4131.64	0.28	829.13	3.04	4960.77	8797.65
HDER S 7	4.89	1	4.000	85.	56	4074.84	2.91	4358.28	0.23	672.20	3.14	5030.47	9105.31
HDER S 8	4.89	1	4.000	85.	64	4074.60	2.90	4356.97	0.34	1000.17	3.25	5357.14	9431.73
HDER S 9	4.89	1	4.000	14.	72	679.21	0.48	726.14	0.08	236.74	0.57	962.88	1642.09
						156515.02	109.14	163703.22	4.96	14453.82	114.10	178157.05	334672.07

COST OF FLUID   0.
INSULATION COST   43227.

TEMPERATURE AT STORE 529.6 DEG-F

	INS	NUM	D IN	LENG FT	MASS UNITS	PCOST $	QTH KW	CQTH $	QF KW	CQF $	TOTAL KW	TOTAL E$	GRAND TOTAL $
HDER S 2	0.	1	2.000	10.	72	240.00	0.	0.	0.00	6.51	0.00	6.51	246.51
HDER S 3	0.	1	2.000	60.	64	1440.00	0.	0.	0.01	27.78	0.01	27.78	1467.78
HDER S 4	0.	1	1.500	60.	56	1380.00	0.	0.	0.02	69.46	0.02	69.46	1449.46
HDER S 5	0.	1	1.500	60.	48	1380.00	0.	0.	0.02	44.34	0.02	44.34	1424.34
HDER S 6	0.	1	1.500	60.	40	1380.00	0.	0.	0.01	26.13	0.01	26.13	1406.13
HDER S 7	0.	1	1.250	60.	32	1350.00	0.	0.	0.01	30.85	0.01	30.85	1380.85
HDER S 8	0.	1	1.250	60.	24	1350.00	0.	0.	0.00	13.43	0.00	13.43	1363.43
HDER S 9	0.	1	1.000	60.	16	1320.00	0.	0.	0.01	18.01	0.01	18.01	1338.01
HDER S 10	0.	1	0.750	60.	8	1290.00	0.	0.	0.00	8.86	0.00	8.86	1298.86
FDER S 1	0.	18	0.500	441.	4	9261.00	0.	0.	0.01	41.96	0.01	41.96	9302.96
FDER S 2	0.	18	0.375	882.	3	18301.50	0.	0.	0.05	134.19	0.05	134.19	18435.69
FDER S 3	0.	18	0.250	882.	2	18081.00	0.	0.	0.08	233.74	0.08	233.74	18314.74
FDER S 4	0.	18	0.125	882.	1	17860.50	0.	0.	0.06	180.94	0.06	180.94	18041.45
COLLECTOR	0.	72	0.125	36.	1	729.00	0.	0.	0.00	7.39	0.00	7.39	736.39
						75363.00	0.	0.	0.29	843.58	0.29	843.58	76206.58

COST OF FLUID   0.
INSULATION COST   0.
SYSTEM DELIVERS   5284. KW AT A COST OF 70.53 $/KW

*

9950-663

ORIGINAL PAGE IS
OF POOR QUALITY

159

INPUT CONFIGURATION I? = C3

H2O/STEAM 0. $/LB
SPACING 49.0 60.0 FT
HEIGHT TO COLLECTOR 0.5 FT
OF COLLECTORS N-S 8 E-W 9
INSULATION COST 20.00 $/LB
MASS FLOW RATE PER UNIT 0.06 LB/SEC
SPECIFIC HEAT HOT 0.9700 COOL 1.0000 BTU/LB DEG F
CONDUCTIVITY 0.5300 HOT 0.3100 COOL BTU-IN/(FT**_-DEG F-HR)
SOURCE TEMPERATURE 510.0 DEG F AMBIENT TEMP 100.0 DEG F
RETURN TEMPERATURE 70.0 DEG F
DENSITY HOT 0.021 COOL 1.000 GM/CM3
VISCOSITY HOT 0.017 COOL 0.610 STKS
CONVENTIONAL PIPING METHODS SCH 80?
INSULATION 1.000 LB/FT**2
COLLECTOR HIGH 17. H
COLLECTOR EFFICIENCY 0.6635

E-2 FACC NETWORK OPTIMIZATION
ALTERNATE PROCESS TEMPERATURE
72 DISH NETWORK
STEAM TEMPERATURE = 489°F
JPL CONVENTIONAL SCHEDULE 80 COST MODEL
COST OF ENERGY = 1500 $/$KW_T$

	TPS	NUM	D IN	LENG FT	MASS UNITS	PCOST $	QH KW	CQH $	QI KW	CQI $	TOTAL KW	TOTAL E$	GRAND TOTAL $
COLLECTOR	3.15	72	0.500	51.	1	1344.64	0.79	1192.37	0.05	158.90	0.85	1351.27	2695.91
FDER S 1	3.08	18	0.500	1247.	1	32752.78	19.20	28798.19	1.34	3893.06	20.54	32691.25	65444.03
FDER S 2	3.40	18	1.000	1247.	2	36180.87	22.05	33073.01	0.55	1607.01	22.60	34680.02	70860.89
FDER S 3	3.40	18	1.000	1247.	3	36178.30	21.95	32927.29	1.84	5363.87	23.79	38291.16	74469.46
FDER S 4	3.60	18	1.250	624.	4	19174.95	11.93	17898.27	0.48	1388.99	12.41	19287.26	38462.21
HDER S 1	3.90	1	2.000	85.	8	2941.93	1.87	2798.20	0.06	168.69	1.92	2966.89	5908.82
HDER S 2	4.06	1	2.500	85.	16	3165.44	2.01	3015.19	0.18	516.76	2.19	3531.94	6697.38
HDER S 3	4.24	1	3.000	85.	24	3422.46	2.19	3279.30	0.19	544.24	2.37	3823.53	7245.99
HDER S 4	4.37	1	3.500	85.	32	3644.06	2.32	3480.83	0.20	592.16	2.52	4072.98	7717.04
HDER S 5	4.48	1	4.000	85.	40	3864.58	2.45	3676.33	0.20	589.50	2.65	[illegible]	8130.41
HDER S 6	4.48	1	4.000	85.	48	3864.24	2.45	[illegible]	0.35	1014.17	2.80	4688.68	8552.93
HDER S 7	4.48	1	4.000	85.	56	3863.81	2.45	[illegible]	0.55	1605.31	3.00	5278.00	9141.81
HDER S 8	4.60	1	5.000	85.	64	4613.81	2.72	4073.35	0.25	725.42	2.96	4798.77	9412.57
HDER S 9	4.68	1	5.000	14.	72	769.14	0.45	678.91	0.06	171.65	0.51	850.56	1619.70
						155701.02	94.83	142238.42	6.30	18339.73	101.12	160578.14	316359.16

COST OF FLUID 0.
INSULATION COST 40500.

TEMPERATURE AT STORE 408.7 DEG F

	TPS	NUM	D IN	LENG FT	MASS UNITS	PCOST $	QH KW	CQH $	QI KW	CQI $	TOTAL KW	TOTAL E$	GRAND TOTAL $
HDER S 2	0.	1	2.000	10.	72	240.00	0.	0.	0.00	6.87	0.00	6.87	246.87
HDER S 3	0.	1	2.000	60.	64	1440.00	0.	0.	0.01	29.28	0.01	29.28	1469.28
HDER S 4	0.	1	1.500	60.	56	1380.00	0.	0.	0.03	73.25	0.03	73.25	1453.25
HDER S 5	0.	1	1.500	60.	48	1380.00	0.	0.	0.02	46.76	0.02	46.76	1426.76
HDER S 6	0.	1	1.500	60.	40	1380.00	0.	0.	0.01	27.54	0.01	27.54	1407.54
HDER S 7	0.	1	1.250	60.	32	1350.00	0.	0.	0.01	32.53	0.01	32.53	1382.53
HDER S 8	0.	1	1.250	60.	24	1350.00	0.	0.	0.00	14.15	0.00	14.15	1364.15
HDER S 9	0.	1	1.000	60.	16	1320.00	0.	0.	0.01	10.99	0.01	10.99	1330.99
HDER S 10	0.	1	0.750	60.	8	1290.00	0.	0.	0.00	9.33	0.00	9.33	1299.31
FDER S 1	0.	18	0.500	441.	4	9261.00	0.	0.	0.02	44.21	0.02	43.21	9305.21
FDER S 2	0.	18	0.375	882.	3	10301.50	0.	0.	0.05	141.44	0.05	131.44	10442.94
FDER S 3	0.	18	0.250	882.	2	10081.00	0.	0.	0.08	246.45	0.08	246.45	10327.45
FDER S 4	0.	18	0.125	882.	1	17860.50	0.	0.	0.07	190.77	0.07	190.77	18051.27
COLLECTOR	0.	72	0.125	36.	1	229.00	0.	0.	0.00	7.79	0.00	7.79	236.79
						25361.00	0.	0.	0.31	889.36	0.31	889.36	26252.36

COST OF FLUID 0.
INSULATION COST 0.
SYSTEM DELIVERS 5295. KW AT A COST OF 74.76 $/KW

E-3 FACC NETWORK OPTIMIZATION
ALTERNATE PROCESS TEMPERATURE
72 DISH NETWORK
STEAM TEMPERATURE = 355°F
CONVENTIONAL SCHEDULE 80 COST MODEL
COST OF ENERGY = 1500 $/$KW_T$

H2O/STEAM 0 $/LB
SPACING 42.0 40.0 FT
HEIGHT TO COLLECTOR 0.5 FT
OF COLLECTORS 8 9
INSULATION COST 26.00 $/LB
MASS FLOW RATE PER UNIT 0.06 LB/SEC
SPECIFIC HEAT HOT 0.6300 COOL 1.0000 BTU/LB-DEG F
CONDUCTIVITY 0.4700 HOT 0.3100 COOL BTU-IN/(FT**2-DEG F HR)
SOURCE TEMPERATURE 380.0 DEG F AMBIENT TEMP 100.0 DEG F
RETURN TEMPERATURE 70.0 DEG F
DENSITY HOT 0.007 COOL 1.000 GM/CM3
VISCOSITY HOT 0.075 COOL 0.010 STKS
CONVENTIONAL PIPING METHODS SCHED80;
INSULATION 1.000 KW/M**2
COLLECTOR DIAM 12. M
COLLECTOR EFFICIENCY 0.6635

	INS	NUM	D IN	LENG FT	MASS UNITS	PCOST $	QTH KW	COTH $	QF KW	COF $	TOTAL KW	TOTAL E$	GRAND TOTAL $
COLLECTOR	2.86	72	1.000	51.	1	1304.63	0.61	919.17	0.03	74.55	0.64	993.73	2378.36
FDER S 1	2.78	18	1.000	1247.	1	33626.62	14.68	22013.24	0.63	1826.59	15.30	23839.83	57466.45
FDER S 2	2.93	18	1.250	1247.	2	35368.00	15.76	23645.58	1.08	3153.95	16.85	26799.53	62167.53
FDER S 3	3.01	18	1.500	1247.	3	36745.12	16.50	24754.64	1.57	4557.97	18.07	29312.61	66057.73
FDER S 4	3.18	18	2.000	624.	4	19765.97	9.04	13563.47	0.48	1409.47	9.53	14972.94	34738.91
HDER S 1	3.31	1	2.500	85.	8	2878.80	1.34	2006.90	0.20	585.70	1.54	2592.61	5471.40
HDER S 2	3.54	1	3.500	85.	16	3279.56	1.55	2326.74	0.23	671.38	1.78	2998.12	6277.67
HDER S 3	3.62	1	4.000	85.	24	3466.17	1.64	2460.23	0.39	1148.57	2.03	3609.80	7074.97
HDER S 4	3.78	1	5.000	85.	32	4145.87	1.83	2743.54	0.28	822.59	2.11	3565.13	7712.09
HDER S 5	3.91	1	6.000	85.	40	4824.92	2.01	3016.59	0.22	630.13	2.23	3646.72	8471.64
HDER S 6	3.91	1	6.000	85.	48	4824.23	2.01	3013.44	0.37	1081.92	2.38	4095.36	8919.59
HDER S 7	3.91	1	6.000	85.	56	4823.35	2.01	3009.91	0.59	1710.01	2.59	4719.92	9543.27
HDER S 8	4.10	1	8.000	85.	64	6155.92	2.34	3505.02	0.21	598.38	2.54	4103.40	10259.31
HDER S 9	4.10	1	8.000	14.	72	1026.32	0.39	584.10	0.05	141.35	0.44	725.46	1751.78
						162315.48	71.71	107562.58	6.32	18412.57	78.03	125975.14	288290.62

COST OF FLUID 0.
INSULATION COST 37573.

TEMPERATURE AT STORE 355.3 DEG F

	INS	NUM	D IN	LENG FT	MASS UNITS	PCOST $	QTH KW	COTH $	QF KW	COF $	TOTAL KW	TOTAL E$	GRAND TOTAL $
HDER S 2	0.	1	2.000	10.	72	240.00	0.	0.	0.00	6.97	0.00	6.97	246.97
HDER S 3	0.	1	2.000	60.	64	1440.00	0.	0.	0.01	29.73	0.01	29.73	1469.73
HDER S 4	0.	1	1.500	60.	56	1380.00	0.	0.	0.03	74.39	0.03	74.39	1454.38
HDER S 5	0.	1	1.500	60.	48	1380.00	0.	0.	0.02	47.48	0.02	47.48	1427.48
HDER S 6	0.	1	1.500	60.	40	1380.00	0.	0.	0.01	27.97	0.01	27.97	1407.97
HDER S 7	0.	1	1.250	60.	32	1350.00	0.	0.	0.01	33.03	0.01	33.03	1383.03
HDER S 8	0.	1	1.250	60.	24	1350.00	0.	0.	0.00	14.37	0.00	14.37	1364.37
HDER S 9	0.	1	1.000	60.	16	1320.00	0.	0.	0.01	19.28	0.01	19.28	1339.28
HDER S 10	0.	1	0.750	60.	8	1290.00	0.	0.	0.00	9.48	0.00	9.48	1299.48
FDER S 1	0.	18	0.500	441.	4	9261.00	0.	0.	0.02	41.89	0.02	41.89	9302.89
FDER S 2	0.	18	0.375	882.	3	18301.50	0.	0.	0.05	143.60	0.05	143.60	18445.10
FDER S 3	0.	18	0.250	882.	2	18081.00	0.	0.	0.09	250.24	0.09	250.24	18331.24
FDER S 4	0.	18	0.125	882.	1	17860.50	0.	0.	0.07	193.71	0.07	193.71	18054.21
COLLECTOR	0.	72	0.125	36.	1	729.00	0.	0.	0.00	7.91	0.00	7.91	736.91
						75363.00	0.	0.	0.31	903.03	0.31	903.03	76266.03

COST OF FLUID 0.
INSULATION COST 0.
SYSTEM DELIVERS 5318. KW AT A COST OF 60.93 $/KW

HUGE
$tern = 9.73 units
$tcost: $ 1.74 to date! $12310.25= 6%

160

IT CONFIGURATION #? = CL

E-4 FACC NETWORK OPTIMIZATION
LARGE PLANT SIZE 352 DISH FIELD
STEAM TEMPERATURE = 529 °F
JPL CONVENTIONAL SCHEDULE 80 COST MODEL
COST OF ENERGY = 1500 $/$KW_T$

H2O/STEAM 0. $/LB
SPACING 49.0 60.0 FT
HEIGHT TO COLLECTOR 0.5 FT
OF COLLECTORS N-S 16 E-W 22
INSULATION COST 20.00 $/LB
MASS FLOW RATE PER UNIT 0.06 LB/SEC
SPECIFIC HEAT HOT 1.1500 COOL 1.0000 BTU/LB-DEG F
CONDUCTIVITY 0.6000 HOT 0.3100 COOL BTU-IN/(FT**2-DEG F-HR)
SOURCE TEMPERATURE 550.0 DEG F AMBIENT TEMP 100.0 DEG F
RETURN TEMPERATURE 70.0 DEG F
DENSITY HOT 0.031 COOL 1.000 GM/CM3
VISCOSITY HOT 0.011 COOL 0.010 STKS
CONVENTIONAL PIPING METHODS SCHED80;
INSOLATION 1.000 KW/M**2
COLLECTOR DIAM 12. M
COLLECTOR EFFICIENCY 0.6635

	INS	NUM	D IN	LENG FT	MASS UNITS	PCOST $	QTH KW	CQTH $	QF KW	CQF $	TOTAL KW	TOTAL C$	GRAND TOTAL $
COLLECTOR	3.40	352	0.500	249.	1	6792.73	4.67	6999.25	0.11	325.64	4.78	7324.88	14117.61
FDER S 1	3.35	44	0.500	3049.	1	82696.80	56.39	84587.48	1.37	3989.04	57.76	88576.53	171273.33
FDER S 2	3.52	44	0.750	3049.	2	86982.30	59.96	89945.20	2.15	6248.68	62.11	96193.88	183176.18
FDER S 3	3.71	44	1.000	3049.	3	91843.37	64.42	96630.46	1.89	5496.74	66.31	102127.20	193970.58
FDER S 4	3.71	44	1.000	3049.	4	91832.11	64.26	96391.22	4.44	12930.75	68.70	109321.97	201154.07
FDER S 5	3.91	44	1.250	3049.	5	97533.40	69.64	104459.64	1.90	5529.88	71.54	109989.52	207522.92
FDER S 6	3.91	44	1.250	3049.	6	97521.04	69.55	104318.52	3.26	9504.86	72.81	113823.38	211344.42
FDER S 7	3.90	44	1.250	3049.	7	97512.13	69.48	104218.48	5.16	15034.98	74.64	119253.46	216765.58
FDER S 8	4.03	44	1.500	1525.	8	50968.62	36.52	54780.75	1.66	4843.30	38.18	59624.05	110592.67
HDER S 1	4.24	1	2.000	85.	16	3075.26	2.21	3322.41	0.19	555.22	2.41	3877.63	6952.88
HDER S 2	4.62	1	3.000	85.	32	3597.25	2.60	3894.15	0.18	536.76	2.78	4430.91	8028.16
HDER S 3	4.76	1	3.500	85.	48	3835.81	2.75	4127.96	0.28	829.13	3.04	4957.09	8792.90
HDER S 4	4.89	1	4.000	85.	64	4073.64	2.90	4353.80	0.34	1000.17	3.25	5353.97	9427.61
HDER S 5	5.11	1	5.000	85.	80	4858.63	3.21	4815.08	0.20	590.56	3.41	5405.64	10264.27
HDER S 6	5.11	1	5.000	85.	96	4858.35	3.21	4813.76	0.35	1015.69	3.56	5829.45	10687.80
HDER S 7	5.11	1	5.000	85.	112	4858.21	3.21	4812.80	0.55	1607.37	3.76	6420.17	11278.38
HDER S 8	5.30	1	6.000	85.	128	5641.21	3.50	5251.19	0.32	941.36	3.82	6192.55	11833.76
HDER S 9	5.30	1	6.000	85.	144	5641.02	3.50	5250.46	0.46	1336.55	3.96	6587.01	12228.03
HDER S 10	5.30	1	6.000	85.	160	5640.80	3.50	5249.80	0.63	1829.20	4.13	7079.01	12719.81
HDER S 11	5.30	1	6.000	85.	176	5640.53	3.50	5248.98	0.83	2430.07	4.33	7679.05	13319.58
HDER S 12	5.59	1	8.000	85.	192	7165.67	4.02	6033.82	0.25	737.11	4.28	6770.92	13936.60
HDER S 13	5.59	1	8.000	85.	208	7165.47	4.02	6033.25	0.32	935.08	4.34	6968.32	14133.79
HDER S 14	5.59	1	8.000	85.	224	7165.29	4.02	6032.70	0.40	1165.63	4.42	7198.33	14363.63
HDER S 15	5.59	1	8.000	85.	240	7165.14	4.02	6032.02	0.49	1431.26	4.51	7463.28	14628.42
HDER S 16	5.59	1	8.000	85.	256	7165.01	4.02	6031.58	0.60	1734.43	4.62	7766.02	14931.03
HDER S 17	5.59	1	8.000	85.	272	7165.12	4.02	6031.11	0.71	2077.64	4.73	8108.74	15273.87
HDER S 18	5.59	1	8.000	85.	288	7164.96	4.02	6030.38	0.85	2463.35	4.87	8493.74	15658.70
HDER S 19	5.59	1	8.000	85.	304	7165.28	4.02	6029.27	0.99	2894.06	5.01	8923.33	16088.61
HDER S 20	5.59	1	8.000	85.	320	7164.86	4.02	6029.02	1.16	3372.24	5.18	9401.26	16566.13
HDER S 21	5.83	1	10.000	85.	336	8726.07	4.55	6821.64	0.41	1206.92	4.96	8028.55	16754.63
HDER S 22	5.83	1	10.000	14.	352	1454.43	0.76	1137.06	0.08	231.00	0.84	1368.06	2822.49
						830070.50	570.48	855713.24	32.57	94824.67	603.04	950537.91	1780608.44

COST OF FLUID 0.
INSULATION COST 245559.

TEMPERATURE AT STORE 527.0 DEG-F

	INS	NUM	D IN	LENG FT	MASS UNITS	PCOST $	QTH KW	CQTH $	QF KW	CQF $	TOTAL KW	TOTAL C$	GRAND TOTAL $
HDER S 2	0.	1	4.000	10.	352	280.00	0.	0.	0.01	20.96	0.01	20.96	300.96
HDER S 3	0.	1	4.000	60.	336	1680.00	0.	0.	0.04	109.82	0.04	109.82	1789.82
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.	0.	0.03	95.27	0.03	95.27	1775.27

E-5

9950-663

HDER S	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
HDER S	[illegible]		1	4.000	60.	288	1680.00	0.	0.	0.02	70.12	0.02	70.12	1750.12
HDER S	7	0.	1	3.500	60.	272	1620.00	0.	0.	0.04	113.99	0.04	113.99	1733.99
HDER S	8	0.	1	3.500	60.	256	1620.00	0.	0.	0.03	95.52	0.03	95.52	1715.52
HDER S	9	0.	1	3.500	60.	240	1620.00	0.	0.	0.03	79.16	0.03	79.16	1699.16
HDER S	10	0.	1	3.500	60.	224	1620.00	0.	0.	0.02	64.77	0.02	64.77	1684.77
HDER S	11	0.	1	3.000	60.	208	1560.00	0.	0.	0.04	110.84	0.04	110.84	1670.84
HDER S	12	0.	1	3.000	60.	192	1560.00	0.	0.	0.03	87.77	0.03	87.77	1647.77
HDER S	13	0.	1	3.000	60.	176	1560.00	0.	0.	0.02	68.13	0.02	68.13	1628.13
HDER S	14	0.	1	3.000	60.	160	1560.00	0.	0.	0.02	51.65	0.02	51.65	1611.65
HDER S	15	0.	1	3.000	60.	144	1560.00	0.	0.	0.01	38.05	0.01	38.05	1598.05
HDER S	16	0.	1	2.500	60.	128	1500.00	0.	0.	0.03	83.19	0.03	83.19	1583.19
HDER S	17	0.	1	2.500	60.	112	1500.00	0.	0.	0.02	56.40	0.02	56.40	1556.40
HDER S	18	0.	1	2.000	60.	96	1440.00	0.	0.	0.03	90.26	0.03	90.26	1530.26
HDER S	19	0.	1	2.000	60.	80	1440.00	0.	0.	0.02	53.07	0.02	53.07	1493.07
HDER S	20	0.	1	2.000	60.	64	1440.00	0.	0.	0.01	27.78	0.01	27.78	1467.78
HDER S	21	0.	1	1.500	60.	48	1380.00	0.	0.	0.02	44.34	0.02	44.34	1424.34
HDER S	22	0.	1	1.250	60.	32	1350.00	0.	0.	0.01	30.85	0.01	30.85	1380.85
HDER S	23	0.	1	1.000	60.	16	1320.00	0.	0.	0.01	18.01	0.01	18.01	1338.01
FDER S	1	0.	44	0.750	1078.	8	23177.00	0.	0.	0.05	159.16	0.05	159.16	23336.16
FDER S	2	0.	44	0.500	2156.	7	45276.00	0.	0.	0.35	1033.61	0.35	1033.61	46309.61
FDER S	3	0.	44	0.500	2156.	6	45276.00	0.	0.	0.23	660.63	0.23	660.63	45936.63
FDER S	4	0.	44	0.500	2156.	5	45276.00	0.	0.	0.13	389.88	0.13	389.88	45665.88
FDER S	5	0.	44	0.500	2156.	4	45276.00	0.	0.	0.07	205.13	0.07	205.13	45481.13
FDER S	6	0.	44	0.375	2156.	3	44737.00	0.	0.	0.11	328.01	0.11	328.01	45065.01
FDER S	7	0.	44	0.250	2156.	2	44198.00	0.	0.	0.20	571.37	0.20	571.37	44769.37
FDER S	8	0.	44	0.125	2156.	1	43659.00	0.	0.	0.15	442.31	0.15	442.31	44101.31
COLLECTOR	0.		352	0.125	176.	1	3564.00	0.	0.	0.01	36.11	0.01	36.11	3600.11
							373089.00	0.	0.	1.83	5318.22	1.83	5318.22	378407.21

```
  COST OF FLUID     0.
 INSULATION COST       0.
 SYSTEM DELIVERS  25777. KW AT A COST OF 84.67 $/KW

*BYE
**cpu =      5.60 units
**cost:  $    1.04 to date:  $12328.63=  6%
**on at 10.499 - off at 10.661 on  03/20/81
```

$ 54.23/m²

E-6

CP DISCONNECTS

UNIT CONFIGURATION 17 - SD

H2O/STEAM 0. $/LB
SPACING 49.0 60.0 FT
HEIGHT TO COLLECTOR 0.5 FT
OF COLLECTORS N S 8 E-W 9
INSULATION COST 20.00 $/LB
MASS FLOW RATE PER UNIT 0.06 LB/SEC
SPECIFIC HEAT HOT 1.1500 COOL 1.0000 BTU/LB-DEG F
CONDUCTIVITY 0.6000 HOT 0.3100 COOL BTU-IN/(FT**2-DEG F-HR)
SOURCE TEMPERATURE 550.0 DEG F AMBIENT TEMP 100.0 DEG F
RETURN TEMPERATURE 70.0 DEG F
DENSITY HOT 0.031 COOL 1.000 GM/CM3
VISCOSITY HOT 0.011 COOL 0.010 STKS
ADVANCED PIPING METHODS SCHL80?
INSULATION 1.000 KG/M**2
COLLECTOR DIAM 12. M
COLLECTOR EFFICIENCY 0.6635

E-5 FACC NETWORK OPTIMIZATION
BASELINE STEOR NETWORK
72 DISH FIELD
STEAM TEMPERATURE = 529°F
JPL ADVANCED CONSTRUCTION COST MODEL
COST OF ENERGY = 1500 $/$KW_T$

ORIGINAL PAGE IS
OF POOR QUALITY

	INS	NUM	D IN	LENG FT	MASS UNITS	PCOST $	QTH KW	CQTH $	QF KW	CQF $	TOTAL KW	TOTAL E$	GRAND TOTAL $
COLLECTOR	3.40	72	0.500	51.	1	897.81	0.95	1431.66	0.02	66.61	0.98	1498.27	2396.08
FDER S 1	3.35	18	0.500	1247.	1	21785.92	23.07	34603.97	0.56	1631.88	23.63	36235.85	58021.77
FDER S 2	3.52	18	0.750	1247.	2	23129.79	24.53	36795.77	0.88	2556.28	25.41	39352.04	62481.84
FDER S 3	3.71	18	1.000	1247.	3	24709.13	26.35	39530.64	0.77	2248.67	27.13	41779.31	66488.44
FDER S 4	3.71	18	1.000	624.	4	12371.45	13.17	19752.88	0.91	2644.93	14.08	22397.81	34769.26
HDER S 1	4.04	1	1.500	85.	8	1908.54	2.04	3066.66	0.09	269.57	2.14	3336.23	5244.77
HDER S 2	4.24	1	2.000	85.	16	2090.06	2.22	3327.44	0.19	555.22	2.41	3882.66	5972.72
HDER S 3	4.43	1	2.500	85.	24	2276.97	2.39	3589.18	0.25	723.62	2.64	4312.80	6589.77
HDER S 4	4.63	1	3.000	85.	32	2500.66	2.60	3898.46	0.18	536.76	2.78	4435.22	6935.87
HDER S 5	4.76	1	3.500	85.	40	2683.66	2.76	4133.21	0.17	482.05	2.92	4615.26	7298.92
HDER S 6	4.76	1	3.500	85.	48	2683.31	2.75	4131.31	0.28	829.13	3.04	4960.44	7643.76
HDER S 7	4.89	1	4.000	85.	56	2874.98	2.91	4357.94	0.23	672.20	3.14	5030.14	7905.12
HDER S 8	4.89	1	4.000	85.	64	2874.52	2.90	4355.26	0.34	1000.17	3.25	5355.43	8230.95
HDER S 9	5.12	1	5.000	14.	72	562.66	0.51	803.29	0.02	71.97	0.56	875.27	1437.93
						103349.46	109.19	163778.67	4.91	14289.06	114.09	178067.73	281417.19

COST OF FLUID 0.
INSULATION COST 43280.

TEMPERATURE AT STORE 529.5 DEG F

	INS	NUM	D IN	LENG FT	MASS UNITS	PCOST $	QTH KW	CQTH $	QF KW	CQF $	TOTAL KW	TOTAL E$	GRAND TOTAL $
HDER S 2	0.	1	2.500	10.	72	127.19	0.	0.	0.00	2.62	0.00	2.62	129.80
HDER S 3	0.	1	2.000	60.	64	742.50	0.	0.	0.01	27.78	0.01	27.78	770.28
HDER S 4	0.	1	2.000	60.	56	742.50	0.	0.	0.01	18.88	0.01	18.88	761.38
HDER S 5	0.	1	2.000	60.	48	742.50	0.	0.	0.00	12.11	0.00	12.11	754.61
HDER S 6	0.	1	1.500	60.	40	721.87	0.	0.	0.01	26.13	0.01	26.13	748.00
HDER S 7	0.	1	1.500	60.	32	721.87	0.	0.	0.00	13.71	0.00	13.71	735.59
HDER S 8	0.	1	1.250	60.	24	711.56	0.	0.	0.00	13.43	0.00	13.43	724.99
HDER S 9	0.	1	1.250	60.	16	711.56	0.	0.	0.00	4.20	0.00	4.20	715.76
HDER S 10	0.	1	0.750	60.	8	690.94	0.	0.	0.00	8.86	0.00	8.86	699.80
FDER S 1	0.	18	0.500	441.	4	5002.59	0.	0.	0.01	41.96	0.01	41.96	5044.55
FDER S 2	0.	18	0.500	882.	3	10005.19	0.	0.	0.01	36.87	0.01	36.87	10042.06
FDER S 3	0.	18	0.375	882.	2	9929.39	0.	0.	0.01	41.93	0.01	41.93	9971.32
FDER S 4	0.	18	0.250	882.	1	9853.59	0.	0.	0.01	31.84	0.01	31.84	9885.44
COLLECTOR	0.	72	0.250	36.	1	402.19	0.	0.	0.00	1.30	0.00	1.30	403.39
						41105.45	0.	0.	0.10	281.62	0.10	281.62	41387.07

COST OF FLUID 0.
INSULATION COST 0.
SYSTEM DELIVERS 5204. KW AT A COST OF 61.05 $/KW

INPUT CONFIGURATION 17 - CB

H2O/STEAM 0. $/LB
SPACING 49.0 60.0 FT
HEIGHT TO COLLECTOR 0.5 FT
OF COLLECTORS N-S 8 E-W 9
INSULATION COST 20.00 $/LB
MASS FLOW RATE PER UNIT 0.06 LB/SEC
SPECIFIC HEAT HOT 1.1500 COOL 1.0000 BTU/LB-DEG F
CONDUCTIVITY 0.6000 HOT 0.3100 COOL BTU-IN/(FT**2-DEG F-HR)
SOURCE TEMPERATURE 550.0 DEG F AMBIENT TEMP 100.0 DEG F
RETURN TEMPERATURE 70.0 DEG F
DENSITY - HOT 0.031 COOL 1.000 GM/CM3
VISCOSITY HOT 0.011 COOL 0.010 STKS
CONVENTIONAL PIPING METHODS SCHED80;
INSOLATION 1.000 KW/M**2
COLLECTOR DIAM 12. M
COLLECTOR EFFICIENCY 0.6635

E-6 FACC NETWORK OPTIMIZATION
BASELINE STEOR NETWORK 72 DISH FIELD
STEAM TEMPERATURE = 530 $^{\circ}$F
JPL CONVENTIONAL SCHEDULE 80 COST MODEL
COST OF ENERGY = 500 \$/KW_T

ORIGINAL PAGE IS OF POOR QUALITY

	INS	NUM	D IN	LENG FT	MASS UNITS	PCOST $	QTH KW	CQTH $	QF KW	CQF $	TOTAL KW	TOTAL E$	GRAND TOTAL $
COLLECTOR	2.12	72	0.375	51.	1	1187.72	1.06	531.01	0.09	85.35	1.15	616.36	1804.08
FDER S 1	2.08	18	0.375	1247.	1	29005.81	25.64	12821.18	2.15	2090.96	27.80	14912.14	43917.95
FDER S 2	2.30	18	0.750	1247.	2	31009.30	29.59	14796.33	0.88	852.09	30.47	15648.42	46657.72
FDER S 3	2.30	18	0.750	1247.	3	31008.01	29.46	14727.55	2.94	2849.22	32.39	17576.77	48584.77
FDER S 4	2.42	18	1.000	624.	4	16188.70	16.03	8014.24	0.91	881.34	16.94	8895.88	25084.58
HDER S 1	2.55	1	1.250	85.	8	2307.72	2.39	1197.22	0.21	207.58	2.61	1404.80	3712.53
HDER S 2	2.76	1	2.000	85.	16	2561.64	2.78	1391.30	0.19	185.07	2.97	1576.37	4138.01
HDER S 3	2.88	1	2.500	85.	24	2733.93	3.04	1517.54	0.25	241.21	3.28	1758.75	4492.68
HDER S 4	3.00	1	3.000	85.	32	2927.34	3.34	1668.59	0.16	178.92	3.52	1847.51	4774.85
HDER S 5	3.00	1	3.000	85.	40	2927.06	3.33	1667.20	0.36	347.63	3.69	2014.83	4941.89
HDER S 6	3.08	1	3.500	85.	48	3098.38	3.57	1783.14	0.28	276.38	3.85	2059.51	5157.90
HDER S 7	3.08	1	3.500	85.	56	3098.21	3.56	1782.28	0.45	437.40	4.02	2219.69	5317.89
HDER S 8	3.15	1	4.000	85.	64	3269.39	3.79	1895.04	0.34	333.39	4.13	2228.43	5497.82
HDER S 9	3.15	1	4.000	14.	72	544.95	0.63	315.87	0.08	78.91	0.71	394.79	939.74
						131868.16	128.22	64108.49	9.32	9045.75	137.54	73154.24	205022.40

COST OF FLUID 0.
INSULATION COST 19740.

TEMPERATURE AT STORE 525.4 DEG-F

	INS	NUM	D IN	LENG FT	MASS UNITS	PCOST $	QTH KW	CQTH $	QF KW	CQF $	TOTAL KW	TOTAL E$	GRAND TOTAL $
HDER S 2	0.	1	1.500	10.	72	230.00	0.	0.	0.01	8.04	0.01	8.04	238.04
HDER S 3	0.	1	1.500	60.	64	1380.00	0.	0.	0.04	34.19	0.04	34.19	1414.19
HDER S 4	0.	1	1.250	60.	56	1350.00	0.	0.	0.05	52.62	0.05	52.62	1402.62
HDER S 5	0.	1	1.250	60.	48	1350.00	0.	0.	0.03	33.50	0.03	33.50	1383.50
HDER S 6	0.	1	1.250	60.	40	1350.00	0.	0.	0.02	19.68	0.02	19.68	1369.68
HDER S 7	0.	1	1.250	60.	32	1350.00	0.	0.	0.01	10.28	0.01	10.28	1360.28
HDER S 8	0.	1	1.000	60.	24	1320.00	0.	0.	0.02	19.50	0.02	19.50	1339.50
HDER S 9	0.	1	0.750	60.	16	1290.00	0.	0.	0.02	22.06	0.02	22.06	1312.06
HDER S 10	0.	1	0.500	60.	8	1260.00	0.	0.	0.01	14.15	0.01	14.15	1274.15
FDER S 1	0.	18	0.375	441.	4	9150.75	0.	0.	0.05	51.43	0.05	51.43	9202.18
FDER S 2	0.	18	0.250	882.	3	18081.00	0.	0.	0.26	254.03	0.26	254.03	18335.03
FDER S 3	0.	18	0.250	882.	2	18081.00	0.	0.	0.08	77.91	0.08	77.91	18158.91
FDER S 4	0.	18	0.125	882.	1	17860.50	0.	0.	0.06	60.31	0.06	60.31	17920.81
COLLECTOR	0.	72	0.125	36.	1	729.00	0.	0.	0.00	2.46	0.00	2.46	731.46
						74782.25	0.	0.	0.68	660.18	0.68	660.18	75442.43

COST OF FLUID 0.
INSULATION COST 0.
SYSTEM DELIVERS 5255. KW AT A COST OF 53.76 $/KW
CAPITAL COST/KW = 39.32 CAPITAL COST/MSQ = 25.38

*FRN

INPUT IGURATION #7 - C3

E-7 FACC NETWORK OPTIMIZATION
ALTERNATE PROCESS TEMPERATURE
72 DISH NETWORK
STEAM TEMPERATURE = 489°F
JPL CONVENTIONAL SCHEDULE 80 COST MODEL
COST OF ENERGY = 500 $/$KW_T$

H20/STEAM 0. $/LB
SPACING 47.0 60.0 FT
HEIGHT TO COLLECTOR 0.5 FT
OF COLLECTORS N-S 0 E W 9
INSULATION COST 20.00 $/LB
MASS FLOW RATE PER UNIT 0.06 LB/SEC
SPECIFIC HEAT HOT 0.9700 COOL 1.0000 BTU/LB-DEG F
CONDUCTIVITY 0.5300 HOT 0.3100 COOL BTU-IN/(FT**2-DEG F-HR)
SOURCE TEMPERATURE 510.0 DEG F AMBIENT TEMP 100.0 DEG F
RETURN TEMPERATURE 70.0 DEG F
DENSITY HOT 0.021 COOL 1.000 GM/CM3
VISCOSITY HOT 0.012 COOL 0.010 STKS
CONVENTIONAL PIPING METHODS SCHED80;
INSOLATION 1.000 KW/M**2
COLLECTOR DIAM 12. M
COLLECTOR EFFICIENCY 0.6635

ORIGINAL PAGE IS OF POOR QUALITY

	INS	NUM	D IN	LENG FT	MASS UNITS	PCOST $	QTH KW	COTH $	QF KW	CQF $	TOTAL KW	TOTAL E$	GRAND TOTAL $
COLLECTOR	2.05	72	0.500	51.	1	1200.46	0.96	478.88	0.05	52.97	1.01	531.85	1732.31
FDER S 1	2.01	18	0.500	1247.	1	29306.74	23.09	11544.13	1.34	1297.69	24.43	12841.81	42148.55
FDER S 2	2.11	18	0.750	1247.	2	30447.20	24.72	12361.38	2.10	2033.97	26.82	14395.35	44842.55
FDER S 3	2.22	18	1.000	1247.	3	31709.16	26.84	13420.25	1.84	1787.96	28.68	15208.21	46917.37
FDER S 4	2.34	18	1.250	624.	4	16587.43	14.77	7386.64	0.48	463.00	15.25	7849.64	24437.07
HDER S 1	2.41	1	1.500	85.	8	2337.14	2.13	1064.97	0.22	214.47	2.35	1279.44	3616.58
HDER S 2	2.53	1	2.000	85.	16	2495.89	2.34	1170.98	0.46	442.24	2.80	1613.23	4109.11
HDER S 3	2.74	1	3.000	85.	24	2840.23	2.83	1412.73	0.19	181.41	3.01	1594.14	4434.37
HDER S 4	2.74	1	3.000	85.	32	2839.85	2.82	1410.86	0.44	427.26	3.26	1838.12	4677.97
HDER S 5	2.82	1	3.500	85.	40	3001.84	3.02	1511.31	0.40	383.54	3.42	1894.85	4896.69
HDER S 6	2.88	1	4.000	85.	48	3163.25	3.22	1609.60	0.35	338.06	3.57	1947.66	5110.90
HDER S 7	2.88	1	4.000	85.	56	3163.03	3.22	1608.78	0.55	535.10	3.77	2143.88	5306.91
HDER S 8	2.88	1	4.000	85.	64	3162.80	3.22	1607.82	0.82	796.81	4.04	2404.63	5567.43
HDER S 9	2.88	1	4.000	14.	72	527.25	0.54	267.90	0.19	190.73	0.73	456.63	983.87
						132782.26	113.71	56056.23	9.42	9143.19	123.13	65999.42	198781.69

COST OF FLUID 0.
INSULATION COST 19012.

TEMPERATURE AT STORE 404.3 DEG-F

	INS	NUM	D IN	LENG FT	MASS UNITS	PCOST $	QTH KW	COTH $	QF KW	CQF $	TOTAL KW	TOTAL E$	GRAND TOTAL $
HDER S 2	0.	1	1.500	10.	72	230.00	0.	0.	0.01	8.49	0.01	8.49	238.49
HDER S 3	0.	1	1.500	60.	64	1380.00	0.	0.	0.04	36.06	0.04	36.06	1416.06
HDER S 4	0.	1	1.500	60.	56	1380.00	0.	0.	0.03	24.42	0.03	24.42	1404.42
HDER S 5	0.	1	1.250	60.	48	1350.00	0.	0.	[illegible]	35.34	0.04	35.34	1385.34
HDER S 6	0.	1	1.250	60.	40	1350.00	0.	0.	0.02	20.75	0.02	20.75	1370.75
HDER S 7	0.	1	1.250	60.	32	1350.00	0.	0.	0.01	10.84	0.01	10.84	1360.84
HDER S 8	0.	1	1.000	60.	24	1320.00	0.	0.	0.02	20.56	0.02	20.56	1340.56
HDER S 9	0.	1	0.750	60.	16	1290.00	0.	0.	0.02	23.27	0.02	23.27	1313.27
HDER S 10	0.	1	0.500	60.	8	1260.00	0.	0.	0.02	14.92	0.02	14.92	1274.92
FDER S 1	0.	18	0.375	441.	4	9150.75	0.	0.	0.06	54.23	0.06	54.23	9204.98
FDER S 2	0.	18	0.375	882.	3	18301.50	0.	0.	0.05	47.15	0.05	47.15	18348.65
FDER S 3	0.	18	0.250	882.	2	18081.00	0.	0.	0.08	82.15	0.08	82.15	18163.15
FDER S 4	0.	18	0.125	882.	1	17860.50	0.	0.	0.07	63.59	0.07	63.59	17924.09
COLLECTOR	0.	72	0.125	36.	1	729.00	0.	0.	0.00	2.60	0.00	2.60	731.60
						75032.75	0.	0.	0.46	444.36	0.46	444.36	75477.11

COST OF FLUID 0.
INSULATION COST 0.
SYSTEM DELIVERS 5270. KW AT A COST OF 52.36 $/KW
CAPITAL COST/KW = 39.43 CAPITAL COST/MSQ = 25.52

#END

9950-663

INPUT CONFIGURATION #Y = C4

E-8 FACC NETWORK OPTIMIZATION
ALTERNATE PROCESS TEMPERATURE
72 DISH NETWORK
STEAM TEMPERATURE = 355°F
CONVENTIONAL SCHEDULE 80 COST MODEL
COST OF ENERGY = 500 $/KW$_T$

ORIGINAL PAGE IS
OF POOR QUALITY

D/STEAM 0. $/LB
SPACING 49.0 60.0 FT
HEIGHT TO COLLECTOR 0.5 FT
OF COLLECTORS N-S 8 E-W 9
INSULATION COST 20.00 $/LB
MASS FLOW RATE PER UNIT 0.06 LB/SEC
SPECIFIC HEAT HOT 0.6300 COOL 1.0000 BTU/LB-DEG F
CONDUCTIVITY 0.4700 HOT 0.3100 COOL BTU-IN/(FT**2-DEG F-HR)
SOURCE TEMPERATURE 300.0 F AMBIENT TEMP 100.0 DEG F
RETURN TEMPERATURE 70.0 F
DENSITY HOT 0.007 COOL 1.000 GM/CM3
VISCOSITY HOT 0.025 COOL 0.010 STKS
CONVENTIONAL PIPING METHODS SCHED80?
INSOLATION 1.000 KW/M**2
COLLECTOR DIAM 12. M
COLLECTOR EFFICIENCY 0.6635

	INS	NUM	D IN	LENG FT	MASS UNITS	PCOST $	QTH KW	CQTH $	QF KW	CQF $	TOTAL KW	TOTAL E$	GRAND TOTAL $
COLLECTOR	1.78	72	0.750	51.	1	1206.06	0.69	347.49	0.10	93.97	0.79	441.45	1647.51
FDER S 1	1.72	18	0.750	1247.	1	29410.82	16.61	8306.06	2.37	2302.23	18.98	10608.29	40019.11
FDER S 2	1.90	18	1.250	1247.	2	31735.89	19.73	9863.33	1.08	1051.32	20.81	10914.65	42650.54
FDER S 3	1.95	18	1.500	1247.	3	32775.23	20.80	10400.80	1.57	1519.32	22.37	11920.12	44695.36
FDER S 4	1.96	18	1.500	624.	4	16402.14	10.38	5189.67	1.84	1784.44	12.22	6974.11	23376.25
HDER S 1	2.13	1	2.500	85.	8	2516.39	1.73	866.10	0.20	195.23	1.93	1061.34	3577.73
HDER S 2	2.26	1	3.500	85.	16	2816.26	2.05	1026.21	0.23	223.79	2.28	1250.00	4066.26
HDER S 3	2.31	1	4.000	85.	24	2958.85	2.19	1093.49	0.39	382.85	2.58	1476.35	4435.20
HDER S 4	2.31	1	4.000	85.	32	2957.77	2.18	1090.41	0.93	900.77	3.11	1991.18	4948.96
HDER S 5	2.39	1	5.000	85.	40	3543.87	2.47	1236.33	0.55	531.87	3.02	1768.20	5312.07
HDER S 6	2.39	1	5.000	85.	48	3543.87	2.47	1234.54	0.94	914.75	3.41	2149.29	5693.15
HDER S 7	2.46	1	6.000	85.	56	4129.88	2.75	1376.43	0.59	570.00	3.34	1946.43	6076.31
HDER S 8	2.46	1	6.000	85.	64	4129.47	2.75	1375.32	0.87	847.80	3.62	2223.12	6352.59
HDER S 9	2.46	1	6.000	14.	72	688.30	0.46	229.16	0.21	200.62	0.67	429.78	1118.08
						138814.80	87.27	43635.34	11.87	11518.97	99.14	55154.31	193969.11

COST OF FLUID 0.
INSULATION COST 17812.

TEMPERATURE AT STORE 349.9 DEG-F

	INS	NUM	D IN	LENG FT	MASS UNITS	PCOST $	QTH KW	CQTH $	QF KW	CQF $	TOTAL KW	TOTAL E$	GRAND TOTAL $
HDER S 2	0.	1	1.500	10.	72	230.00	0.	0.	0.01	8.62	0.01	8.62	238.62
HDER S 3	0.	1	1.500	60.	64	1380.00	0.	0.	0.04	36.62	0.04	36.62	1416.62
HDER S 4	0.	1	1.500	60.	56	1380.00	0.	0.	0.03	24.80	0.03	24.80	1404.79
HDER S 5	0.	1	1.250	60.	48	1350.00	0.	0.	0.04	35.89	0.04	35.89	1385.89
HDER S 6	0.	1	1.250	60.	40	1350.00	0.	0.	0.02	21.07	0.02	21.07	1371.07
HDER S 7	0.	1	1.250	60.	32	1350.00	0.	0.	0.01	11.01	0.01	11.01	1361.01
HDER S 8	0.	1	1.000	60.	24	1320.00	0.	0.	0.02	20.88	0.02	20.88	1340.88
HDER S 9	0.	1	0.750	60.	16	1290.00	0.	0.	0.02	23.63	0.02	23.63	1313.63
HDER S 10	0.	1	0.500	60.	8	1260.00	0.	0.	0.02	15.15	0.02	15.15	1275.15
FDER S 1	0.	18	0.375	441.	4	9150.75	0.	0.	0.06	55.06	0.06	55.06	9205.81
FDER S 2	0.	18	0.375	882.	3	18301.50	0.	0.	0.05	47.87	0.05	47.87	18349.37
FDER S 3	0.	18	0.250	882.	2	18081.00	0.	0.	0.09	83.41	0.09	83.41	18164.41
FDER S 4	0.	18	0.125	882.	1	17860.50	0.	0.	0.07	64.57	0.07	64.57	17925.07
COLLECTOR	0.	72	0.125	36.	1	729.00	0.	0.	0.00	2.64	0.00	2.64	731.64
						75032.75	0.	0.	0.46	451.21	0.46	451.21	75483.96

COST OF FLUID 0.
INSULATION COST 0.
SYSTEM DELIVERS 5292. KW AT A COST OF 51.14 $/KW
CAPITAL COST/KW = 40.41 CAPITAL COST/MSQ = 26.26

*FRN

INPUT IGURATION #7 = CL

E-9 FACC NETWORK OPTIMIZATION
LARGE PLANT SIZE 352 DISH FIELD
STEAM TEMPERATURE =529 °F
JPL CONVENTIONAL SCHEDULE 80 COST MODEL
COST OF ENERGY = 500 $/$KW_T$

H2O/STEAM 0. $/LB
SPACING 49.0 60.0 FT
HEIGHT TO COLLECTOR 0.5 FT
OF COLLECTORS N-S 16 E-W 22
INSULATION COST 20.00 $/LB
MASS FLOW RATE PER UNIT 0.06 LB/SEC
SPECIFIC HEAT HOT 1.1500 COOL 1.0000 BTU/LB-DEG F
CONDUCTIVITY 0.6000 HOT 0.3100 COOL BTU-IN/(FT**2-DEG F-HR)
SOURCE TEMPERATURE 550.0 DEG F AMBIENT TEMP 100.0 DEG F
RETURN TEMPERATURE 70.0 DEG F
DENSITY HOT 0.031 COOL 1.000 GM/CM3
VISCOSITY HOT 0.011 COOL 0.010 STKS
CONVENTIONAL PIPING METHODS SCHED80;
INSOLATION 1.000 KW/M**2
COLLECTOR DIAM 12. M
COLLECTOR EFFICIENCY 0.6635

		INS	NUM	D IN	LENG FT	MASS UNITS	PCOST $	QTH KW	CRTH $	QF KW	CQF $	TOTAL KW	TOTAL E$	GRAND TOTAL $
COLLECTOR		2.12	352	0.375	249.	1	5806.64	5.19	2596.06	0.43	417.24	5.62	3013.30	8819.94
FDER S	1	2.08	44	0.375	3049.	1	70903.08	62.68	31340.66	5.27	5111.24	67.95	36451.90	107354.99
FDER S	2	2.30	44	0.750	3049.	2	75800.51	72.34	36168.80	2.15	2082.89	74.48	38251.69	114052.20
FDER S	3	2.30	44	0.750	3049.	3	75797.35	72.00	36000.68	7.18	6964.75	79.18	42965.43	118762.78
FDER S	4	2.42	44	1.000	3049.	4	79091.58	78.20	39098.42	4.44	4310.25	82.64	43408.67	122500.24
FDER S	5	2.42	44	1.000	3049.	5	79087.37	78.05	39026.36	8.63	8379.27	86.69	47405.64	126493.01
FDER S	6	2.55	44	1.250	3049.	6	82859.35	85.58	42790.25	3.26	3168.29	88.84	45958.53	128817.89
FDER S	7	2.55	44	1.250	3049.	7	82852.54	85.47	42733.16	5.16	5011.66	90.63	47744.82	130597.36
FDER S	8	2.55	44	1.250	1525.	8	41440.66	42.74	21369.16	3.84	3729.47	46.58	25098.63	66539.30
HDER S	1	2.76	1	2.000	85.	16	2561.03	2.78	1389.22	0.19	185.07	2.97	1574.29	4135.32
HDER S	2	3.00	1	3.000	85.	32	2926.62	3.33	1666.45	0.18	178.92	3.52	1845.37	4771.99
HDER S	3	3.08	1	3.500	85.	48	3097.79	3.56	1781.42	0.28	276.38	3.85	2057.80	5155.58
HDER S	4	3.15	1	4.000	85.	64	3268.90	3.79	1893.69	0.34	333.39	4.13	2227.08	5495.98
HDER S	5	3.15	1	4.000	85.	80	3268.74	3.79	1892.80	0.67	648.17	4.45	2540.96	5809.71
HDER S	6	3.15	1	4.000	85.	96	3268.44	3.78	1892.09	1.15	1116.55	4.93	3008.64	6277.08
HDER S	7	3.28	1	5.000	85.	112	3913.48	4.25	2124.72	0.55	535.79	4.80	2660.51	6573.99
HDER S	8	3.28	1	5.000	85.	128	3913.36	4.25	2124.25	0.82	797.70	5.07	2921.95	6835.32
HDER S	9	3.28	1	5.000	85.	144	3913.42	4.25	2123.76	1.17	1133.46	5.42	3257.22	7170.64
HDER S	10	3.39	1	6.000	85.	160	4558.64	4.69	2347.10	0.63	609.73	5.32	2956.84	7515.47
HDER S	11	3.39	1	6.000	85.	176	4558.52	4.69	2346.73	0.83	810.02	5.53	3156.75	7715.27
HDER S	12	3.39	1	6.000	85.	192	4558.38	4.69	2346.46	1.08	1049.96	5.77	3396.41	7954.80
HDER S	13	3.39	1	6.000	85.	208	4558.18	4.69	2345.03	1.37	1333.12	6.07	3679.15	8237.33
HDER S	14	3.39	1	6.000	85.	224	4557.74	4.69	2345.91	1.71	1663.09	6.41	4009.00	8566.74
HDER S	15	3.39	1	6.000	85.	240	4557.76	4.69	2345.42	2.11	2043.44	6.80	4388.87	8946.63
HDER S	16	3.55	1	8.000	85.	256	5826.59	5.50	2750.97	0.60	578.14	6.10	3329.12	9155.71
HDER S	17	3.55	1	8.000	85.	272	5826.48	5.50	2750.67	0.71	692.55	6.21	3443.22	9269.70
HDER S	18	3.55	1	8.000	85.	288	5826.38	5.50	2750.39	0.85	821.12	6.35	3571.51	9397.89
HDER S	19	3.55	1	8.000	85.	304	5826.29	5.50	2750.14	0.99	964.69	6.49	3714.83	9541.12
HDER S	20	3.55	1	8.000	85.	320	5826.21	5.50	2749.96	1.16	1124.08	6.66	3874.04	9700.24
HDER S	21	3.55	1	8.000	85.	336	5825.61	5.50	2750.25	1.34	1300.13	6.84	4050.38	9875.99
HDER S	22	3.55	1	8.000	14.	352	970.98	0.92	450.38	0.26	248.94	1.17	707.32	1678.30
							607048.65	678.10	339050.36	59.37	57619.51	737.47	396669.86	1003718.50

COST OF FLUID 0.
INSULATION COST 113801.

TEMPERATURE AT STORE 523.1 DEG-F

HDER S	2	0.	1	3.500	10.	352	270.00	0.	0.	0.01	13.46	0.01	13.46	283.46
HDER S	3	0.	1	3.500	60.	336	1620.00	0.	0.	0.07	70.46	0.07	70.46	1690.46
HDER S	4	0.	1	3.500	60.	320	1620.00	0.	0.	0.06	61.00	0.06	61.00	1681.00
HDER S	5	0.	1	4.000	60.	304	1560.00	0.	0.	0.12	112.22	0.12	112.22	1672.22

ORIGINAL PAGE IS OF POOR QUALITY

HDER S	6	0.	1	3.000	60.	208	1560.00	0.	0.	0.10	95.75	0.10	95.75	1655.75
HDER S	7	0.	1	3.000	60.	272	1560.00	0.	0.	0.08	80.97	0.08	80.97	1640.97
HDER S	8	0.	1	3.000	60.	256	1560.00	0.	0.	0.07	67.80	0.07	67.80	1627.80
HDER S	9	0.	1	3.000	60.	240	1560.00	0.	0.	0.06	56.13	0.06	56.13	1616.13
HDER S	10	0.	1	3.000	60.	224	1560.00	0.	0.	0.05	45.87	0.05	45.87	1605.87
HDER S	11	0.	1	3.000	60.	208	1560.00	0.	0.	0.04	36.95	0.04	36.95	1596.95
HDER S	12	0.	1	3.000	60.	192	1560.00	0.	0.	0.03	29.26	0.03	29.26	1589.26
HDER S	13	0.	1	2.500	60.	176	1500.00	0.	0.	0.07	70.35	0.07	70.35	1570.35
HDER S	14	0.	1	2.500	60.	160	1500.00	0.	0.	0.05	53.21	0.05	53.21	1553.21
HDER S	15	0.	1	2.000	60.	144	1440.00	0.	0.	0.10	98.66	0.10	98.66	1538.66
HDER S	16	0.	1	2.000	60.	128	1440.00	0.	0.	0.07	69.82	0.07	69.82	1509.82
HDER S	17	0.	1	2.000	60.	112	1440.00	0.	0.	0.05	47.21	0.05	47.21	1487.21
HDER S	18	0.	1	2.000	60.	96	1440.00	0.	0.	0.03	30.09	0.03	30.09	1470.09
HDER S	19	0.	1	1.500	60.	80	1380.00	0.	0.	0.07	65.73	0.07	65.73	1445.73
HDER S	20	0.	1	1.500	60.	64	1380.00	0.	0.	0.04	34.19	0.04	34.19	1414.19
HDER S	21	0.	1	1.250	60.	48	1350.00	0.	0.	0.03	33.50	0.03	33.50	1383.50
HDER S	22	0.	1	1.250	60.	32	1350.00	0.	0.	0.01	10.28	0.01	10.28	1360.28
HDER S	23	0.	1	0.750	60.	16	1290.00	0.	0.	0.02	22.06	0.02	22.06	1312.06
FDER S	1	0.	44	0.500	1078.	8	22638.00	0.	0.	0.26	254.17	0.26	254.17	22892.17
FDER S	2	0.	44	0.500	2156.	7	45276.00	0.	0.	0.35	344.54	0.35	344.54	45620.54
FDER S	3	0.	44	0.500	2156.	6	45276.00	0.	0.	0.23	220.21	0.23	220.21	45496.21
FDER S	4	0.	44	0.375	2156.	5	44737.00	0.	0.	0.50	481.49	0.50	481.49	45218.49
FDER S	5	0.	44	0.375	2156.	4	44737.00	0.	0.	0.26	251.43	0.26	251.43	44988.43
FDER S	6	0.	44	0.250	2156.	3	44198.00	0.	0.	0.64	620.97	0.64	620.97	44818.97
FDER S	7	0.	44	0.250	2156.	2	44198.00	0.	0.	0.20	190.46	0.20	190.46	44388.46
FDER S	8	0.	44	0.125	2156.	1	43659.00	0.	0.	0.15	147.44	0.15	147.44	43806.44
COLLECTOR		0.	352	0.125	176.	1	3564.00	0.	0.	0.01	12.04	0.01	12.04	3576.04
							369783.00	0.	0.	3.84	3727.79	3.84	3727.79	373510.80

COST OF FLUID 0.
INSULATION COST 0.
SYSTEM DELIVERS 25613. KW AT A COST OF 57.38 $/KW
CAPITAL COST/KW = 41.26 CAPITAL COST/HSQ = 26.55

*BYE
**cpu = 24.09 units
**cost: $ 3.52 to date: $12333.59= 6%
**on at 14.252 - off at 14.741 on 03/23/81