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Denver, Colorado

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APPENDICES

SOLAR CENTRAL RECEIVER HYBRID POWER SYSTEM, PHASE I

MARTIN MARIETTA CORPORATION
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FOREWORD

This report is submitted by Martin Marietta Corporation to the Department of Energy in accordance with provisions of contract DE-AC03-78ET21038. This final technical report summarizes the work related to the conceptual design, cost and performance of the Solar Central Receiver Hybrid Power System, Phase I, which was performed during the period of October 1978 through August 1979. The report consists of the following volumes:

Volume I - Executive Summary;

Volume II - Conceptual Design;

Volume III - Appendices.

The contract was under the direction of Dr. S. Douglass Elliott, Jr. of the Department of Energy, San Francisco Operations Office, Oakland, California. Mr. Kirk Battleson of Sandia Laboratories, Livermore, California was the Technical Manager.

The efforts performed by the Martin Marietta team are as follows:

1) Martin Marietta	Program Management; System Design and Optimization, Interface Definition; Conceptual Design, Analysis and Optimization of the Heliostat Field and Receiver; System Economic Analysis
2) Badger Energy, Inc.	Conceptual Design, Analysis and Optimization of the High-Temperature Salt Subsystems
3) Gibbs & Hill, Inc.	Conceptual Design, Analysis and Optimization of the Electric Power Generation System (EPGS), Tower, and Nonsolar Support Facilities
4) Foster Wheller Development Corporation	Conceptual Design, Analysis and Optimization of the Nonsolar Energy Source
5) Arizona Public Service	Utility Engineering Review of System Design, Utilization and Economics; and Development of the Market Analysis

CONTENTS

APPENDIX A: PARAMETRIC SALT PIPING DATA

This appendix contains piping data generated by Badger Plants in support of the parametric analyses performed in Task 3. These data have been broken down into Table A-1, Piping Vs. Plant Size, and Table A-2, Module Piping. Each table details the length, pipe size, material, and required valves and fittings required for each plant size and module configuration. The piping in the Appendix includes the tower piping, piping through the collector field, and interconnecting piping to the plant.

Table A-1 provides the salt piping details for 581 MWth, 1162 MWth and 1743 MWth plant sizes. The plant configurations are 3-, 6- and 9- 193 MWth modules, respectively.

Table A-2 provides the salt piping details for module piping (tower piping and field piping through the collector field only) for 150, 300, 450 and 600 MWth module sizes.

Additional discussion and cost data is contained in Section 3.3, Volume II.

APPENDIX A

TABLE A-1 PIPING VS PLANT SIZE

This table provides details of pipe length, pipe size, fittings, valves and expansion loops required for a range of thermal rated plants from 581 MW_{th} to 1743 MW_{th}. The details provided are a result of rough plant layouts for each case and are limited to network piping, risers and downcomers and headers. Further discussion is contained in Section 3.3

581 MW_{th}

Horizontal Branch Lines:

316 Stainless Steel

2 x 1355' 12" sch 30
2440'
8 expansion loops x { 4 - 12" sch 30 els; 4 - 12' sch 30 flexible joints; 40'- 12" sch 30 }

3 x 6 12" sch 30 els
3 12" gate - 600# WNRTJ
3 12" PCV - 600# WNRTJ

Carbon Steel

2 x 1355' 12' sch 20
2440'
4 expansion loops x { 4 - 12" sch 20 els; 4 - 12" sch 20 flex. joints; 40'- 12" sch 20 }
3 x 5 12" sch 20 els
3 x 2 12" sch 20 "T_s"
3 x 3 12" 300# gates

Risers and Downcomers

316SS
3 x 270' - 12" sch 5S
3 x 200' - 12" sch 20
3 x 50' - 12" sch 30
3 expansion loops x { 4 - 12" sch 30 els; 4 - 12" sch 30 flex joints; 40'- 12" sch 30 }

Carbon Steel

3 x 220' - 14" sch 20
3 x 250' - 14" sch 40
3 x 50' - 14" sch 60
3 x 6 - 14" sch 60 els
3 x 2 - 14" sch 60 "T_s"

TABLE A-1 PIPING VS. PLANT SIZE (cont.)

$581MW_{th}$

Risers and Downcomers (continued)

C. S.

3 14" PCV 600#
3 x 2 - 14" check 600#
3 x 2 - 14" gate 600#

Headers

316SS

2 x 2300' 12" sch 5s
2 x 4 expansion loops x { 4 - 12" sch 5s els
4 - 12" sch 5s flexible joints
40'- 12" sch 5s }

C.S.

2 x 2300' 12 sch 20
2 x 2 expansion loops x { 4 - 12" sch 20 els
4 - 12" sch 20 flexible joints
40'- 12' sch 20 }

TABLE A-1 PIPING VS. PLANT SIZE (cont.)

1162MW_{th}

Horizontal Branch Lines

316 Stainless Steel

6 x 2300' - 12" sch 30 4 12" sch 30 els
6 x 4 expansion loops x 4 12" sch 30 flexible joint
6 x 6 - 12" sch 30 els 40' - 12" sch 30
6 x 1 - 12" gate 600# WNRTJ
6 x 1 - 12" PCV 600# WNRTJ

Carbon Steel

6 x 2300' - 12" sch 20 4 12" sch 20 els
6 x 2 expansion loops x 4 12" sch 20 flexible joints
6 x 5 - 12" sch 20 els 40' 12" sch 20
6 x 2 - 12" sch 20 "T_s"
6 x 3 - 12" 300# gate

Risers and Downcomers

316 Stainless Steel

6 x 270' - 12" sch 5s
6 x 200' - 12" sch 20
6 x 50' - 12" sch 30 4 12" sch 30 els
6 x 1 expansion loop x 4 12" 30 flexible joints
40'- 12" sch 30

Carbon Steel

6 x 220' - 14" sch 20
6 x 250' - 14" sch 40
6 x 50' - 14" sch 60
6 x 6 - 14" sch 60 els
6 x 2 - 14" sch 60 "Ts"
6 x 1 - 14" pcv 600#
6 x 1 - 14" check 600#
6 x 2 - 14" 600#gate

1162MW_{th}

Headers:

316SS

6325' 18" sch 10	4-18" sch 10 els
10 expansion loops x	4-18" sch 10 flexible joints
4 - 18" sch 10 "Ts"	40'-18" sch 10
4 - 18" x 12" sch 10 reducers	
1355' 24" sch 5s	4-24" sch 5s els
2 - expansion loops x	4-24" sch 5s flexible joints
2 - 24" sch 5s "Ts"	40'-24" 5s
2 - 24" x 12" 5s reducers	

C.S.

6325' 18" sch 10	4-18" sch 10 els
4 - expansion loops x	4-18" sch flexible joints
4-18" sch 10 "Ts"	40'-18" sch 10
4-18" x 12" sch 10 reducers	
1355' 24" sch 20	4-24" sch 20 els
1-expansion loop x	4-24" sch 20 flexible joints
2-24" sch 20 "Ts"	40'-24" sch 20
2-24" x 12' sch 20 reducers	

TABLE A-1 PIPING VS. PLANT SIZE (cont.)

$1743MW_{th}$

Risers and Downcomers

316SS

9 x 270' - 12" sch 5s
9 x 200' - 12" sch 20
9 x 50' - 12" sch 30
9 x 1 expansion loop x { 4 - 12" sch 30 els; 4 - 12" sch 30 flexible joints; 40'- 12" sch 30 }

C.S.

9 x 220' - 14" sch 20
9 x 250' - 14" sch 40
9 x 50' - 14" sch 60
9 x 6 - 14" sch 60 els
9 x 2 - 14" sch 60 "T$_s$"
9 x 1 - 14" pcv 600#
9 x 2 - 14" check 600#
9 x 2 - 14" gate 600#

Horizontal Branch Lines

316SS

5 x 1355' / 4 x 2440' 12" sch 30
26 expansion loops x { 4 - 12" sch 30 els; 4 - 12" sch 30 flexible joints; 40'- 12" sch 30 }
9 x 6 - 12" sch 30 els
9 x 1 - 12" gate 600# WNRTJ
9 x 1 - 12" pcv 600# WNRTJ

C. S.

5 x 1355' / 4 x 2440' 12" sch 20
13 expansion loops X { 4 - 12" sch 20 els; 4 - 12" sch 20 flexible joints; 40'- 12" sch 20 }
9 x 5 12" sch 20 els
9 x 2 12" sch 20 "T$_s$"
9 x 3 12" 300# gate

TABLE A-1 PIPING VS. PLANT SIZE (cont.)

Headers 1743MW_{th}

316SS

2 x 2300' 12" sch 30	4 - 12" sch 30 els
2 x 4 expansion loops	4 - 12" sch 30 flexible joints
2 x 2 18"x12" sch 30 reducers	40'- 12" sch 30
2 x 2300' 18" sch 10	4 - 18" sch 10 els
2 x 4 expansion loops	4 - 18" sch 10 flexible joints
2 x 1 18" sch 10 "T"	40'- 18" sch 10
2 x 2300' 20" sch 5s	4 - 20" sch 5s els
2 x 4 expansion loops	4 - 20" sch 5s flexible joints
2 x 1 20" sch 5s "T"	40'- 20" sch 5s
2 x 1 20" x 18" sch 5s reducer	
2 x 1 20" x 12" sch 5s reducer	
2 x 2300' - 24" sch 5s	4 - 24" sch 5s els
2 x 4 expansion loops	4 - 24" sch 5s flexible joints
2 x 1 - 24" x 20" sch 5s reducer	40'- 24" sch 5s
2 x 1 - 24" x 12" sch 5s reducer	

TABLE A-1 PIPING VS. PLANT SIZE (concluded)

$1743 MW_{th}$ Headers C.S.

C.S.

2 x 2300' 12" sch 20		4 - 12" sch 20 els
2 x 2 expansion loops	x	4 - 12" sch 20 flex joints
2 x 2-18"x12" sch 20 reducers		40'- 12" sch 20
2 x 2300' 18" sch 10		4 - 18" sch 10 els
2 x 2 expansion loops	x	4 - 18" sch 10 flex joints
2 x 1 18" sch 10 T		40'- 18" sch 10
2 x 2300' 20" sch 20		4 - 20" sch 20 els
2 x 2 expansion loops	x	4 - 20" sch 20 flex joints
2 x 1 20" sch 20 T		40'- 20" sch 20
2 x 1 20"x18" sch 20 reducer		
2 x 1 20"x12" sch 20 reducer		
2 x 2300' 24" sch 20		4 - 24" sch 20 els
2 x 2 expansion loops	x	4 - 24" sch 20 flex joints
2 x 1 24" sch 20 T		40'- 24" sch 20
2 x 1 24" x 20" sch 20 reducer		
2 x 1 24" x 12" sch 20 reducer		

TABLE A-2 MODULE PIPING

Summaries of piping, fittings, and valves are given for thermal ratings of 150, 300, 450 and 600 MW_{th} each for 1, 3, 6 and 9 collector modules. Each thermal rating is divided into vertical, horizontal fixed and horizontal variable piping and associated fittings, expansion loops and valves. Additional discussion is contained in Section 3.3.

150 MW_{th}

Vertical

Carbon Steel

200 ft 12" sch 40
200 ft 12" sch 20
1 el 12" sch 40
3 els 12" sch 20
1 exp loop x { 4 flexible joints 12" sch 20
4 els 12" sch 20
40 ft 12" sch 20 }

316 SS - (welded + x-ray)

200 ft 12" sch 30
200 ft 12" sch 10s
1 el 12" sch 30
3 els 12" sch 10s
1 exp loop x { 4 flexible joints 12" sch 10s
4 els 12" sch 10s
40 ft 12" sch 10s }

Horizontal - fixed

Carbon Steel

100 ft 12" sch 40
8 els 12" sch 40
2 "Ts" 12" sch 40
2 check valves 12" - 600#
2 gate valves 12" - 600#
1 PCV 12" - 600#

70 ft 12" sch 20
11 els 12" sch 20
2 "Ts" 12" sch 20
2 gate valves 12" - 300#

316 SS

170 ft 12" sch 10s
6 els 12" sch 10s
1 gate valve 12" - 300#
1 PCV 12" - 600#

TABLE A-2 MODULE PIPING (cont.)

150 MW_{th}

Horizontal - variable

1 module

Carbon Steel

890 ft 12" sch 20
1 exp loops @ { 40 ft 12" sch 20
4 els 12" sch 20
4 flexible joints 12" sch 20 }

316 SS

890 ft 12" sch 10s
1 exp loops @ { 40 ft 12" sch 10s
4 els 12" sch 10s
4 flexible joints 12" sch 10s }

3 modules

Carbon Steel

2 x 890 ft 12" sch 20
2 exp loops @ { 40 ft 12" sch 20
4 els 12" sch 20
4 flexible joints 12" sch 20 }

1 x 1640 ft 12" sch 20
1 exp loop @ { 40 ft 12" sch 20
4 els 12" sch 20
4 flexible joints 12" sch 20 }

316 SS

2 x 890 ft 12" sch 10s
2 exp loops @ { 40 ft 12" sch 10s
4 els 12" sch 10s
4 flexible joints 12" sch 10s }

1 x 1640 ft 12" sch 10s
2 exp loops @ { 40 ft 12" sch 10s
4 els 12" sch 10s
4 flexible joints 12" sch 10s }

TABLE A-2 MODULE PIPING (cont.)

150 MW_{th}

Horizontal - variable (continued)

6 modules

Carbon Steel

	6 x 1510 ft	12" sch 20		
6 exp loops @	40 ft	12" sch 20		
	4 els	12" sch 20		
	4 flexible joints		12" sch 20	

316 SS

	6 x 1510 ft	12" sch 10s	
12 exp loops @	40 ft	12" sch 10s	
	4 els	12" sch 10s	
	4 flexible joints		12" sch 10s

9 modules

Carbon Steel

	5 x 890 ft	12" sch 20	
5 exp loops @	40 ft	12" sch 20	
	4 els	12" sch 20	
	4 flexible joints		12" sch 20
	4 x 1640 ft	12" sch 20	
4 exp loops @	40 ft	12" sch 20	
	4 els	12" sch 20	
	4 flexible joints		12" sch 20

316 SS

	5 x 890 ft	12" sch 10s	
5 exp loops @	40 ft	12" sch 10s	
	4 els	12" sch 10s	
	4 flexible joints		12" sch 10s
	4 x 1640 ft	12" sch 10s	
8 exp loops @	40 ft	12" sch 10s	
	4 els	12" sch 10s	
	4 flexible joints		12" sch 10s

TABLE A-2 MODULE PIPING (cont.)

300 MW_{th}

Vertical

Carbon Steel

	330 ft	16" sch 60		
	330 ft	16" sch 10		
	1 el	16" sch 60		
	3 els	16" sch 10		
1 exp loop @	4 flexible joints		16" sch 10	
	4 els		16" sch 10	
	40 ft		16" sch 10	

316 SS

	330 ft	16" sch 40	
	330 ft	16" sch 10	
	1 el	16" sch 40	
	3 els	16" sch 10	
1 exp loop @	4 flexible joints		16" sch 10
	4 els		16" sch 10
	40 ft		16" sch 10

Horizontal - fixed

Carbon Steel

100 ft	16" sch 60	
8 els	16" sch 60	
2 "Ts"	16" sch 60	
2 check valves		16" - 600#
2 gate valves		16" - 600#
1 PCV		16" - 600#
70 ft	16" sch 10	
11 els	16" sch 10	
2 "Ts"	16" sch 10	
2 gate valves		16" - 300#

316 SS

170 ft	16" sch 10	
6 els	16" sch 10	
1 gate valve		16" - 300#
1 PCV		16" - 600#

TABLE A-2 MODULE PIPING (cont.)

300 MW_{th}

Horizontal - variable

1 module

Carbon Steel

1400 ft 16" sch 10

1 exp loop @
- 40 ft 16" sch 10
- 4 els 16" sch 10
- 4 flexible joints 16" sch 10

316 SS

1400 ft 16" sch 10

2 exp loops @
- 40 ft 16" sch 10
- 4 els 16" sch 10
- 4 flexible joints 16" sch 10

3 modules

Carbon Steel

2 x 1400 ft 16" sch 10

2 exp loops @
- 40 ft 16" sch 10
- 4 els 16" sch 10
- 4 flexible joints 16" sch 10

1 x 2625 ft 16" sch 10

2 exp loops @
- 40 ft 16" sch 10
- 4 els 16" sch 10
- 4 flexible joints 16" sch 10

316 SS

2 x 1400 ft 16" sch 10

4 exp loops @
- 40 ft 16" sch 10
- 4 els 16" sch 10
- 4 flexible joints 16" sch 10

1 x 2625 ft 16" sch 10

4 exp loops @
- 40 ft 16" sch 10
- 4 els 16" sch 10
- 4 flexible joints 16" sch 10

TABLE A-2 MODULE PIPING (Cont.)

300 MW_{th}

Horizontal - variable (continued)

6 modules

Carbon Steel

6 x 2560 ft 16" sch 10

12 exp loops @
- 40 ft 16" sch 10
- 4 els 16" sch 10
- 4 flexible joints 16" sch 10

316 SS

6 x 2560 ft 16" sch 10

24 exp loops @
- 40 ft 16" sch 10
- 4 els 16" sch 10
- 4 flexible joints 16" sch 10

9 modules

Carbon Steel

5 x 1400 ft 16" sch 10

5 exp loops @
- 40 ft 16" sch 10
- 4 els 16" sch 10
- 4 flexible joints 16" sch 10

4 x 2625 ft 16" sch 10

8 exp loops @
- 40 ft 16" sch 10
- 4 els 16" sch 10
- 4 flexible joints 16" sch 10

316 SS

5 x 1400 ft 16" sch 10

10 exp loops @
- 40 ft 16" sch 10
- 4 els 16" sch 10
- 4 flexible joints 16" sch 10

4 x 2625 ft 16" sch 10

16 exp loops @
- 40 ft 16" sch 10
- 4 els 16" sch 10
- 4 flexible joints 16" sch 10

TABLE A-2 MODULE PIPING (cont.)

450 MW_{th}

Vertical

Carbon Steel

	410 ft	18" sch 60	
	410 ft	18" sch 20	
	1 el	18" sch 60	
	3 els	18" sch 20	
	40 ft		
1 exp loop x	4 els		18" sch 20
	4 flexible joints		

316 SS (welded + x-ray)

	410 ft	18" sch 40	
	410 ft	18" sch 20	
	1 el	18" sch 40	
	3 els	18" sch 20	
	40 ft		
2 exp loops x	4 4ls		1 @ 18" sch 20
	4 flexible joints		1 @ 18" sch 40

Horizontal - fixed

Carbon Steel

100 ft	18" sch 60	
8 els	18" sch 60	
2 "Ts"	18" sch 60	
2 check valves		18" - 600#
2 gate valves		18" - 600#
1 PCV		18" - 600#
70 ft	18" sch 20	
11 els	18" sch 20	
2 "Ts"	18" sch 20	
2 gate valves		18" - 300#

316 SS

170 ft	18" sch 20	
6 els	18" sch 20	
1 gate valve		18" - 300# WNRTJ
1 PCV		18" - 900# WNRTJ

TABLE A-2 MODULE PIPING (cont.)

$450\ MW_{th}$

Horizontal - variable

1 module

Carbon Steel

	1675 ft 18" sch 20
1 exp loop @	40 ft 18" sch 20 4 els 18" sch 20 4 flexible joints 18" sch 20

316 SS

	1675 ft 18" sch 20
3 exp loops @	40 ft 18" sch 20 4 els 18" sch 20 4 flexible joints 18" sch 20

3 modules

Carbon Steel

	2 x 1675 ft 18" sch 20
2 exp loops @	40 ft 18" sch 20 4 els 18" sch 20 4 flexible joints 18" sch 20
	1 x 3150 ft 18" sch 20
2 exp loops @	40 ft 18" sch 20 4 els 18" sch 20 4 flexible joints 18" sch 20

316 SS

	2 x 1675 ft 18" sch 20
6 exp loops @	40 ft 18" sch 20 4 els 18" sch 20 4 flexible joints 18" sch 20
	1 x 3150 ft 18" sch 20
5 exp loops @	40 ft 18" sch 20 4 els 18" sch 20 4 flexible joints 18" sch 20

TABLE A-2 MODULE PIPING (cont.)

<u>450 MW_{th}</u>

<u>Horizontal - variable</u> (continued)

6 modules

Carbon Steel

6 x 3120 ft 18" sch 20

12 exp loops @
- 40 ft 18" sch 20
- 4 els 18" sch 20
- 4 flexible joints 18" sch 20

316 SS

6 x 3120 ft 18" sch 20

30 exp loops @
- 40 ft 18" sch 20
- 4 els 18" sch 20
- 4 flexible joints 18" sch 20

9 modules

Carbon Steel

5 x 1675 ft 18" sch 20

5 exp loops @
- 40 ft 18" sch 20
- 4 els 18" sch 20
- 4 flexible joints 18" sch 20

4 x 3150 ft 18" sch 20

8 exp loops @
- 40 ft 18" sch 20
- 4 els 18" sch 20
- 4 flexible joints 18" sch 20

316 SS

5 x 1675 ft 18" sch 20

15 exp loops @
- 40 ft 18" sch 20
- 4 els 18" sch 20
- 4 flexible joints 18" sch 20

4 x 3150 ft 18" sch 20

20 exp loops @
- 40 ft 18" sch 20
- 4 els 18" sch 20
- 4 flexible joints 18" sch 20

TABLE A-2 MODULE PIPING (cont.)

600 MW_{th}

Vertical

Carbon Steel

525 ft 20" sch 80
525 ft 20" sch 20
1 el 20" sch 80
3 els 20" sch 20

1 exp loop x
40 ft 20 sch 20
4 els 20" sch 20
4 flexible joints 20" sch 20

316 SS (welded + x-ray)

525 ft 20" sch 60
525 ft 20" sch 20
1 el 20" sch 60
3 els 20" sch 20

2 exp loops x
40 ft 1 @ 20" sch 60
4 els 1 @ 20" sch 20
4 flexible joints

Horizontal - fixed

Carbon Steel

100 ft 20" sch 80
8 els 20" sch 80
2 "Ts" 20" sch 80
2 check valves 20" - 900#
2 gate valves 20" - 900#
1 PCV 20" - 900#
70 ft 20" sch 20
11 els 20" sch 20
2 "Ts" 20" sch 20
2 gates 20" - 300#

316 SS (welded + x-ray)

170 ft 20" sch 20
6 els 20" sch 20
1 gate valve 20" - 300# WNRTJ
1 PCV 20" - 900# WNRTJ

TABLE A-2 MODULE PIPING (cont.)

600 MW_{th}

Horizontal - variable

1 module

Carbon Steel

	2215 ft 20" sch 20	
2 exp loops @	40 ft 20" sch 20	
	4 els 20" sch 20	
	4 flexible joints	20" sch 20

316 SS

	2215 ft 20" sch 20	
3 exp loops @	40 ft 20" sch 20	
	4 els 20" sch 20	
	4 flexible joints	20" sch 20

3 modules

Carbon Steel

	2 x 2215 ft 20" sch 20	
4 exp loops @	40 ft 20" sch 20	
	4 els 20" sch 20	
	4 flexible joints	20" sch 20
	1 x 4265 ft 20" sch 20	
3 exp loops @	40 ft 20" sch 20	
	4 els 20" sch 20	
	4 flexible joints	20" sch 20

6 modules

Carbon Steel

	6 x 4265 ft 20" sch 20	
18 exp loops @	40 ft 20" sch 20	
	4 els 20" sch 20	
	4 flexible joints	20" sch 20

316 SS

	6 x 4265 ft 20" sch 20	
36 exp loops @	40 ft 20" sch 20	
	4 els 20" sch 20	
	4 flexible joints	20" sch 20

TABLE A-2 MODULE PIPING (cont.)

600 MW_{th}

Horizontal - variable (continued)

9 modules

Carbon Steel

5 x 2215 ft 20" sch 20

10 exp loops @ { 40 ft 20" sch 20; 4 els 20" sch 20; 4 flexible joints 20" sch 20 }

4 x 4265 ft 20" sch 20

12 exp loops @ { 40 ft 20" sch 20; 4 els 20" sch 20; 4 flexible joints 20" sch 20 }

316 SS

5 x 2215 ft 20" sch 20

15 exp loops @ { 40 ft 20" sch 20; 4 els 20" sch 20; 4 flexible joints 20" sch 20 }

4 x 4265 ft 20" sch 20

24 exp loops @ { 40 ft 20" sch 20; 4 els 20" sch 20; 4 flexible joints 20" sch 20 }

APPENDIX B

Table B-1 Sample Heat Exchanger Calculations

Sample heat exchanger calculations are given for a selected set of turbine throttle/reheat steam conditions in terms of a heat balance across the heat exchanger set. Relevant water/steam enthalpies, mass flow rates and heat rates are given as well as an estimate of the critical approach condition. Additional discussion is contained in Section 3.3.

Given:

Throttle Steam: 359,700 kg/hr; 16.6 MPa(g); 510°C
(793,000 lbs/hr; 2400 psig; 950°F)

Hot Reheat Steam: 323,400 kg/hr; 510°C
(713,000 lbs/hr; 950°C)

Boiler Feed Water Conditions: 238°C; 17.9 MPa(g)
(460°F; 2600 psig)

Cold Reheat Steam
(Conditions out of HP Turbine): 3.7 MPa(g); 299°C
(540 psig; 570°F)

Assumptions:

Reheater Steam Side ΔP: 103 kPa(g) (15 psi) (across reheater)

Blowdown = 2% of throttle steam

Water/Steam Enthalpies:

Boiler Feed Water In: 1026.7 kj/kg (441.4 Btu/lb)

Boiler Feed Water Out: 1676.9 kj/kg (720.9 Btu/lb)

Steam Out of Boiler: 2556.6 kj/kg (1099.1 Btu/lb)

Steam Out of Superheater: 3320.3 kj/kg (1427.4 Btu/lb)

Steam Into Reheater: 2964.4 kj/kg (1274.4 Btu/lb)

Steam Out of Reheater: 3469.4 kj/kg (1491.5 Btu/lb)

Therefore, for the boiler feed water preheater:

$$\Delta H - 1676.9 \text{ kj/kg} - 1026.7 \text{ kj/kg} = 650.2 \text{ kj/kg}$$

$$(720.9 \text{ Btu/lb} - 441.4 \text{ Btu/lb} = 279.5 \text{ Btu/lb})$$

W = 359,700 kg/hr + 0.2 (blowdown) X 359,700 kg/hr = 366,893 kg/hr (W = 793,000 lbs/hr + [0.2 (blowdown) X 793,000 lbs/hr] = 808,860 lbs/hr)

Q = 650.1 kj/kg X 366,893 kg/hr = $2.386 \text{ X } 10^8$ kj/hr = 66.26 MWth (Q = 279.5 Btu/lb X 808,860 lbs/hr = $2.261 \text{ X } 10^8$ Btu/hr)

Similar calculations are carried out for the boiler, superheater and reheater. Since there is a constraint of a 5.6°C (10°F) approach on the boiler feed water preheater, the salt flow rate is calculated as follows:

Salt Temp. into BFW preheater =

Water temperature out of BFW preheater + 5.6° (10°F) = 356.3°C (673.4°F)

$$Q = W\, C_p\, \Delta T$$

Q = Q boiler + Q superheater + Q reheater = 209.7 MW_{th} ($7.150 \text{x} 10^8$ Btu/hr)

C_p = 1.553 kj/kg - °C (0.371 Btu/lb - °F)

ΔT = 562.8°C - 356.3°C = 206.5°C (1045°F - 673.4°F = 371.6°F)

$W = 2.353 \times 10^6$ kg/hr (5.187×10^6 lbs/hr)

Salt temp. out of BFW preheater =

356.3°C (673.4°F) - ΔT_{BFW}

$$\Delta T_{BFW} = Q_{BFW}/WC_p = \frac{2.386 \times 10^8 \text{ kj/hr}}{2.353 \times 10^6 \text{ kg/hr} \times 1.553 \text{ kj/kg - C}} = 65.3°\text{C}$$

$$\left(\frac{2.261 \times 10^8 \text{ Btu/hr}}{5.187 \times 10^6 \text{ lbs/hr} \times 0.371 \text{ Btu/lb°F}} = 117.5°\text{F}\right)$$

Salt temp. out of BFW preheater =

356.3°C - 65.3°C = 291°C (673.4°F - 117.5°F = 555.9°F)

APPENDIX C: SALT CHEMISTRY AND SALT/MATERIALS COMPATIBILITY EVALUATION

Appendix C is divided into two sections, Section C.1 will include the salt chemical and physical properties, the salt chemical reaction data, salt processing and cost considerations, and discuss the safety aspects and storage and handling of the salt. Section C.2 will cover the materials compatibility review done by Martin Marietta.

C.1 Salt Chemistry

Draw salt is a mixture of 60% sodium nitrate and 40% potassium nitrate by weight. The salt was chosen for use in this system because it is thermally stable over the system operating temperature range, is compatible with the materials selected (see Section C.2), is inexpensive, and the raw materials are plentiful.

This section will discuss the properties of the salt, the chemical reactions the salt is expected to undergo during system operation, processing and cost considerations, and the safety and handling aspects of the salt.

C.1.1 Physical Properties

The molten salt chosen for consideration in this system is a eutectic mixture of 60% sodium nitrate and 40% potassium nitrate, or "draw" salt. The properties listed below are those necessary for a detailed design of a salt storage system. The data is based on published literature as referenced.

a) Density - The density for various mixtures of potassium nitrate (KNO_3) and sodium nitrate ($NaNO_3$) are given in Table C-1. Draw salt is 64 mole % $NaNO_3$.

b) Viscosity - Table C-2 shows the viscosity for various compositions of salt.

c) Temperature-Composition Phase Diagram - Figure C-1 shows a phase diagram for the KNO_3-$NaNO_3$ mixture, in mole percentage of $NaNO_3$. Note that a 50-50 mole % mixture gives the minimum melting point of 494K (430°F), which is considerably lower than the lowest operating temperature for this system.

d) Heat Transfer Coefficient - The heat transfer coefficient ranges from 3860 to 14000 Kcal/hr$\cdot$m$^2\cdot$°C (800-2900 Btu/hr$\cdot$ft$^2\cdot$°F) from data in Ref. C-9.

T(K)	100	90	80	70	60	50	40	30	20	10	0	46
625	1.878	1.876	1.874	1.872	1.870	1.867	1.865	1.863	1.861	1.859	1.856	1.866
630	1.875	1.873	1.871	1.869	1.866	1.864	1.862	1.860	1.857	1.855	1.853	1.863
635	1.872	1.870	1.868	1.865	1.863	1.861	1.859	1.856	1.854	1.852	1.850	1.860
640	1.869	1.867	1.865	1.862	1.860	1.858	1.855	1.853	1.851	1.849	1.846	1.857
645	1.866	1.864	1.862	1.859	1.857	1.855	1.852	1.850	1.848	1.845	1.843	1.854
650	1.863	1.861	1.858	1.856	1.854	1.851	1.849	1.847	1.844	1.842	1.839	1.850
655	1.860	1.858	1.855	1.853	1.850	1.848	1.846	1.843	1.841	1.838	1.836	1.847
660	1.857	1.854	1.852	1.850	1.847	1.845	1.842	1.840	1.837	1.835	1.832	1.844
665	1.854	1.851	1.849	1.846	1.844	1.841	1.839	1.836	1.834	1.831	1.829	1.840
670	1.851	1.848	1.845	1.843	1.840	1.838	1.835	1.833	1.830	1.828	1.825	1.837
675	1.847	1.845	1.842	1.840	1.837	1.835	1.832	1.829	1.827	1.824	1.822	1.834
680	1.844	1.842	1.839	1.836	1.834	1.831	1.829	1.826	1.823	1.821	1.818	1.830
685	1.841	1.838	1.836	1.833	1.830	1.828	1.825	1.822	1.820	1.817	1.815	1.827
690	1.838	1.835	1.832	1.830	1.827	1.824	1.822	1.819	1.816	1.814	1.811	1.823
695	1.834	1.832	1.829	1.826	1.823	1.821	1.818	1.815	1.813	1.810	1.907	1.820
700	1.831	1.828	1.825	1.823	1.820	1.817	1.814	1.812	1.809	1.806	1.803	1.816
705	1.828	1.825	1.822	1.819	1.816	1.814	1.811	1.808	1.805	1.803	1.800	1.813
710	1.824	1.821	1.819	1.816	1.813	1.810	1.007	1.804	1.802	1.799	1.796	1.809
715	1.821	1.818	1.815	1.812	1.809	1.807	1.804	1.801	1.798	1.795	1.792	1.805
720	1.817	1.815	1.812	1.809	1.806	1.803	1.800	1.797	1.794	1.791	1.788	1.802

Table C-1 Density Data
Mole Percent $NaNO_3$
Numerical Values in $gm \cdot cm^{-3}$ (Ref 8)

T(K)	100	75	50	25	0
520			4.725		
530			4.381		
540			4.064		
550			3.772		
560			3.506		
570		3.038	3.262	3.372	
580		2.879	3.040	3.165	
590		2.728	2.839	2.978	
600	2.708	2.585	2.657	2.808	
610	2.574	2.450	2.494	2.653	
620	2.445	2.323	2.348	2.511	2.763
630	2.323	2.205	2.217	2.380	2.608
640	2.208	2.094	2.100	2.260	2.465
650	2.101	1.992	1.997	2.150	2.334
660	2.000	1.899	1.906	2.048	2.214
670	1.907	1.812	1.826	1.954	2.102
680	1.822	1.735	1.755	1.867	2.001
690	1.744	1.665	1.692	1.786	1.906
700	1.675	1.604	1.636	1.710	1.819
710	1.614	1.551	1.585	1.640	1.738
720	1.562	1.506	1.540	1.574	1.662

Table C-2 Viscosity Data
Mole Percent $NaNO_3$
Numerical Values in Centipoises (Ref 8)

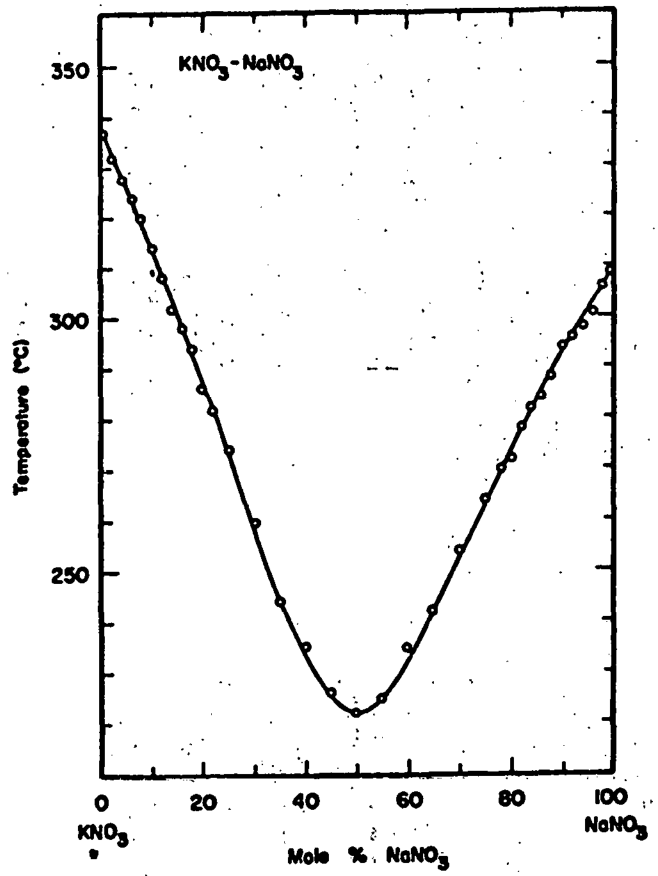


Figure C-1 Temperature - Composition Phase Diagram for KNO_3-$NaNO_3$ (Ref 8)

e) Surface Tension - The surface tension for varying compositions of KNO_3-$NaNO_3$ mixtures is given in Table C-3.

f) Specific Heat - The specific heat of the melt is 0.37 cal/gm· °C (Btu/lb·°F), and is 0.32 cal/gm·°C (Btu/lb·°F) for the solid mixture (Ref. 9).

g) Heat of Fusion - The heat of fusion is 19.5 cal/gm (35 Btu/lb) as stated in Ref. 9.

h) Thermal Conductivity - Ref. 9 gives the thermal conductivity as 0.491 Kcal/hr·m^2·°C/m (0.33 Btu/hr·ft^2·°F/ft).

i) Electrical Resistivity - 0.77 ohm·cm is the value given for the electrical resistivity in Ref. 9.

j) Coefficient of Expansion - The coefficient of linear expansion is 5.13×10^{-5}/°C (2.85×10^{-5}/°F), and 3.64×10^{-4}/°C (2.02×10^{-4}/°F) is the coefficient of cubic expansion (Ref. 9).

C.1.2 Nitrate-Nitrite Equilibrium Reactions

The nitrate-nitrite equilibrium reactions are those reactions which shift the relative amounts of the nitrate and nitrite salts, but have no effects on the overall performance of the draw salt.

The reactions listed below are the major reactions of this phenomenon:

$$XNO_3(\ell) \longrightarrow XNO_2(\ell) + 1/2\ O\ (g) \qquad (1)$$

$$XNO_2(\ell) + 1/2\ O_2(g) \longrightarrow XNO_3(\ell) \qquad (2)$$

(where: X = Na, K, or a mixture)

When the nitrate (sodium or potassium) is heated above its melting point, the salt liberates some oxygen to yield the corresponding nitrite. As shown in Eq. 2, the reaction is reversible.

A quantitative equilibrium expression for the forward (Eq. 1) and reverse (Eq. 2) reactions is written as follows:

$$K = \frac{[XNO_2]P_{O_2}^{\frac{1}{2}}}{[XNO_3]} \qquad (3)$$

at constant temperature. The equilibrium constant, K, is defined to be the ratio of the concentration of products to reactants.

T(K)	100	90	80	70	60	50	40	30	20	10	0	46
500						122.2						122.1
510					121.8	121.4	121.2					121.3
520					121.0	120.7	120.4					120.6
530					120.3	120.0	119.7	119.4				119.8
540				120.1	119.6	119.2	118.9	118.7				119.1
550				119.4	118.9	118.5	118.2	117.9	117.7			118.4
560			119.2	118.7	118.2	117.8	117.4	117.1	116.9			117.6
570			118.5	118.0	117.5	117.0	116.6	116.3	116.1	115.9		116.9
580			117.9	117.3	116.7	116.3	115.9	115.5	115.3	115.1		116.1
590		117.9	117.2	116.6	116.0	115.5	115.1	114.8	114.5	114.3	114.1	115.3
600		117.2	116.5	115.9	115.3	114.8	114.3	114.0	113.7	113.4	113.3	114.6
610		116.6	115.8	115.2	114.5	114.0	113.6	113.2	112.9	112.6	112.4	113.8
620	116.8	115.9	115.1	114.4	113.8	113.3	112.8	112.4	112.0	111.8	111.6	113.1
630	116.2	115.3	114.5	113.7	113.1	112.5	112.0	111.6	111.2	110.9	110.7	112.3
640	115.5	114.6	113.8	113.0	112.3	111.7	111.2	110.8	110.4	110.1	109.9	111.5
650	114.9	114.0	113.1	112.3	111.6	111.0	110.4	110.0	109.6	109.2	109.0	110.8
660	114.3	113.3	112.4	111.6	110.9	110.2	109.6	109.1	108.7	108.4	108.1	110.0
670	113.6	112.6	111.7	110.9	110.1	109.5	108.9	108.3	107.9	107.5	107.3	109.2

Table C-3 Surface Tension Data - Mole Percent $NaNO_3$ Numerical Values $dyn \cdot cm^{-1}$

The concentration of oxygen in the gas phase is expressed as the partial pressure (P_{O2}) of oxygen.

The partial pressure of oxygen is an important factor in determining the point when concentrations of nitrate and nitrite have reached a final equilibrium. If nitrogen is used as the ullage gas, the nitrites will be formed in solution. All the nitrate will be converted to nitrite if the ullage is swept with nitrogen (Ref. C-1, C-5, C-6). Dry air is recommended as the ullage gas to minimize the shift of nitrates to nitrite.

C.1.3 Draw Salt Degradation Reactions

The degradation reactions discussed in this report are those which, unlike the nitrate-nitrite equilibrium reaction, are non-reversible reactions in a typical engineering system, and may alter the thermal properties of the salt. It should be noted that these are chemically reversible.

Three types of degradation reactions take place in the salt, oxide formation, hydroxide formation, and carbonate formation. The reactions are listed below:

$$2\ XNO_2(\ell) \longrightarrow X_2O\ (s) + NO_2(g) + NO\ (g) \qquad (4)$$

$$X_2O\ (s) + 2NO_2(g) \longrightarrow XNO_2(\ell) + XNO_3(\ell) \qquad (5)$$

$$X_2O(s) + H_2O\ (\ell/g) \longrightarrow 2XOH\ (s) \qquad (6)$$

$$X_2O(s) + CO_2(g) \longrightarrow X_2CO_3(s) \qquad (7)$$

$$2XOH(s) + CO_2(g) \longrightarrow X_2CO_3(s) + H_2O\ (\ell) \qquad (8)$$

Eq. 4 shows the formation of the oxide, and Eq. 5, 6, 7 show its consumption. The amount of oxide formed is dependent on the concentration of the nitrite, which can be "controlled" by the oxygen partial pressure as shown in the previous section.

As seen in Eq. 5, the oxide formation can be chemically "reversed" by reacting it with nitrogen dioxide to give a nitrate and nitrite. This reaction seems to be the best method for salt recovery (Ref. C-1, C-5, C-6, C-10) (see Section C.1.4).

The oxide concentration can also be decreased upon reaction with water (Eq. 7) or CO_2 (Eq. 8), forming the salt hydroxide or carbonate. The hydroxide and carbonate are both solids which precipitate out of the molten salt.

The carbonate can also be formed by the reaction of the hydroxide with CO_2 as seen in Eq. 8 (Ref. C-1, C-5, C-6, C-10).

The precipitates formed from the degradation reactions may interfere with heat transfer in heat exchangers, mechanically foul pumps and lines, and ultimately remove a portion of the salt from service.

C.1.4 Salt Processing and Cost Considerations

C.1.4.1 Initial Processing

The quantity of salt required for heat transfer and storage in the plant is large, about 43 MKg. It would certainly be uneconomical, if not impossible to obtain this large an amount of salt from heat transfer salt manufacturers. The cost of prepared and packaged heat transfer salt is between \$0.45 and \$0.65 per kilogram (\$0.20 and \$0.30 per pound). Therefore, it would be advantageous to buy the raw materials in bulk quantities and mix and melt the salt at the plant site. The two raw materials are potassium nitrate the sodium nitrate.

Tables C-4 and C-5 show the analyses and specifications for the two salts. The analyses indicate that there are no impurities in sufficient quantities to cause problems in heat transfer, phase separation, or promote corrosion. Most of the impurities that appear in the raw materials are those that would be found if chemically pure materials were used due to the chemical equilibria of salt with air.

Table C-4 Specification for Potassium Nitrate

Component	Wt. %
KNO_3	96.4-97.8
$NaNO_3$	1.8-3.2
$NaCO_3$	0.15 max.
NaOH	0.10 max.
Chlorides as $C\ell$	0.03 max.
Sulfur as SO_3	0.06 max.
Iron as Fe_2O_3	0.015 max.
Calcium as Ca	0.03 max.
Magnesium as Mg	0.03 max.
Silica as SiO_2	0.02 max.
Alumina as $A\ell_2O_3$	0.03 max.

Table C-5 Specification for Sodium Nitrate

Sodium Nitrate, bulk:	$154/net Ton (f.o.b. Lake Charles, La)	
Source: Olin		
<u>Component</u>	<u>Typical Wt. %</u>	<u>Maximum Wt. %</u>
$NaNO_3$	99.4-99.5	
$NaNO_2$	0.012	0.02
$NaC\ell$	0.15	0.25
Na_2SO_4	0.30	0.35
SiO_2	0.0030	0.004
CaO	0.005	0.03
MgO	0.0010	0.002
$A\ell_2O_3$	0.0004	0.001
Mn	0.00003	0.0001

The equipment required for unloading, mixing and melting the salt is shown in Figure C-2. The cost of the equipment would be approximately $750,000. The fuel cost for melting the salt would be about $0.00132 per kilogram of salt ($0.0006/lb).

C.1.4.2 Salt Conditioning

The small amount of degradation in the salt over a period may be corrected in several ways. A small quantity of the salt may be removed periodically from the bottom of the storage tanks, and either regenerated or discarded and replaced. Regeneration may be performed by using the same equipment that is used for melting, and bubbling nitrogen dioxide through the molten salt. If the salt were replaced at a rate of 2.5 percent per year, the cost would be $1.315 per kilogram per year ($0.0029/lb/yr), or $39.009 per kilogram ($0.086/lb) over the 30 year life of the plant.

C.1.4.3 Salt Cost

Prices of the raw materials quoted by the manufacturers during July 1979 are:

Potassium Nitrate: $200/T fob, Vicksburg, Mississippi
$220/metric ton

Sodium Nitrate: $154/T fob, Lake Charles, Louisiana
$169/metric ton

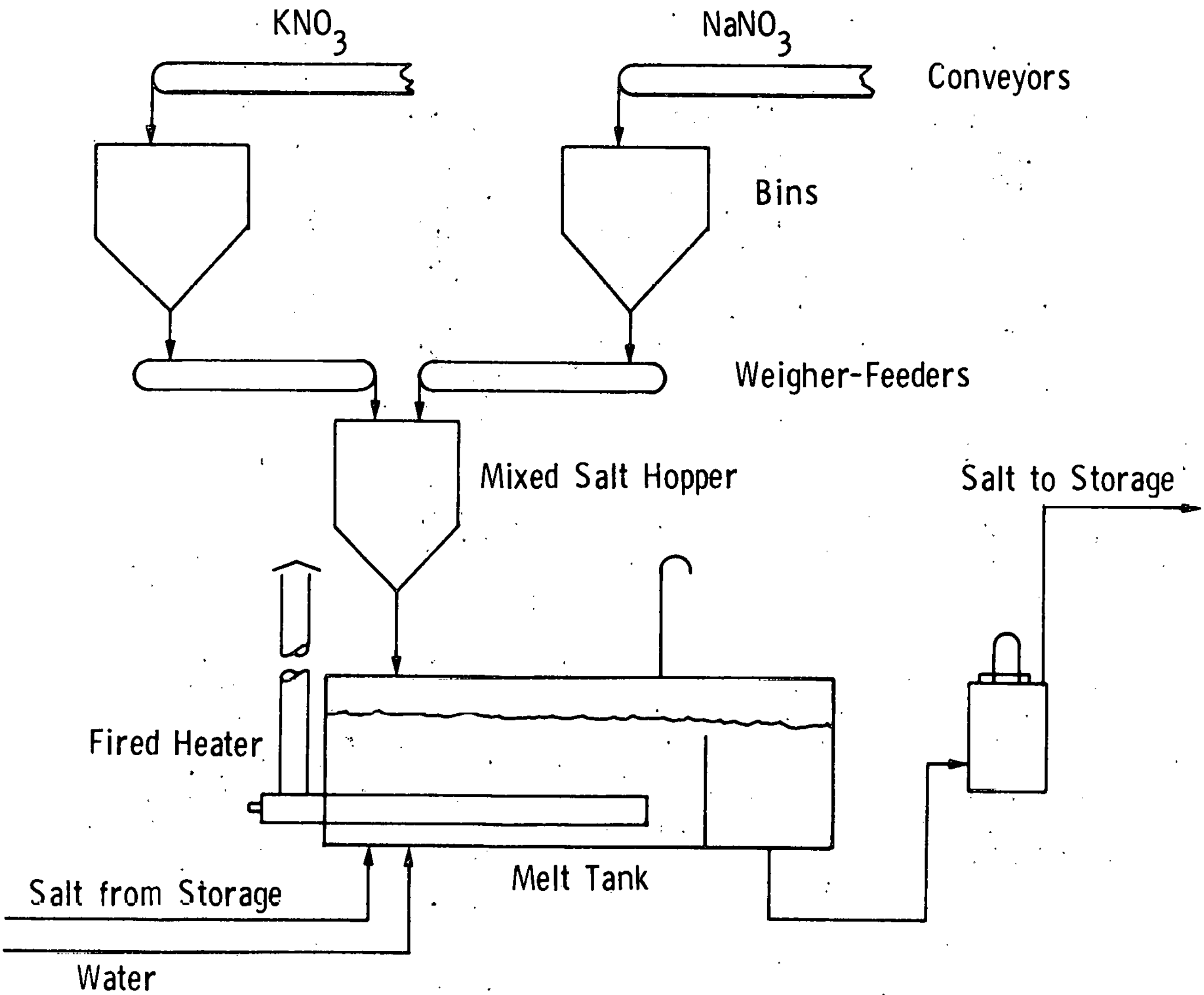


Figure C-2 Salt Melting Flow Diagram

Because the salt will be 60 percent sodium nitrate and 40 percent potassium nitrate by weight, the cost of the salt is $189.40 per metric ton excluding transportation. Transportation costs are estimated at $54.20 per metric ton, FOB origination, making the total cost $243.60 per metric ton ($0.111/lb).

C.1.5 Safety & Handling

The major safety hazards associated with the molten draw salt are those which apply to the use of any liquid at elevated temperature. The system design and operating manuals should include proper protection for operating personnel from burns in case of equipment failure.

The draw salt in a solid state gives off no toxic vapors, but, as shown in previous sections, due to the decomposition reactions, toxic vapors of the nitrogen oxides are liberated by the molten salt. Adequate ventilation must be provided to protect personnel from these fumes.

Although the salt is nonflammable, it will support combustion of other materials. Combustible solids, such as wood, coke, paper, plastics, cyanides, chlorides, ammonium salts, and active metals, such as aluminum and magnesium should be stored or used in areas away from the salt.

Combustible vapors generally react slowly with the salt, and generally escape before combustion is complete. Flammable liquids tend to vaporize rapidly in the molten salt and burn at the surface in the same manner as they would on any hot surface.

Care should be taken to protect personnel from the hot salt, which spatters due to the sub-surface vaporization of the flammable liquids or vapors.

Water from spray sprinklers or low-velocity fog nozzles will not penetrate the surface of the salt sufficiently to cause spattering, and is the recommended method of fire protection for processes involving combustible materials. Carbon dioxide or approved dry powder type fire extinguishers can be used to combat fires in the vicinity of the salt system, and an adequate supply of dry sand should be maintained for slagging and diking to confine the spread of escaped molten salt.

Operating personnel should wear flame-proof garb or uniforms while working around the molten salt. Gloves should be worn, and a cream which is an effective barrier, should be used on the skin, to minimize contact of the salt with the skin.

Care should be taken to avoid ingestion of the salt. Although small quantities of sodium nitrite is currently being used as a food additive, large doses may cause headaches, collapse, and even death.

Draw salt is somewhat hydroscopic, and should be stored in a dry area to prevent caking. Readily combustible materials should not be stored in the vicinity of the salt. For more information on the safety, storage and handling of draw salt, consult Ref. C-3.

C.2 Salt/Materials Compatibility Evaluation

Molten draw salt systems designed with a 30-year lifetime present many material issues. A literature search was undertaken to locate data on the corrosion resistance of materials in a salt environment at elevated temperatures. Several references were found (Ref C-1 thru C-6) but reliable data of engineering systems at elevated operating temperatures were not available. The literature data are summarized in Table C-6 and Table C-7. Therefore, because of the lack of data, candidate materials have been selected to undergo corrosion tests at Martin Marietta.

The corrosion tests have been designed to determine three types of corrosion properties: (1) general corrosion, (2) stress corrosion of the parent materials, and (3) general corrosion of the weld metals. This appendix addresses the corrosion data resulting from previous Martin Marietta tests. For more information on these tests, see Reference C-5.

Candidate materials were chosen on the basis of high temperature stability-strength properties, general corrosion resistance, fabricability, availability, and cost. The materials selected are listed in Table C-8. The compositions of the candidate materials are given in Table C-9.

The results of the corrosion were evaluated by weight gain and/or loss of samples. The weight gain/loss data for all materials tested are shown in Figures C-3, C-4, and C-5. Some of the general corrosion effects visually noted were (1) the carbon steel, A516, showed areas of bare metal due to flaking of the corrosion layer at 755K (900°F), as did the stainless steel 321 at 866K (1100°F), (2) the corrosion layer on the Incoloy 800 sample was a black, smooth, uniform film, and (3) all the samples gained weight with increasing time unless flaking occurred.

Corrosion data on the individual materials tested are discussed in the following sections.

a. Carbon Steel A516 - At an initial test temperature of 755K (900°F), the carbon steel showed a weight gain, but after 10 days flaking occurred, causing a noticeable weight loss (Figure C-3). The weight loss at 755K (900°F) makes this material unacceptable for use in the high-temperature portion of the system. At temperatures of 589K (600°F) and 672K (750°F), the A516 corrosion layer was stable, with no flaking noted. These data indicate that the carbon steel should be a suitable material for the low-temperature portion of the

Table C-7 Qualitative Assessments of Corrosion by Heat Transfer Salt (Hitec)

ALLOY	TIME YR	TEMP. °C (°F)	BLANKET GAS	SYSTEM	COMMENTS
ASTM-A-285 GRADE C CARBON STEEL	3	427 (800)	AIR	CIRCULATING	NO NOTICEABLE CORROSION
	3	418-427 (785-800)	LIMITED AIR	CIRCULATING	NO NOTICEABLE CORROSION
	2.5	468 (875)	STEAM	CIRCULATING	NO NOTICEABLE CORROSION
347 SS	1.3	566 (1050)	AIR	HEAT TREAT BATH	NEGLIGIBLE CORROSION
	2	538 (1000)	STEAM	CIRCULATING	NO NOTICEABLE CORROSION
SEAMLESS STAINLESS TUBING	0.8	499-549 (930-1020)	?	CIRCULATING	NO VISIBLE ATTACK

REFERENCE: BOHLMANN, E.G., "HEAT TRANSFER SALT FOR HIGH TEMPERATURE STEAM GENERATION," ORNL-TM-3777, OAK RIDGE NATIONAL LABORATORY

Table C-8 Corrosion Test Materials

Material	Specification	Condition
Carbon Steel	ASTM A516 Grade 70	Normalized
3/4 Cr - 1/2 Mo	ASTM A387 Grace C	Normalized & Tempered
316 CRES	QQ-S-766	Annealed
321 CRES	QQ-S-766	Annealed
347 CRES	QQ-S-766	Annealed
A286	AMS 5525	Solution Heat Tempered
Incoloy 800	ASTM B409	Annealed

MATERIAL	C	MN	SI	CR	NI	MO	TI	P	S	OTHER	FE
CARBON STEEL											
A516	0.31 max	1.25 max	0.33 max	--	---	--	--	0.035 max	0.04 max	---	Remainder
CHROME-MOLY											
A387	0.15 max	0.60 max	0.55 max	4.00 6.00	---	0.70 max	--	0.040 max	0.030 max	---	Remainder
STAINLESS											
316SS	0.08 max	2.00 max	1.00 max	16.0 18.0	10.0 14.0	2.00 3.00	--	0.045 max	0.03 max	---	Remainder
321SS	0.08 max	2.00 max	1.00 max	17.0 19.0	9.00 12.00	--	5xC min	0.045 max	0.03 max	---	Remainder
347SS	0.08 max	2.00 max	1.00 max	17.0 19.0	9.00 13.00	--	--	0.045 max	0.03 max	10xC min Cb + Ta	Remainder Remainder
A286	0.05 max	0.2	0.70	15.00	25.0	1.25	2.15	---	--	V,0.30; Aℓ,0.20	Remainder
NICKEL ALLOY											
INCOLOY 800	0.05	0.75	0.50	21.0	32.5	--	0.38	--	0.008	Aℓ,0.38; Cu,0.38	Remainder

Table C-9 Primary Steel Candidates

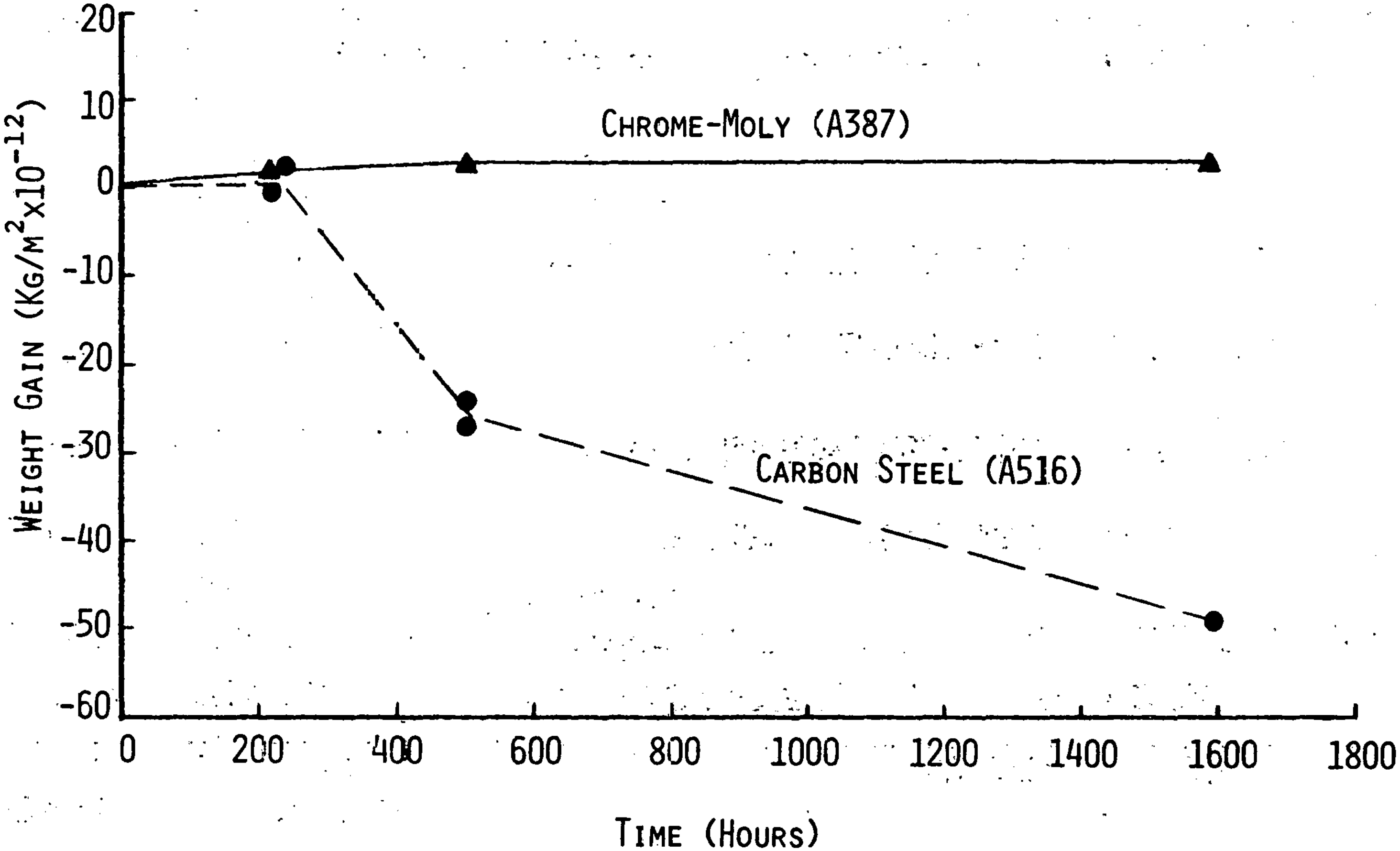


Figure C-2 Corrosion Comparison at 482°C (900°F) - Carbon Steel and Low Chromium Steel

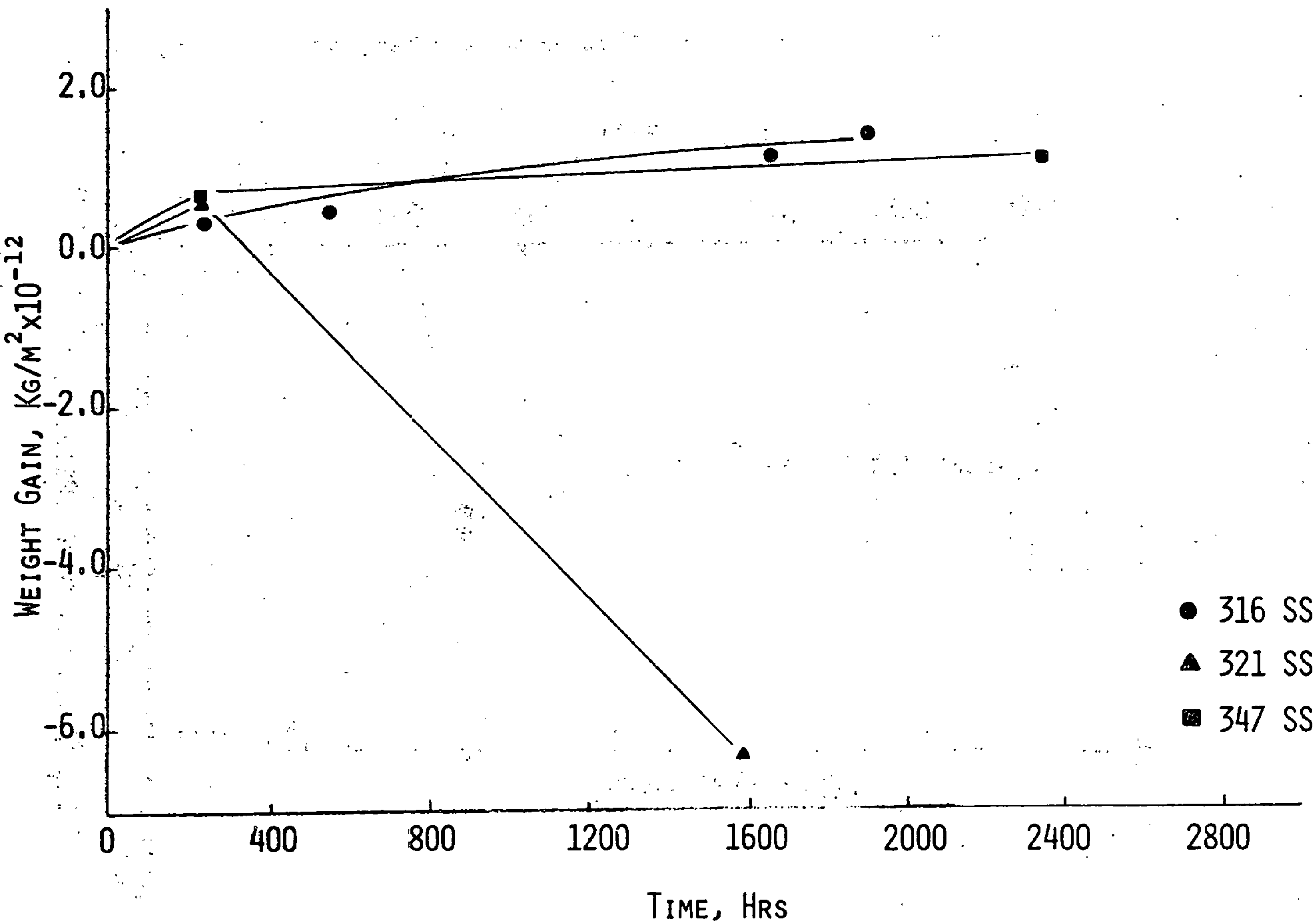


Figure C-3 Corrosion Test Result Comparison at 593°C (1100°F) for Austenitic Steels

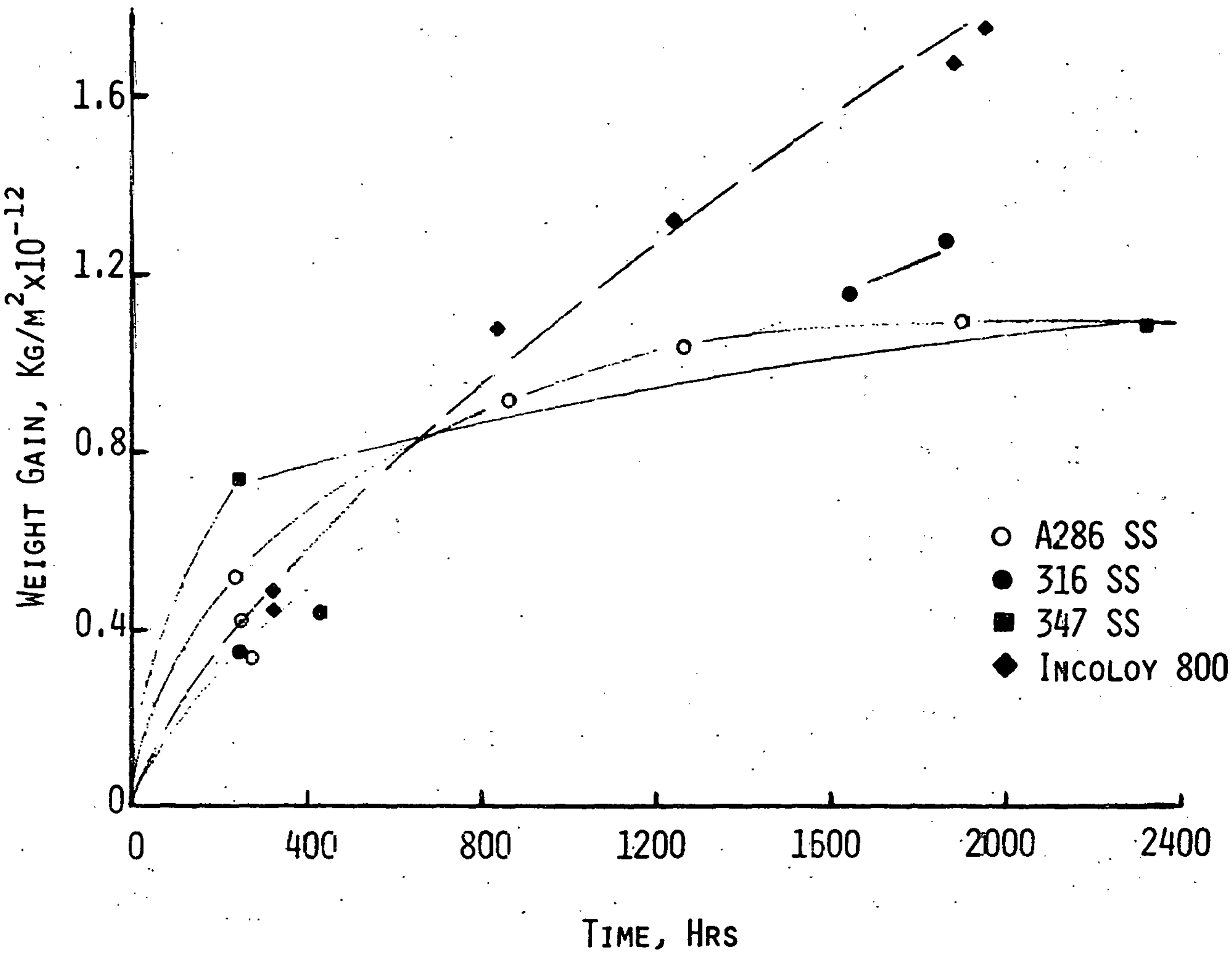


Figure C-4 Corrosion Test Results at 593°C (1100°F) for Stainless Steel and Nickel Alloy Steels salt system. For more information on the corrosion test results for A516, consult Reference C-5.

b. Chrome-Moly Steel, A387 - The chrome-moly steel was tested to investigate the corrosion effects of the addition of chromium to a low-alloy steel. The A387 did not lose weight as rapidly as the carbon steel, but flaking eventually occurred at 755K (900°F), making it unsuitable for applications in the high-temperature portion of the system (Figure C-3). Since the carbon steel has a lower cost and greater weldability, the slightly increased corrosion resistance of chrome-moly steel was not necessary on the low-temperature side of the salt system, but it does have applicability in an intermediate-temperature range [589 to 755K (600 to 900°F)] where the carbon steel is not resistant. Detailed results of the A387 tests can be found in Reference C-5.

c. Stainless Steel A286 - The A286 SS was tested at a temperature of 894K (1150°F), with the sample initially gaining weight by the formation of a uniform-appearing dark oxide layer. After approximately 12 weeks, the oxide layer began to flake and expose the bare metal surface. Due to some anomalies with the test apparatus (see Ref. C-5), no conclusions were drawn as to the use of this material in the salt system.

d. Stainless Steel 316 - No flaking was noted for 316. From a weight gain standpoint, the 316 stainless steel looked favorable for high-temperature use (811K, 1000°F), but examination of the photomicrograph showed intergranular corrosion due to sensitization. Sensitization would eventually reduce the effective load-carrying cross section of the material. The general corrosion resistance makes 316 stainless steel a good candidate for use at less than 700K (800°F). A more detailed discussion of the results is given in Reference C-5. A low carbon stainless steel, 316L, would reduce sensitization and intergranular corrosion but also has lower strength and is not coded above 850°F for power application piping.

e. Stainless Steel 321 - This stainless was originally selected because it does not sensitize like some of the other 300-series stainless steels. The sample initially showed a weight gain at 865K (1100°F), but flaking had occurred by the end of test, exposing the bare metal. Examination of the photomicrograph at 811K (1000°F) showed sensitization and intergranular corrosion similar to that of 316 stainless. Although literature data (Ref. C-1) point to use of 321 in high-temperature salt systems, further testing must be completed before a recommendation could be made on the use of 321 SS based on the data from this test program. Further results can be found in Reference C-5.

f. Stainless Steel 347 - Stainless steel 347 is similar to 321 except that the stabilizing agents added are colombium and tantalum, rather than the titanium in 321. The literature survey (Ref. C-1, C-2, C-3) shows extensive use of 347 stainless, both in practical applications and in corrosion testing at temperatures up to 812K (1000°F) with no noticeable corrosion. The weight gain for this material is shown in Figures C-4 and C-5. Both figures show the weight gain stabilizing at approximately 1600 hours into the test. No flaking of the oxide layer was noticed. The results of this test and previous use of the material at system operating temperatures make it the most attractive candidate material for use in the high-temperature portion of the salt piping and heat exchanger system.

g. Incoloy 800 - Incoloy 800 is a high-nickel alloy used extensively in corrosive environments. Figure C-5 shows the weight gain history of the sample at 866K (1100°F). At approximately 2000 hours into the test, the weight gain leveled off to a point where no appreciable buildup of the oxide layer was noticed. The layer appeared to be uniform throughout the test, with no flaking noted. Photomicrographs (Ref. C-5) showed no intergranular corrosion occurring during the test duration. Incoloy 800 is an excellent candidate for use in the high-temperature portion of the system, but comparing it with 347 stainless steel, the cost of the Incoloy 800 makes it less favorable for piping systems. The higher strength of Incoloy 800 makes it an excellent material for receiver tubing.

After reviewing the literature and data, 347 stainless steel was chosen as the candidate material for the high-temperature piping and heat exchanger surface area of the draw salt system, and carbon steel was chosen for use in the low-temperature side of the system. A low chrome molybdenum steel, A387, was chosen for intermediate-temperature applications in the heat exchangers and salt heater. Incoloy 800 was chosen for the receiver tubing.

For more details and discussions of the Martin Marietta corrosion test program, consult Reference C-5.

For equipment materials other than metals, very little was found in the literature. Reference C-5 gives the following recommendations:

"Flat-faced flanged fittings are generally satisfactory for piping to carry 'Hitec,' but tongue-and-groove type fittings are recommended for severe applications. Welded pipe bends and connections should be used whenever possible, and piping should be laid out so that the molten salt will drain by gravity to the storage reservoir when the unit is shut down. Exposed salt lines and valves should be insulated in order to prevent excessive radiation of heat, although for some high-temperature applications it is necessary to use valves fitted with radiation fins in order to protect the packing glands. Salt lines and valves should be traced or steam-jacketed in order to prevent freezing by solidified salt, especially for intermittent operations.

"Both manually operated, steel gate valves and automatic valves can be used satisfactorily with 'Hitec,' taking care to install the valves so that they can drain freely. Submerged centrifugal pumps can be used to circulate molten 'Hitec,' and these should be of a type which permits no contact of the liquid with the packing gland."

"Metallic asbestos gaskets, asbestos sheet gaskets, and asbestos packing have all been used successfully. The use of organic valve-packing lubricants or excessive pipe dope should be avoided in order to prevent reaction between the organic material and the 'Hitec.' Graphite-lubricated asbestos is satisfactory, but the graphite content should be held to a minimum."

"The salt-heating unit should be designed to prevent localized overheating during start-up and in cases when the circulation of salt might be stopped suddenly. Remelting of 'Hitec' is preferably done with electric immersion heaters or steam coils which pass through the surface of the salt. Heating of a 'frozen' 'Hitec' bath from the bottom alone can develop sufficient pressure to rupture equipment or, more likely, to expel molten 'Hitec' through the solid salt surface."

REFERENCES

C-1 E. G. Bohlman: "Heat Transfer Salt for High-Temperature Steam Generation,"

C-2 H. P. Voznik and V. W. Uhl: "Molten Salt for Heat Transfer," *Chem. Engrg.* 70, 129, May 27, 1963.

C-3 *DuPont Hitec*^{R} *Heat Transfer Salt.* E. I. duPont de Nemours and Co., Explosives Dept., Chem. Products Sales Div., Wilmington, Delaware, 19898.

C-4 C. Kramer, W. H. Smyrl, and W. B. Estill: *Corrosion of Fe Alloys in Hitec at 823K.* SAND78-8256, Sandia Laboratories, February 1979.

C-5 *Conceptual Design of Advanced Central Receiver Power System, Phase I, Final Report.* Martin Marietta Aerospace, Denver Division, Denver, Colorado, September 1978.

C-6 M. D. Silverman and J. R. Engel: *Survey of Technology for Storage of Thermal Energy in Heat Transfer Salt.* ORNL/TM5682, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830.

C-7 W. E. Kirst, W. M. Nagle, and J. B. Castner, "A New Heat Transfer Medium for High Temperatures," *Trans. of Amer. Inst. of Chem. Engr.*, XXXXVI, 1940.

C-8 G. J. Janz, U. Krebs, H. F. Siegenthalr, and R.P.T. Tomkins, "Electrical Conductance, Density, Viscosity, and Surface Tension Data," *J. Phys. Chem. Ref. Data,* Vol. 1, No. 3, 1972.

C-9 *Partherm Heat Transfer Salts.* Technical Bulletin J-9, Park Chemical Co., 8074 Military Ave, Detroit, Michigan, 48204.

C-10 K. H. Stern, "High Temperature Properties and Decomposition of Inorganic Salts Part 3. Nitrates and Nitrites," *J. Phys. Chem. Ref. Data,* Vol. 1, No. 3, 1972.

APPENDIX D: HELIOSTAT FIELD COORDINATES

The coordinates for a 12,484 heliostat module have been supplied to Sandia-Livermore on a magnetic tape. The format of the tape is:

Column 1 - Heliostat Row Number
Column 2 - Heliostat Number
Column 3 - X-coordinate (meters)
Column 4 - Y-coordinate (meters)
Column 5 - Z-coordinate (meters)

The coordinate system has its origin at the centerline of the tower, with Z = 0.0 at the plane of the heliostat elevation axis. Positive X is due east, positive Y being due north.

The aiming strategy, as discussed in Volume II, Section 5.3, has been adapted to the MIRVAL program in the following tables. The zone radius refers to the horizontal distance from the centerline of the tower for which a given aimpoint is applicable. For example, a zone radius of 121.0 m means that all heliostats less than 121 m from the centerline of the tower (up to the previous aim zone) are aimed at the given aimpoint. The aimpoint coordinate system has its origin at the center of the respective aperture. All heliostats in the south quadrant are aimed at the center of the south aperture.

Table D-1 North Quadrant Aim Inputs

Zone Radius	(X	Y	Z)
121.00	0.00	0.00	-5.67
148.00	0.00	0.00	-3.90
175.00	0.00	0.00	-2.75
200.00	0.00	0.00	0.00
225.00	0.00	0.00	1.83
251.00	0.00	0.00	3.96
275.00	0.00	0.00	3.21
303.00	0.00	0.00	5.28
327.00	0.00	0.00	3.21
355.00	0.00	0.00	3.21
382.00	0.00	0.00	-5.02
415.00	0.00	0.00	4.78
446.00	0.00	0.00	4.58
482.00	0.00	0.00	4.37
520.00	0.00	0.00	4.14
562.00	0.00	0.00	-3.78
605.00	0.00	0.00	3.60
652.00	0.00	0.00	3.29

Table D-2 East/West Quadrant Aim Inputs

Zone Radius	(X	Y	Z)
121.00	0.00	0.00	-4.70
148.00	0.00	0.00	-3.76
175.00	0.00	0.00	-2.65
200.00	0.00	0.00	0.00
225.00	0.00	0.00	1.77
251.00	0.00	0.00	0.00
275.00	0.00	0.00	0.00
303.00	0.00	0.00	.88
327.00	0.00	0.00	3.10
355.00	0.00	0.00	3.10
382.00	0.00	0.00	0.00
415.00	0.00	0.00	.88
446.00	0.00	0.00	-2.65
482.00	0.00	0.00	3.10
520.00	0.00	0.00	-2.65
562.00	0.00	0.00	-2.96
605.00	0.00	0.00	0.00
652.00	0.00	0.00	0.00

APPENDIX E: DATA LISTS

This appendix contains the requested data for the design characteristics and performance for each subsystem of the selected 100 MWe-18 hour solar central receiver hybrid power system.

I. COLLECTOR SUBSYSTEM

A. Design Characteristics

1. Field Geometry and Size: 2 collector fields, each surrounding radial stagger arrays, overall dimensions of 1800 m (5905 ft) N-S by 1940 m (6364 ft) E-W, with a central exclusion radius of 110 m (361 ft).

2. Field Layout: Radial stagger arrays, heliostat coordinates provided in Appendix D.

3. Field Oversizing for Dirt on Mirrors, Reliability, etc.: Heliostat reliability of 0.997 used in design point stairstep, resulting in oversizing of each hleiostat field of 1837 m^2 (37.45 heliostats).

4. Beam Pointing Accuracy: 0.75 mrad (1 sigma) elevation axis error, 0.75 mrad (1 sigma) azimuthal axis error.

5. Beam Quality: 1.0 mrad (1 sigma) single axis mirror aberration error.

6. Heliostat Geometry and Size: 12-facet glass/steel inverting stow heliostat; 49.05 m^2 (528 ft^2) reflective surface; 7.416 m x 7.378 m (24.33 ft x 24.20 ft) overall dimensions.

7. Number of Heliostats: 12,484 per field, 25,968 total plant.

B. Operating Characteristics

1. Power to Track: 25 W/heliostat (5.097×10^{-7} MWe/m^2); Standby Power: 0.0 W/heliostat

2. Heliostat Operating Modes: The Collector Subsystem reflects solar radiation onto the Receiver Subsystem in a manner which satisfies receiver incident heat flux requirements. In addition, the Collector Subsystem will execute alternative drive modes in response to commands from the Master Control Subsystem for emergency defocusing of the reflected energy or to protect the heliostat array against environmental extremes. The

heliostat will be properly positioned for repair or maintenance in response to either master control or local commands. Heliostat design provides for stored or safe position for use at night, during periodic maintenance and during adverse weather conditions.

3. Control System Characteristics: See Section 5.7.2, Volume II.

4. Operation and Survival Versus Environmental Conditions: The heliostat operation and survival meets the environmental conditions specified in the Systems Requirement Definition, as discussed in Reference 5-1.

   Maximum temperature for operation = 40°C (104°F)

   Minimum temperature for operation = 0°C (32°F)

   Maximum windspeed for heliostat operation, per Reference 5-1, pg 6-23, is 16.1 m/s (36 mph).

5. Field efficiency values, F(θa,θe) for the 12,484 heliostat field are given below. These values are based on MIRVAL analysis and include effects of the aiming strategy discussed in Section 5.3 of this report. These efficiencies include an average reflectivity of 0.90.

		SUN AZIMUTH ANGLE, DEGREES						
		0	30	60	75	90	110	130
SUN ELEVATION ANGLE, DEGREES	5	.282	.282	.274	.255	.245	.240	.237
	15	.527	.520	.495	.4763	.460	.452	.448
	25	.616	.612	.600	.581	.569	.555	.551
	45	.685	.683	.668	.655	.634	.622	.616
	65	.703	.699	.686	.670	.658	.650	.647
	89.5	.690	.689	.687	.684	.679	.676	.677

II. RECEIVER SUBSYSTEM

A. Design Characteristics

1. Receiver height = 30.8 m (101 ft)
   Receiver width = 26.7 m (87.6 ft)
   Receiver depth = 26.7 m (87.6 ft)

2. Area of Apertures:

North	16.5 m (54.1 ft) square	=	272.3 m^2 (2942 ft^2)
South	10.6 m (34.8 ft) square	=	112.4 m^2 (1214 ft^2)
East	14.6 m (47.9 ft) square	=	213.2 m^2 (2303 ft^2)
West	14.6 m (47.9 ft) square	=	213.2 m^2 (2303 ft^2)
			811.1 m^2 (8762 ft^2)

Area of Absorbing Surfaces: (Assumes all panels are flat surfaces, i.e., does not account for circumferential tube surface area. Includes front and back surfaces for panels with two sided heating. Only active surfaces are included.)

North:	back wall	=	99.0 m^2 (1065.6 ft^2)
	east side wall	=	233.0 m^2 (2507.7 ft^2)
	west side wall	=	233.0 m^2 (2507.7 ft^2)
South:	back wall	=	72.0 m^2 (775.0 ft^2)
	east side wall	=	126.6 m^2 (1362.4 ft^2)
	west side wall	=	126.6 m^2 (1362.4 ft^2)
East:	back wall	=	80.4 m^2 (865.8 ft^2)
	north side wall	=	197.7 m^2 (2128.5 ft^2)
	south side wall	=	151.1 m^2 (1626.9 ft^2)
West:	back wall	=	80.4 m^2 (865.8 ft^2)
	north side wall	=	197.7 m^2 (2128.5 ft^2)
	south side wall	=	151.1 m^2 (1626.9 ft^2)
	Total	=	1748.6 m^2 (18823.2 ft^2)

3. Absorber Tube:

OD = 38.1 mm (1.5 in.)
ID = 34.8 mm (1.37 in.)
Wall = 1.65 mm (0.065 in.)

4. Absorber tube lengths (east zone listed, west zone identical)

Panel	1	20.5 m	(67.3 ft)
	2	23.0 m	(75.5 ft)
	3	23.0 m	(75.5 ft)
	4	22.7 m	(74.5 ft)
	5	22.0 m	(72.2 ft)
	6	21.3 m	(69.9 ft)
	7	19.1 m	(62.7 ft)
	8	19.1 m	(62.7 ft)
	9	18.8 m	(61.7 ft)
	10	18.0 m	(59.1 ft)
Total per Zone		207.5 m	(681.1 ft)

5. Number of panels = 20

Number of tubes/panel = 78

6. Panel materials -Incoloy 800
Total mass of panels = 49,146 Kg (108,350)
Mass per panel (east zone listed, west zone identical)

1	2,428 Kg	(5,353 lbs)
2	2,724 Kg	(6,005 lbs)
3	2,724 Kg	(6,005 lbs)
4	2,688 Kg	(5,926 lbs)
5	2,605 Kg	(5,743 lbs)
6	2,522 Kg	(5,560 lbs)
7	2,262 Kg	(4,987 lbs)
8	2,262 Kg	(4,987 lbs)
9	2,226 Kg	(4,908 lbs)
10	2,132 Kg	(4,701 lbs)
Total Per Zone	24,573 Kg	(54,175 lbs)

7. Heat Pipe Material - not applicable.

8. Header Material - Incoloy 800
Total Mass of Headers = 5941 Kg (13, 097 lbs)
Mass per header, includes upper and lower header (east zone listed, west zone identical)

Panel	1	302 Kg	(666.12 lb)
	2	277 Kg	(609.82 lb)
	3	302 Kg	(666.12 lb)
	4	302 Kg	(666.12 lb)
	5	302 Kg	(666.12 lb)
	6	302 Kg	(666.12 lb)
	7	277 Kg	(609.82 lb)
	8	302 Kg	(666.12 lb)
	9	302 Kg	(666.12 lb)
	10	302 Kg	(666.12 lb)
Total per Zone	=	2,970 Kg	(6548.6 lbs)

9. Insulation Material:

Duraback, Fiberfax Ceramic Fiber
The Carborundum Company
P.O. Box 808
Niagara Falls, NY 14302

Total mass of insulation: 26,631 Kg (58,710 lbs)

10. Structure Material:

Standard A36 steel sections
14 ga Corrigated steel siding
.0008m (.032 in.) industrial aluminum roof covering

Total mass of structure (including siding, roofing and doors) = 666,476 Kg (1,469,304 lbs).

11. Support Material:

Standard A36 steel sections

Total mass of support structure = 39,817 Kg (87,780 lbs).

12. Piping Material: Incoloy 800 and 347 cres.

Total mass of receiver piping (excluding panels, headers, valves and tower riser and downcomer) = 16,508 Kg (36, 393 lbs).

13. Valve Material: 347 cres

Valves (Receiver only)

2	.3048 m (12 in.) @ 408 Kg (900 lb) ea	= 816.0 Kg (1800 lb)
8	.1016 m (4 in.) @ 36.3 Kg (80 lb) ea	= 210.4 Kg (640 lb)
10	.0508 m (2 in.) @ 8.2 Kg (18 lb) ea	= 82.0 Kg (180 lb)
	Total per receiver	= 1188.4 Kg (2,620 lb)

14. Receiver Pumps - not applicable

15. Other Receiver Items:

Absorber panel lateral support pipe	=	28,121 Kg (61,994 lbs)
Pipe supports, valve supports, access ladders, railing, gratings, insulation attachments, etc.	=	9,307 Kg (20,517 lb)
Door hoist mechanisms	=	6,753 Kg (14,888 lb)
Total other items/receiver	=	44,181 Kg (97,399 lb)

16. Total Dry Mass on Top of Tower: 849,889 Kg (1,873,653 lbs)

17. Total Mass of Receiving Working Fluid

(excluding tower riser and downcomer) = 127,348 Kg (280,749 lbs)

18. Receiver operational seismic load (at the aperture centerline elevation):

    Vertical acceleration $\leq 0.45g$
    Horizontal acceleration $\leq 0.16g$

19. Receiver survival seismic load (at the aperture centerline elevation):

    Vertical acceleration $\leq 0.75g$
    Horizontal acceleration $\leq 0.317g$

20. Receiver is designed to meet Section I of the ASME Boiler and Pressure Vessel Code.

21. Optical Characteristics:

    Pyromark series 2500 high temperature protective coating
    Tempil Division
    Big Three Industries, Inc.
    South Plainfield, NJ 07080

    Panel absorbing surfaces, $\alpha_s=0.95$, $\epsilon=0.90$

    Inactive Surfaces, $\alpha_s=0.32$, $\epsilon=0.84$

22. Receiver pressure drop correlations: see 5.3.3

23. Receiver heat transfer correlations: see 5.3.3

24. Receiver heat transfer correlations (for receiver losses): see 5.3.4

25. Tower Construction: Reinforced concrete conical tower, 156.67 m (514 ft) to top of tower.

26. Riser Material: Carbon steel

    OD/ID/Wall, mm(in): 457.2(18)/SCH 60

    Downcomer material: 347 SS

    OD/ID/wall, mm(in): 457.2 (18)/SCH 10, SCH 20, SCH 30

27. Riser/downcomer total lengths, m(ft): 701 (2300) (Two Modules)

28. Mass of riser/downcomer, kg(lb): 113465.3 (250,191) (Two Modules)

29. Riser insulation material: Calcium silicate or equivalent

    Thickness, mm(in): 152.4 (6)

    Downcomer insulation material: Calcium silicate or equivalent

    Thickness, mm(in): 228.6 (9)

30. Mass of Riser/Downcomer insulation, kg(lb): 55056.7 (121,400)
(Two Modules)

32. Horizontal piping material: Cold Lines: C.S. A106 GR.B
Hot Lines: S.S. A347S

Thickness: Cold Lines: SCH 10
Hot Lines: SCH 30

33. Horizontal piping total lengths, m(ft): 6754.4 (22,160)

34. Mass of horizontal piping, kg (lb): 695692 (1,534,000)

35. Horizontal piping insulation material: Calcium silicate or equivalent, thickness, mm(in): 152.4 (6); 228.6 (9).

36. Mass of horizontal piping insulation, kg(lb): 367,347 (810,000)

37. Valve material: stainless steel

Size of valves, mm(in): 101.6 (4); 304.8-406.4 (12-16); 457.2 (18); 19.05 (3/4)

38. Number of valves (ground level only): 66

Mass of valves, kg(lb): 77,098 (170,000)

39. Receiver booster pumps: PP-105 A,B,S and PP-106A,B,S
Pump material: S-5 Carbon Steel
Number of pumps: Four operating, two spares
Mass of receiver pumps, kg(lb): 10748.3 (23700) ea. pump
64489.8 (142200) total

PP-102 A,B,C,D,S: Main Circulation Pumps
Material: S-5 carbon steel
Number: Four operating; one spare
Mass, Kg(lb): 14,125.2 (6406) ea.

PP 101: Salt transfer pump (from melt tank to cold storage tank)
Material: S-5 Carbon Steel
Number: One operating
Mass; kg(lb): 407.7 (899) ea. pump

PP-107A,S: Water Recirculation Pump
Material: C-6 Carbon Steel
Number: One operating; one spare
Mass, kg(lb): 963.7 (2125) ea. pump
1927.4 (4250) total

40. Pump Characteristics for Receiver Subsystem Pumps

PP-101: Salt Transfer Pump
Type: Centrifugal
Speed: 1750 rpm
Head: 17.1 m (56 ft)
NPSH: .914 m (3 ft)
Operating Temperature: 288°C (550°F)
Power: 6.11 KW (8.2 HP)
Capacity: .0216 m^3/s (200 gpm)

PP-102A,B,C,D,S: Main Circulation Pumps
Type: Centrifugal
Speed: 1750 rpm
Head: 44.2 m (145 ft)
NPSH: 5.18 m (17 ft)
Operating Temperature: 288°C (550°F)
Power: 2.57 KW (3.44 HP)
Capacity: .2601 m^3/s (4,125 gpm)

PP-105 A,B,S, and PP-106 A,B,S: Receiver Booster Pumps
Type: Centrifugal
Speed: 3550 rpm
Head: 294.1 m (965 ft)
NPSH: 12.80 m (43 ft)
Operating Temperature: 288°C (550°F)
Power: 1883.6 KW (2526 HP)
Capacity: .2601 m^3/s (4125 gpm)

PP-107 A,S: Water Recirculation Pump
Type: Centrifugal
Speed: 3350 rpm
Head: 38.40 m (126 ft)
NPSH: 2.44 m (8 ft)
Operating Temperature: 330°C (625°F)
Power: 5.47 KW (7.7 HP)
Capacity: .0158 m^3/s (250 gpm)

41. Steam Generator Heat Exchanger Characteristics

TT-101
Service: Boiler feedwater preheater
Number Required: One
Type: NEN (TEMA Standard)
Orientation: Horizontal
Number of Tube Passes: One
Number of Shell Passes: One
Tube Side Fluid: Boiler feedwater
Shell Side Fluid: Molten draw salt
Tube Material: Carbon Steel
Shell Material: Carbon Steel
Number of Tubes: 3395
Tube OD/ID/Wall, mm(in): .159 (5/8)
Tube Layout and Pitch Dimension, mm (in): ⇔ 30 19.84 (25/32)
Baffle Type and Spacing, mm(in): Triple segment, 404.8 (15 15/16)
Unit Size (tube length/Hx I.D.), m(ft): 12.19 (40)/1.19 (3.92)
Mass Per Unit, kg(lb): 59637.2 (131,500)
Active External Surface Area Per Unit, $m^2(ft^2)$: 2064.2 (22220)
LMTD, °C(°F): 8.372 (47.07)

TT-102
Service: Steam generator
Number Required: One
Type: NEN (TEMA Standard)
Orientation: Vertical
Number of Tube Passes: One
Number of Shell Passes: One
Tube Side Fluid: Boiler feedwater/steam
Shell Side Fluid: Molten draw salt
Tube Material: 1 Cr ½Mo
Shell Material: 1 Cr ½Mo
Number of Tubes: 3200
Tube OD/ID/Wall: .1905 (3/4)
Tube Layout and Pitch Dimension, mm(in): ⇔ 30 23.81 (15/16)
Baffle Type and Spacing, mm (in): Triple segment 450.9 (17 3/4)
Unit Size (tube length/Hx I.D.), m(ft): 12.9 (40)/1.47 (4.83)
Mass per Unit, kg(lb): 87,466 (192,600)
Active External Surface Area per Unit, $m^2(ft^2)$: 2334.9 (25133)
LMTD, °C(°F): 28.27 (84.14)

TT-103
Service: Steam superheater
Number Required: One
Type: NEN (TEMA Standard)
Orientation: Horizontal
Number of Tube Passes: One
Number of Shell Passes: One
Tube Side Fluid: Steam
Shell Side Pump: Molten draw salt
Tube Material: 347 SS
Shell Material: 347 SS
Number of Tubes: 2242
Tube OD/ID/Wall, mm(in): .159 (5/8)
Tube Layout and Pitch Dimension, mm(in): ↔ 30 19.84 (25/32)
Baffle Type and Spacing, mm(in): Triple segment, 409.6 (16' 1/8")
Unit Size (tube length/Hx I.D.), m(ft): 12.19 (40)/1.04 (3.42)
Mass per Unit, kg(lb): 62630 (138,100)
Active External Surface Area per Unit, $m^2(ft^2)$: 1363.2 (14674)
LMTD, °C(°F): 42.44 (108.4)

TT-104
Service: Steam reheater
Number Required: One
Type: NEN (TEMA Standard)
Orientation: Horizontal
Number of Tube Passes: One
Number of Shell Passes: One
Tube Side Fluid: Steam
Shell Side Fluid: Molten Draw Salt
Tube Material: 347 SS
Shell Material: 347 SS
Number of Tubes: 2481
Tube OD/ID/Wall, mm(in): .159 (5/8)
Tube Layout and Pitch Dimension, mm (in): ↔ 30 19.84 (25/32)
Baffle Type and Spacing, mm(in): Triple segment, 409.6 (16 1/8)
Unit Size (tube length/Hx I.D.), m(ft): 9.14 (30)/1.07 (3.5)
Mass per Unit, kg(lb): 40,000 (88,200)
Active External Surface Area per Unit, $m^2(ft^2)$: 1131.5 (12180)
LMTD, °C(°F): 37 (102.2)

B. Operating Characteristics

1. Receiver Incident Power (Noon Day 172)

Panel (East zone listed, West zone identical)	@ Maximum Insolation MWt(990 W/m^2)	@ Design Point Insolation MWt(950 W/m^2)	@ Minimum Operating Condition MWt
1	19.8	19.1	
2	24.5	23.5	
3	37.9	36.4	
4	41.2	39.5	
5	19.3	18.5	Not Determined
6	3.1	3.1	
7	14.1	13.6	
8	28.7	27.6	
9	18.7	17.9	
10	3.2	3.1	
Total per Zone	210.5	202.3	Not Determined
Total per Receiver	421.0	404.5	

2. Receiver Absorbed Power (incident minus solar reflected) noon day 172

Panel (East zone listed, West zone identical)	@ Maximum Insolation MWt(990 W/m^2)	@ Design Point Insolation MWt(950 W/m^2)	@ Minimum Operating Condition MWt
1	19.4	18.7	
2	24.0	23.0	
3	37.2	35.7	
4	40.4	38.7	
5	18.9	18.1	Not Determined
6	3.2	3.1	
7	13.5	13.0	
8	28.1	27.0	
9	18.3	17.6	
10	3.3	3.2	
Total per Zone	206.3	198.1	Not Determined
Total per Receiver	412.6	396.2	

3. Flux Maps: See 5.3.2.7

4. Peak Flux Absorbed (incident minus solar reflected solar), noon day 172

   @ maximum insolation (panel 2) = .607 MWt/m^2 ($191.7x10^3$ $Btu/hr-ft^2$)

   @ design point insolation (panel 2) = .582 MWt/m^2 ($184x10^3$ $Btu/hr-ft^2$)

5. Average Flux Absorbed (incident minus reflected solar), noon day 172 (Surface area, 1748.6 m, defined in II.A.2)

   @ maximum insolation: $\frac{412.6 \text{ MWt}}{1748.6 \text{ m}^2} = 0.236 \text{ MWt/m}^2$

   @ design point insolation: $\frac{396.2 \text{ MWt}}{1748.6 \text{ m}^2} = 0.227 \text{ MWt/m}^2$

   @ minimum operating condition: not determined

6. Salt temperature into receiver = 288°C (550°F)

   Salt temperature out of receiver = 566°C (1050°F)

7. Receiver working fluid operating pressure:

   in = 2.206 MPa (320 psig)

   out = 0.103 MPa (15 psig)

8. Receiver working fluid flow rates:

   @ maximum insolation -

   per panel = $1.619x10^6$ Kg/hr ($3.569x10^6$ lb/hr)
   total = $3.238x10^6$ Kg/hr ($7.139x10^6$ lb/hr)

   @ design point insolation -

   per panel = $1.548x10^6$ Kg/hr ($3.413x10^6$ lb/hr)
   total = $3.096x10^6$ Kg/hr ($6.826x10^6$ lb/hr)

   @ minimum operating condition - not determined

9. Receiver working fluid velocities: See 5.3.3

10. Receiver losses: See 5.3.4.2 and 5.3.4.3

11. Peak metal temperatures in receiver: See 5.3.4.3

12. Peak working stress in receiver: See 5.3.2.5

13. Fatigue life: See 5.3.2.5 and 5.3.3

14. Receiver heat transfer coefficients: See 5.3.3

15. Receiver ramp rate:

Expected average ramp rate = 3% of maximum absorbed power per minute.

16. Steam generator heat exchanger discharge rate (with collector field operating and storage being charged), design:

Total, MWt: 263.61

Unit	Name	Rate, MWt
TT-101	Boiler Feedwater Preheater	50.26
TT-102	Steam Generator	106.1
TT-103	Steam Superheater	71.62
TT-104	Steam Reheater	35.63

17. Working fluid (salt) operating temperatures:

Unit	Name	In, °C(°F)	Out, °C(°F)
TT-101	Boiler feedwater preheater	340.3(644.4)	287.9(550)
TT-102	Steam generator	451.0(843.6)	340.3(644.4)
TT-103	Steam superheater	562.9(1045)	451(843.6)
TT-104	Steam reheater	562.9(1045)	451(843.6)

18. Water/steam operating temperatures:

Unit	Name	In, °C(°F)	Out, °C(°F)
TT-101	Boiler feedwater preheater	237.9(460)	328.9(623.8)
TT-102	Steam generator	328.9(623.8)	328.0(623.8)
TT-103	Steam superheater	328.9(623.8)	539.1(1002)
TT-104	Steam reheater	339.8(643.3)	539.1(1002)

19. Working fluid (salt) operating pressures:

Unit	Name	In, KPag(psig)	Out, KPag(psig)
TT-101	Boiler feedwater preheater	489.7(71)	420.7(61)
TT-102	Steam generator	551.8(80)	510.4(74)
TT-103	Steam superheater	648.4(94)	565.6(82)
TT-104	Steam reheater	648.4(94)	631.1(92)

20. Water/steam operating pressures:

Unit	Name	In, Kpag (psig)	Out, Kpag(psig)
TT-101	Boiler feedwater preheater	12,656(1835)	12,649(1834)
TT-102	Steam generator	12,643(1833)	12,566(1822)
TT-103	Steam superheater	12,553(1820)	12,519(1815)
TT-104	Steam reheater	2,800(405)	2,731(396)

21. Working fluid (salt) flow rates:

Total

design, kg/hr (lb/hr): 617.5 ($4.901x10^6$)

TT-101 Boiler Feedwater Preheater

design, kg/hr(lb/hr): 617.5 ($4.901x10^6$)

TT-102 Steam Generator

design, kg/hr(lb/hr): 617.5 ($4.901x10^6$)

TT-103 Steam Superheater

design, kg/hr(lb/hr): 412.2 ($3.272x10^6$)

TT-104 Steam Reheater

design, kg/hr(lb/hr): 205.2 ($1.628x10^6$)

22. Water/steam flowrates

Total

design, kg/hr(lb/hr): 102.4 ($8.133x10^5$)

TT-101: Boiler Feedwater Preheater

design, kg/hr(lb/hr): 102.4 ($8.133x10^5$)

TT-102: Steam Generator

design, kg/hr(lb/hr): 92.28 ($7.326x10^5$)

TT-103: Steam Superheater

design, kg/hr(lb/hr): 92.28 ($7.326x10^5$)

TT-104: Steam reheater

design, kg/hr(lb/hr): 79.42 ($6.303x10^3$)

23. Steam Generator Heat Transfer Coefficients, W/m^2-°C (Btu/h-ft^2-°F)

(All coefficients and resistances are based on outside tube surface area. The breakdown of heat transfer coefficients listed were calculated for purpose of specifying heat exchangers for quotes and is reflected in the "overall calculated." The "overall for design" was used for system design purposes.)

	TT-101	TT-102	TT-103	TT-104
tube side	2190.1 (385.8)	4420.5 (778.7)	1669.0 (294.0)	985.5 (173.6)
tube fouling	0.0036 (0.00063)	0.0036 (0.00064)	0.0036 (0.00063)	0.0036 (0.00063)
tube wall	0.0012 (0.00021)	0.0015 (0.00027)	0.0031 (0.00054)	0.0031 (0.00054)
shell fouling	0.0028 (0.0005)	0.0028 (0.0005)	0.0028 (0.0005)	0.0028 (0.0005)
shell side	3167.1 (557.9)	2885.0 (508.2)	4496.0 (792.0)	2711.8 (477.7)
overall (calculated)	992.3 (174.8)	1218.2* (214.6)	895.8 (157.8)	596.1 (105)
overall (for design)	970.7 (171)	1004.8 (177)	894.7 (157.6)	567.7 (100)

*Flux limiting design

III. STORAGE SUBSYSTEM

A. Design Characteristics

1. Storage Media: Molten draw salt (60% KNO_3, 40% $NaNO_3$)

   Specific Heat: 1.553 Kj/kg/°C (.371 Btu/lb/°F)

   Viscosity, cp: 3.4 at 288°C (550°F)
   0.9 at 566°C (1050°F)

   Density, Kg/m^3 (lb/ft^3): 7.44 (119.2) at 288°C (550°F)
   6.72 (107.6) at 566°C (1050°F)

2. Storage Media Mass: 19,195,328 Kg (42,325,700 lb) each tank (2 tanks)

3. Tank Characteristics

3.1 MF-103 A/B: Hot salt storage

Number of tanks: two

Tank geometry and dimensions, m(ft)
Diameter: 29.2 (96.0)
Height: 17.3 (57)

Tank volume, m^3 (ft^3): 11,683 (412,578)

Tank material: SA-516, grade 70

Tank shell design temperature, °C(°F): 315 (600)

Tank mass, kg(lb): 380950 (840,000) ea.
761900 (1,680,000) total

Tank surface area:

top, m^2 (ft^2):	840 (9047)	1680 (18094) Total
side, m^2 (ft^2):	1597 (17,190)	3194 (34380) Total
Bottom, m^2 (ft^2):	672 (7238)	1344 (14476) Total
Total, m^2 (ft^2):	13994 (45916)	27988 (91832) Total

Tank insulation material:

External insulation:	Top	- Duraboard
	Sides	- Fiberglass
	Bottom	- Insulating concrete (actively cooled)
Internal Insulation:	Top	- Duraboard
	Sides	- Krylite 30
	Bottom	- Krylite 30
Liner Material:	347 SS	

External insulation thickness, mm(in):

Top - 152.4 (6)
Sides - 203.2 (8)
Bottom - 304.8 (12)

Internal insulation thickness, mm(in):

Top - 152.4 (6)
Sides - 228.6 (9)
Bottom - 228.6 (9)

3.2 MF-102 A/B: Cold salt storage

Number of tanks: Two

Tank Geometry and dimensions, m(ft):

Diameter: 26.2 (86)
Height: 19.2 (63)

Tank volume, m^3 (ft^3): 10364 (365,960)

Tank material: SA-516 Grade 70

Tank shell design temperature, °C(°F): 315 (600)

Tank mass, kg(lb): 314020 (692,450) ea.
628040 (1,384,900) Total

Tank surface area:

Top, m^2(ft^2):	674 (7261)	1348 (14522) Total
Side, m^2(ft^2):	1581 (17021)	3162 (34042) Total
Bottom, m^2(ft^2):	539 (5808)	1078 (11616) Total
Total, m^2(ft^2):	2794 (30090)	5588 (60180) Total

Tank insulation, external:

Top: Duraboard
Sides: Duraboard
Bottom: Insulating concrete

External insulation thickness, mm(in):

Top: 101.6 (4)
Sides: 152.4 (6)
Bottom: 304.8 (12)

3.3 <u>MF-106: Hot salt sump</u>

Number of tanks: One

Tank geometry and dimensions; m(ft):
Diameter: 10.2 (33.5)
Height: 3.04 (10)

Tank volume, m^3 (ft^3): 597 (6430)

Tank material: SA-516, grade 70

Tank shell design temperature, °C(°F): 315 (600)

Tank mass, kg(lb): 14965 (33000)

Tank surface area:

Top, $m^2(ft^2)$: 81.7 (880)
Side, $m^2(ft^2)$: 97.7 (1052)
Bottom, $m^2(ft^2)$: 81.7 (880)
Total (single tank), $m^2(ft^2)$: 261.1 (2812)

Tank insulation:

External insulation:	Top	- Duraboard
	Sides	- Fiberglass
	Bottom	- Brick
Internal insulation:	Top	- Duraboard
	Sides	- Krylite 30
	Bottom	- Krylite 30
Liner Material:	347SS	

External insulation thickness, mm(in):

Top	- 152.4 (6)
Sides	- 203.2 (8)
Bottom	- 254.0 (10)

Internal insulation thickness, mm(in):

Top	- 152.4 (6)
Sides	- 152.4 (6)
Bottom	- 152.4 (6)

4. Piping material, OD/ID/Wall, mm(in):

   Cold Lines: Carbon Steel A-106 GR.B, 457.2 (18) SCH 60

   Hot Lines: Stainless Steel A-347 S, 457.2 (18) SCH 10

5. Piping total lengths, m (ft): 377.95 (1240)

6. Mass of piping, kg(lb): 39002 (86,000)

7. Piping insulation material: Calcium silicate or equivalent

   Piping insulation thickness, cold, hot, mm(in.): 152.4 (6); 228.6 (9)

8. Mass of piping insulation, kg (lb): 22902 (50,500/lbs)

9. Pump material, number and mass of storage pumps

PP-103 A,B,S:	Hot salt pump
Material:	347 SS
Number:	two operating; one spare
Mass., Kg(lb):	7936.5 (17,500) ea.

10. Pump characteristics for all storage subsystem pumps

PP-103 A,B,S:	Hot salt pump
Type:	Vertical cantilever
Speed:	880 rpm
Head:	49.07 m (161 ft)
NPSH:	4.267 m (14 ft)
Operating Temperature:	566°C (1050°F)
Power:	216.9 kw (291 hp)
Capacity:	.1892 m^3/s (3000 gpm)

B. <u>Operating Characteristics</u>

1. Extractable capacity, MWHt (Btu): 4445.46 ($1.52x10^{10}$)

2. Charging rate:

Maximum, MWt:	775 MWt
Design, MWt:	479 MWt
Minimum, MWt:	0

3. Discharging rate:

Maximum, MWt:	296.44
Design, MWt:	247.03
Minimum, MWt:	41.17

4. Duration

    Design discharge rate, hrs: 18.0

5. Storage media operating temperatures (hot/cold) °C(°F):

    566°/288° (1050°/550°)

6. Storage tank operating pressures

    for fully charged storage, hot tank:

top, kPa (psig)	101.4 (14.7)
bottom, kPa (psig)	286.9 (41.6)

    for fully discharged storage, cold tank:

top, kPa (psig)	101.4 (14.7)
bottom, kPa (psig)	368.1 (51.2)

7. Heat loss rate,

    for fully charged storage, MWt: .627

    for fully discharged storage, MWt: .326

8. Storage ramp rate, % of maximum discharge power per minute: Not identified.

IV. <u>ELECTRIC POWER GENERATION SUBSYSTEM</u>

A. <u>Design Characteristics</u>

1. Turbine Generator: Single shaft, 3600 rpm, tandem compound, two-flow, reheat, condensing unit. Nameplate rating: 110.96 MWe.

2. Turbine Inlet conditions

Temperature:	538°C (1000°F)
Pressure:	12.41 MPag (1800 psig)
Flowrate:	331,200 kg/hr (731,800 lbm/hr)

3. Turbine Hot Reheat conditions

Temperature:	538°C (1000°F)
Pressure:	2.69 MPag (385 psig)
Flowrate:	273,600 kg/hr (630,300 lbm/hr)

Turbine Cold Reheat conditions

Temperature:	340°C (643°F)
Pressure:	2.95 MPag (428 psig)
Flowrate:	273,600 kg/hr (630,300 lbm/hr)

4. Feedwater Heaters:

   Feedwater Heater 1, Horizontal U-tube, .54 MW (1.95x10^6 Btu/h)

   Feedwater Heater 2, Horizontal U-tube, 11.6 MW (39.6x10^6 Btu/h)

   Feedwater Heater 3, Horizontal U-tube, 10.3 MW (35.0x10^6 Btu/h)

   Feedwater Heater 4, Horizontal U-tube, 6.8 MW (23.3x10^6 Btu/h)

   Feedwater Heater 6, Horizontal U-tube, 9.8 MW (33.5x10^6 Btu/h)

   Feedwater Heater 7, Horizontal U-tube, 21.5 MW (73.5x10^6 Btu/h)

   Deaerator 5, Direct contact tray, 6.0 MW (20.5x10^6 Btu/h)
   5 ppm (0.005 CC/L Oxygen) Max

5. Condenser type and configuration:

   Single pressure, single-shell, divided waterbox, one pass — 4108 m^2 (45000 ft^2)

6. Feedwater Pumps: (2) multistage, horizontal split case

   0.056 m^3/s (885 gpm) at 1565 m (5134 ft)

7. Auxiliary Steam Supply: Not identified.

8. Sealing Steam Requirements: Not identified.

9. Turbine Startup and Shutdown Characteristics: Not identified; standard turbine.

10. Nonsolar Energy Source Design: 50 MWe oil-fired salt heater

Heat Transfer Surface Description

Item	Effective Heat Transfer Area m^2 (ft^2)	No. of Tubes	Tube Size O.D. mm(in)	Tube Size Min. Wall mm(in)
Economizer	175(1880)	200	57.15(2-1/4)	4.572(0.180)
HRA Section				
Walls	309(3330)	365	50.80(2)	4.191(0.165)
Primary Bundle	1173(12630)	225	38.10(1-1/2)	4.191(0.165)
Secondary Bundle	1173(12630)	225	38.10(1-1/2)	4.191(0.165)
Furnace				
Floor	5(50)	106	63.50(2-1/2)	4.572(0.180)
Rear Wall	74(800)	192	34.925(1-3/8)	5.588(0.220)
Sides, Front Wall and Roof	229(2460)	360	34.925(1-3/8)	4.191(0.165)
Division Wall	92(990)	130	34.925(1-3/8)	4.191(0.165)
Finishing Pendants	632(6800)	675	34.925(1-3/8)	4.191(0.165)
Total Heat Transfer Area	3862(41570)			

Salt Heater Tube Material and Weight

	Tube Material & Weight (Tons) Carbon Steel SA-106C	(1 CR - 1/2 Mo) SA 213-T 12	347SS SA 213-347	Cumulative Tube Weight (tons)
Economizer	6.2			6.2
HRA Section				
Walls	40.0			46.2
Primary Bundle		35.0		81.2
Secondary Bundle			35.0	116.2
Furnace				
Floor	6.1			122.3
Rear Wall		11.5		133.8
Sides, Front Wall, and Roof		30.5		164.3
Division Wall			5.3	169.6
Finishing Pendants			24.0	193.6
	52.3	77.0	64.3	

Overall dimensions: 6.7m (22 ft) Width; 14.0m (46 ft) Length; 15.0m (50 ft) Height

Salt Heater Auxiliaries

Firing Equipment

Mfg:	Forney Engineering
Model:	4-PAF, 2 POM, 150 MKB, QAAH

Soot Blowers

Mfg:	Copes Vulcan
Model:	T-30, TEC

FD Fan & Drive

Fan Mfg:	Westinghouse
Model:	4054, DWDI, Arr 3, Cl 1800
Operating Power:	kW (BHP) 572 (767)
Weight:	M kg (M lb) 15 (33)
Drive Mfg:	General Electric
Model:	1000 HP, 1800 RPM, WP Cl II
Voltage:	3ϕ, 60C, 4000V
Frame:	8309 S
Weight:	M kg (M lb) 4 (8)

Air Heater

Mfg:	Air Preheater
Model:	24HR66
Operating Power:	kW (BHP) 10 (8)
Weight:	M kg (M lb) 114 (251)

M = Thousand

Salt Heater Salt Pump

Pump Characteristic

PP-104 A,S:	salt heater booster pump
Material:	S-5 Carbon Steel
Number:	One operating; one spare
Mass; kg(lb):	4383.7 (9666) ea. pump 8767.4 (19332) total

Pump Performance

PP-104 A,S:	salt heater booster pumps
Type:	Centrifugal
Speed:	1776 rpm
Head:	110.9 m (364 ft)
NPSH:	4.57 m (15 ft)
Operating Temperature:	288°C (550°F)
Power:	510.06 KW (684 HP)
Capacity:	.1892 m^3/s (3000 gpm)

11. Non-solar emission level limits:

NO_x = 0.3 lb per million Btu

SO_x = 0.75 lb per million Btu

particulates = 99.5% efficiency for electrostatic precipitators

B. Operational Characteristics

1. EPGS

	Receiver Operation	Storage Operation	Nonsolar* Operation
Gross Turbine Cycle Eff.	.424	.424	.424
Net Turbine Cycle Eff.	.382	.4058	.4003
Fraction of Turbine Cycle Heat Input - Solar	1.00	1.00	0.00
Gross Cycle Heat Rate Kj/kW-hr (Btu/kW-hr)	8495 (8052)	8495 (8052)	8495 (8052)
Net Cycle Heat Rate kJ/kW-hr (Btu/kW-hr)	9425 (8934)	8872 (8409)	8995 (8511)
Turbine Back Pressure,kPa(in)	8.5(2.5)	(8.5(2.5)	8.5(2.5)
Feedwater Temperature,°C(°F)	230(446)	230(446)	230(446)
Flowrate to Turbine, kg/hr (lb/hr)	$3.31x10^3$ $(7.32x10^3)$	$3.31x10^3$ $(7.32x10^3)$	$3.31x10^3$ $(7.32x10^3)$
Auxiliary Loads (MWe)			
EPGS	4.55	4.26	4.26
Nonsolar Support	-	-	.35
Nonsolar Energy Source	-	-	.55
Collector	.62	-	
Pumps	5.79	.455	1.012
Total	10.96	4.715	6.172
Net Electrical Output	100 MWe	106.25 MWe	104.79 MWe

*Nonsolar plus storage operation to provide 100 MWe net

2. Nonsolar Fuel: Number 6 Fuel Oil

3. Fuel Characteristics:

Elemental Composition (% by weight)

S	0.7
H_2	11.2
C	86.6
H_2O	0.37
N_2	0.58
O_2	0.55
	100.00

Specific gravity	=	0.972 @ 288°K (60°F)
Viscosity	=	500 centistokes @ 311°K (100°F)
Pour point	=	283°K (50°F)
Vanadium	=	366 ppm
Sodium	=	36 ppm
Nickel	=	43 ppm
Iron	=	3 ppm
Ash	=	0.05% by weight

4. Fuel Heating Value (as fired):

10438 Kcal/Kg (18785 Btu/lb)

5. Fuel Burning Rate:

12600 Kg/hr (27,720 lb/hr)

6. Nonsolar Discharge Rate, Design: 133 MWt (452×10^6 Btu/hr)

7. Gas Operating Temperatures; Design:

Temp. air leaving FD fan	38°C (100°F)
Temp. air leaving air heater	371°C (700°F)
Temp. gas leaving furnace	1213°C (2215°F)
Temp. gas entering primary bundle	501°C (933°F)
Temp. gas entering secondary bundle	827°C (1520°F)
Temp. gas leaving economizer	418°C (785°F)
Temp. gas leaving air heater	143°C (290°F)

8. Working Fluid (Salt) Operating Temperatures, Design:

   Salt Temperature, Inlet: 288°C (550°F)

   Salt Temperature, Outlet: 566°C (1050°F)

9. Working Fluid (Salt) Operating Pressures, Design:

   Salt Pressure, Inlet: 2758 kPa (400 psi)

   Salt Pressure, Outlet: 483 kPa (70 psi)

   See Section 5.6.3 for complete detail of pressure losses.

10. Working Fluid (Salt) Flow Rates, Design:

    1.098×10^6 Kg/hr (2.415×10^6 lb/hr)

11. Heat Losses, Design Power:

Dry gas	3.81%
Hydrogen and moisture in fuel	6.09%
Moisture in air	0.01%
Unburned combustible	0.0%
Radiation	0.30%
Unaccounted for and mfrs. margin	1.0%
Total losses	11.21%
Efficiency	88.79%

12. Nonsolar Startup and Shutdown Characteristics: See Sect. 5.6.3.2.

APPENDIX F STEAEC INPUTS

The following are the STEAEC program input values and rationale used to derive the yearly performance profile for the 100 MWe hybrid plant.

Note: Input values are given in the units required for input to STEAEC, whether SI or customary system. Where values are given in SI units, the customary equivalent is given in parentheses.

A. CONCOEF - Collector/Receiver Interface

FR - collector field efficiency as a function of azimuth and elevation of sun; includes effects of reflectivity, atmospheric attenuation, heliostat blocking and shading, cosine, tower shadow, tracking and alignment errors, receiver interception ("spillage"), and heliostat reliability.

		AZR - Azimuth (South = 0°)					NY = 7	
		0°	30°	60°	75°	90°	110°	130°
ELR -	5°	0.282	0.282	0.274	0.255	0.245	0.240	0.237
Elevation	15°	0.527	0.520	0.495	0.476	0.460	0.452	0.448
(Horizon	25°	0.616	0.612	0.600	0.581	0.569	0.555	0.551
= 0°)	45°	0.685	0.683	0.668	0.655	0.634	0.622	0.616
	65°	0.703	0.699	0.686	0.670	0.658	0.650	0.647
NX = 6	89.5°	0.689	0.689	0.687	0.684	0.679	0.676	0.677

The azimuth/elevation pairs that are blocked-in in the matrix FR are those through which the sun passes from Barstow, California. Efficiencies for blocking, shading, cosine, tower shadow, and spillage for some of these combinations were obtained using the MIRVAL program with the collector field layout and receiver configuration described earlier. Values for other sun positions, including those that the sun never reaches from Barstow, were extrapolated from these MIRVAL values. The STEAEC default values for FR, derived for a 100 MWe field, were used as a guide. A reflectivity of 0.90 represents the generally accepted value for average reflectivity of the heliostat mirrors between washings.

An MMC atmospheric attenuation model was used in the MIRVAL program. Atmospheric attenuation was calculated to be 0.9419. Heliostat reliability is 0.997 or better.

Tracking and alignment errors were included in the MIRVAL inputs as part of the aiming and focusing parameters, and are therefore part of the spillage efficiencies.

B. CONCOLF - Collector Field

1) FS - Field Size x Number of Fields

$1224755\ m^2\ (13183156\ ft^2) =$

$49.051\ m^2\ (528\ ft^2)$/heliostat x 12484 heliostats/field x 2 fields.

2) ASB - Collector field auxiliary power requirements on standby

$0.0\ MWe/m^2$.

Mirror fields require no power when stowed at night or during high winds.

3) AOL - Collector field auxiliary power requirements on line

$5.097 \times 10^{-7}\ MWe/m^2$.

Heliostats are assumed to require 25.0 watts per heliostat, or

$$\frac{25.0 \text{ watts/heliostat}}{49.051 \text{ m}^2\text{/heliostat}} = 5.097 \times 10^{-7} \text{ MWe/m}^2$$

4) TLIML - Plant dry bulb temperature lower limit = -29°C (-20°F). The contract requirements definition states that heliostat lower operating limit is -29 C (-20°F).

5) TLIMU - Plant dry bulb temperature upper limit = 49°C (120°F). The contract requirements definition states that heliostat upper operating limit is 49 C (120°F).

6) ELIM - Minimum sun elevation for collector field operation

0.0°

Our heliostats begin tracking at 0.0°.

7) WSLIM - Maximum wind speed for collector field operation

12 m/s (27 mph)

The contract requirements definition states that operational wind speeds are 0-12 m/s (0-27 mph).

8) RFLCTY - Efficiency coefficient for atmospheric attenuation and heliostat reliability

1.000

These effects are included in CONCOEF matrix FR.

9) WSEF - Heliostat efficiency as a function of wind speed

WSX - wind speed, m/s (ft/s) NEFWS = 8

(0)	(6.56)	(13.1)	(19.7)	(26.2)	(32.8)	(39.4)	(44.0)
0	2	4	6	8	10	12	13.4
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Heliostat focusing parameters input to the MIRVAL program were those evaluated at survival wind speed (12 m/s (39.4 ft/s)). Because wind speed efficiency has already been accounted for elsewhere, values of WSEF below 12 m/s should actually be greater than 100%; however, we have input values of 1.0 for all wind speeds.

C. CONRCVR - Receiver

1) EPS - Receiver proportional efficiency (absorptivity)

0.98

A TRASYS model was used to determine total energy absorbed by the advanced water steam cavity receiver after allowing for cavity solar radiation interchange. This total energy absorbed was then divided by the incident energy passing through the aperture to determine the cavities effective absorptivity, and similarly the effective absorptivity for the whole receiver.

2) XHR - Startup thermal capacity parameter =

$$\frac{\text{Energy required to heat receiver to operating conditions}}{\text{receiver size x cold-start time}}$$

0.04976

Because we anticipate circulating cold salt (288°C) (550°F) through the receivers at night, "cold" start time as well as the energy required to heat the receivers to operating conditions is minimized. A "cold start," then, means heating the receivers from about 288 C (550°F) to a receiver panel-averaged temperature of 427 C (800°F).

For each receiver, the weight is to be heated is 187,000 kg (413,000 lb) total, including 75,000 kg (166,000 lb) of tubes and 112,000 kg (247,000 lb) of salt, and having an average specific heat of 1130. J/kg-C (0.270 Btu/lb-°F).

The energy, E, required to heat the receiver to operating conditions =

weight heated x average Cp x ΔT or

E = 187,000 kg (413,000 lb) x 1130. J/kg-C
(.270 Btu/lb-°F) x [427 C (800°F) - 288 C (550°F)]

= 2.94 x 10^7 kJ (8.68. kWh) (2.788 x 10^7 Btu)

The rise rate of normal solar flux at sunrise on the equinox (representative of the annual average) is 0.70 kW/m^2-h (222 Btu/h-ft^2-h). The amount of energy available to heat the receiver after sunrise, noting that this rise rate is nearly linear for a short time after sunrise, is E = (solar flux rise rate x time after sunrise) x time after sunrise x ½ x heliostat area per field x efficiency at "leaving receiver" step of stairstep at equinox sunrise = 0.70 kW/m^2-h (222 Btu/h-ft^2-h) x TCS x TCS x ½ x 612378 m^2 (6591578 ft^2) x 0.2503

where TCS = time required for "cold" start.

Because E = energy required to heat receiver to operating conditions, we get TCS = 0.3902 h.

Using RS = receiver size, as defined later.

$$XHR = \frac{8.168 \text{ MWh x 2 receivers}}{0.3902 \text{ h x } 841.42 \text{ MW}_t} = 0.04976$$

3) RS - Receiver size (maximum power incident on both receivers) 841.42 MW_t (2.872 x 10^9 Btu/h)

4) ALPHAR - Receiver cool down parameter = 0.382.

ALPHAR is used to derive XT, a parameter identifying how far along the cool down curve the receiver has traveled since shutdown. A value of XT = 1.0 implies that the receiver's thermal losses equal those at operating conditions; XT = 0.5 means the receiver has cooled to the point where thermal losses are half those calculated for normal operation. In this way, STEAEC can determine when input flux exceeds thermal losses, and how long it will take for the receiver to reach operating conditions (a "warm" receiver will take less time and energy).

Because most shutdowns occur at night, when the receivers will be kept warm with 288°C (550°F) salt, losses after shutdown will be a constant value equal to the losses with the aperture doors closed. Therefore, the STEAEC equation calculating XT after shutdown was replaced with XT = ALPHAR, and ALPHAR was set equal to that fraction of normal operation losses expected when all the receiver panels are at 288 C (550°F) and the aperture doors have just been opened in the morning. These losses were calculated using the methods described under FXLR that follows and using an ambient air temperature of 10 C (50°F) and wind speed of 8 m/s (26 ft/s).

5) TCS - Time required for a cold start = 0.3902 h.

The derivation of TCS is described under XHR explained previously.

6) RMF - Receiver minimum flow factor (fraction of RS) = 0.05.

Current design calls for 20:1 valves.

7) CAXP - Receiver auxiliary power coefficient $\frac{5.799 \text{ MWe}}{803.87 \text{ MWe}} = 0.0072$.

From Badger, the receiver auxiliary power requirements, given 803.89 MW_t power to the working fluid, is 5.799 MWe.

8) DEPTF - Derated power threshold factor (fraction of RS) = 1.0.

The receivers have no derated capability.

9) MODPO - Plant option mode - 1.

The plant has no derated capability.

10) XTD - Value of X(t) at derated operation = 1.0.

The receivers have no derated capability.

11) DTST - Time interval between turbine synchronization and rated conditions = 0.25 h.

Estimated from General Electric turbine information.

12) FXLR - Matrix of receiver subtractive loss coefficients for reradiation, conduction, and convection losses (fractions of RS).

		RXLR - Wind Speeds, m/s (ft/s) NCXLR = 5				
		(0) 0	(13.1) 4	(26.2) 8	(39.4) 12	(52.5) 16
CXLR - Dry Bulb Tempera- ture, °F NRXLR = 6	- 10	0.0626	0.0637	0.0659	0.0685	0.0715
	+ 20	0.0614	0.0625	0.0644	0.0669	0.0696
	+ 50	0.0599	0.0607	0.0625	0.0650	0.0681
	+ 80	0.0583	0.0590	0.0607	0.0629	0.0655
	+110	0.0568	0.0575	0.0591	0.0613	0.0639
	+140	0.0552	0.0557	0.0572	0.0591	0.0616

Hybrid receiver absorber panel temperatures were input into the Advanced Water Steam (AWS) Convection/IR radiation loss MITAS model described in Section 5.3.4.3 for various ambient temperatures and wind speeds. The losses obtained were then multiplied by the ratio of the hybrid to AWS aperture areas to obtain the hybrid cavity convection and IR radiation losses. Conduction losses were calculated to be 0.5 percent of the absorbed flux and were assumed to be constant over the range of the operating wind speed and temperature conditions. Convection, conduction and IR radiation losses as a percent of incident flux were then totalled to obtain matrix FXLR.

D. CONPIPE - Piping between Receivers and EPGS

1) YXLP - Vector of thermal loss coefficients versus ambient temperature for piping (fraction of RS). TXLP - ambient temperature, °F NXLP = 9.

-22	-4	+14	+32	+50
1.88×10^{-3}	1.84×10^{-3}	1.80×10^{-3}	1.75×10^{-3}	1.71×10^{-3}
+68	+86	+104	+122	
1.67×10^{-3}	1.62×10^{-3}	1.58×10^{-3}	1.54×10^{-3}	

Piping losses for rated operating conditions were calculated by Badger for an ambient air temperature of 28°C (83°F). This loss of 1.3 MWt was proportioned by the ratio of temperature differences between the pipes and the air to obtain losses at other ambient temperatures.

E. CONTRBN - Turbine

1) ALPHA - Turbine shell cooldown parameter, 0.0050999/h

2) BETA - Turbine shell cooldown parameter, 0.034625/h

3) TAUR - Turbine operating temperature factor when previous shutdown was during operation from receiver, 2.9246/h.

4) TAUS - Turbine operating temperature factor when previous shutdown was during operation from storage, 2.9246/h.

ALPHA, BETA, TAUR, and TAUS (α, β, τ_r, τ_s respectively) were obtained from a curve fit to the equation.

$T_{ave}(t_{sb}) = 100 + 450\ [\exp(-\alpha(t_{sb}+\tau_r)) + \exp(-\beta(t_{sb}+\tau_s))]$

using the turbine cooldown curve supplied by Gibbs and Hill. In our system, it makes no difference whether the turbine was running from the receiver or storage before shutdown, so TAUR = TAUS.

5) ALPHR - Coefficient of auxiliary power needs when operating from the receivers = 0.0174 MWe/MWt.

From Gibbs & Hill data, the EPGS requires about 4.55 MWe for a turbine output of 110.96 MWe. Turbine auxiliary power is normalized by the nominal power to the turbine (261.78 MW_t). The STEAEC program, varies turbine auxiliary loads as a function of power available from the receivers

$$ALPHR = \frac{4.55\ MWe}{261.78\ MW_t} = 0.0174\ \frac{MWe}{MW_t}$$

6) ALPHS - Coefficient of auxiliary power needs when operating from storage

$$\frac{4.26\ MWe}{247.03\ MW_t} = 0.0172\ \frac{MWe}{MW_t}$$

EPGS auxiliary power requirements are assumed to remain a constant percentage of the gross turbine output whether running from storage or the receiver. Gross turbine output when running from solar is:

100 MWe, net + 10.97, MWe, total auxiliaries = 110.97 MWe.

The percentage of the gross output required for EPGS auxiliaries can then be found from:

$$x(110.97) - 0.605 = 4.55$$
$$x = .0464 \text{ or } 4.64\%$$

where the .605 term is an adjustment to convert 2400 to 1800 psig.

Since, besides the EPGS, the only auxiliaries required when running from storage are the storage pumps, which need 0.455 MWe, the gross turbine output is:

100 + 0.455 + y MWe

where y represents EPGS auxiliary needs.

They y can be found from:

$$0.0464(100.455 + y) -.605 = y$$
$$y = 4.26\ MWe$$

This turbine auxiliary power is normalized by the nominal power to the turbine (247.03 MW_t, running from storage).

$$ALPHS = \frac{4.26\ MWe}{247.03\ MW_t} = 0.0172\ \frac{MWe}{MW_t}$$

7) TPFRL - Maximum thermal power turbine may receiver from receiver 261.78 MW_t.

The total auxiliaries requirement when running from the receiver is 10.97 MWe. The turbine efficiency at the design point wet bulb temperature of 74°F is 0.4239.

Therefore,

$$\text{TPFRL} = \frac{(100 + 10.97)\ \text{MWe}}{0.4239\ \frac{\text{MWe}}{\text{MW}_t}} = 261.78\ \text{MW}_t$$

8) TPFSL = Maximum thermal power turbine may receive from storage 247.03 MW_t.

The auxiliaries requirement when running from storage is 4.715 MWe.

Therefore,

$$\text{TPFSL} = \frac{(100 + 4.715)\ \text{MWe}}{0.4239\ \frac{\text{MWe}}{\text{MW}_t}} = 247.03\ \text{MW}_t$$

9) AUXPC - Standby auxiliary power coefficient 0.00294 MWe/MW_t.

From Gibbs & Hill, EPGS auxiliary power needed for lighting, air conditioning, etc. (assume turbine is shut down completely when not in use) is 0.77 MWe. This is normalized by TPFRL.

$$\text{SUXPC} = \frac{0.77\ \text{MWe}}{261.78\ \text{MW}_t} = 0.00294\ \frac{\text{MWe}}{\text{MW}_t}$$

10) TMFR - Turbine minimum flow rate coefficient for power from receiver (fraction of maximum flow rate), 0.05 minimum flow rate used by General Electric for their turbines.

11) TMFS - Turbine minimum flow rate ocefficient for power from storage (fraction of maximum flow rate, 0.05 minimum flow rate used by General Electric for their turbines.

12) SMFC - Storage minimum charge rate (fraction of maximum charge rate 0.05. Design calls for 20:1 valves.

13) SMFD - Storage minimum discharge rate (fraction of maximum discharge rate) 0.05. Design calls for 20:1 valves.

14) TURBSS - Turbine sealing steam coefficient, 0.0 MWt. As the turbine is shut down completely when not in use, it requires no sealing steam.

15) MOPMF - Mode of plant operation during minimum flow conditions = 2 (1 = turbine priority, 2 = storage priority). Storage priority maximizes energy produced.

16) FEPSR - Matrix of thermal to electric conversion efficiencies for power from receivers as a function of mass flow fraction and wet bulb temperature from Gibbs & Hill.

		REPSR - Mass Flow Fraction			NCEPSR = 4
		0.25	0.50	0.75	1.00
CEPSR - Wet Bulb Temperature, °F NREPSR = 6	30	0.3955	0.4185	0.4258	0.4271
	40	0.3896	0.4170	0.4253	0.4273
	50	0.3833	0.4142	0.4249	0.4273
	60	0.3763	0.4098	0.4234	0.4273
	70	0.3663	0.4038	0.4202	0.4251
	80	0.3556	0.3956	0.4148	0.4209

17) FEPSS - Matrix of thermal to electric conversion efficiencies for power from storage as a function of mass flow fraction and wet bulb temperature.

Matrix is identical to FEPSR, above, except that REPSR, NCEPSR, CEPSR, and NREPSR are replaced by REPSS, NCEPSS, CEPSS, and NREPSS, respectively.

F. CONSTRG - Storage

1) PTSMAX - Maximum storage charge rate = 841.42 MWt.

Storage can receive maximum power from receivers.

2) PFSMAX - Maximum storage discharge rate = 247.03 MWt.

This value is limited by the capacity of the salt-steam heat exchangers, so it is equal to TPFSL.

3) EMAX - Maximum storage capacity = 4486.14 MWh.

The storage tanks hold enough to discharge for 18 hours at a nominal rate of 247.03 MWt, maximum storage discharge rate + 2.20 MWt, storage thermal losses = 249.73 MWt.

EMAX = (249.73 MWt)(18 hours) = 4486.14 MWh_t.

4) EMIN - Minimum energy in storage = 0.0 MWh_t.

Storage tanks can be completely drained with a very small residual salt level.

5) ES - Energy in storage at beginning of run = 0.0 MWh_t.

Assume STEAEC run starts with EMIN in storage.

6) XLL - Storage loss factor during standby (fraction of PFSMAX needed to keep heat exchangers hot during standby) = 0.001.

This value is a rough estimate of the heat loss factor for the heat exchangers while on standby.

7) A - Storage charge auxiliary power coefficient = 0.0 MWe/MWt.

Our system does not use a charging heat exchanger; salt is pumped directly into storage tanks from the receiver.

8) B - Storage discharge auxiliary power coefficient = 0.00184 MWe/MWt.

From Badger, the cantilever hot salt pump and the preheater feedwater pump require 0.455 MWe. This is normalized by PFSMAX.

9) ALPHC - Storage loss factor during charge = 1.0.

There are no thermal losses during charge.

10) ALPHD - Storage loss factor during discharge = 1.0.

There are no thermal losses during discharge.

11) ALPHL - Tank storage loss factor [1-(average fraction of energy lost from storage tanks in 0.25 hours)] = 0.99982.

Average daily storage heat rate losses are 2.20 MWt. If we estimate that, on the average, the tanks are 2/3 full during one 24-hour period, then fraction of storage energy lost from tanks in 0.25 hours is

$$\frac{2.20 \text{ MWt} \times 0.25 \text{ h}}{2/3 \times \text{EMAX}} = \frac{2.20 \times 0.25}{2/3 \times 4486.14} = 0.0001841$$

12) C1, C2, C3 - Quadratic coefficients for storage loss function during charge = 1,0,0.

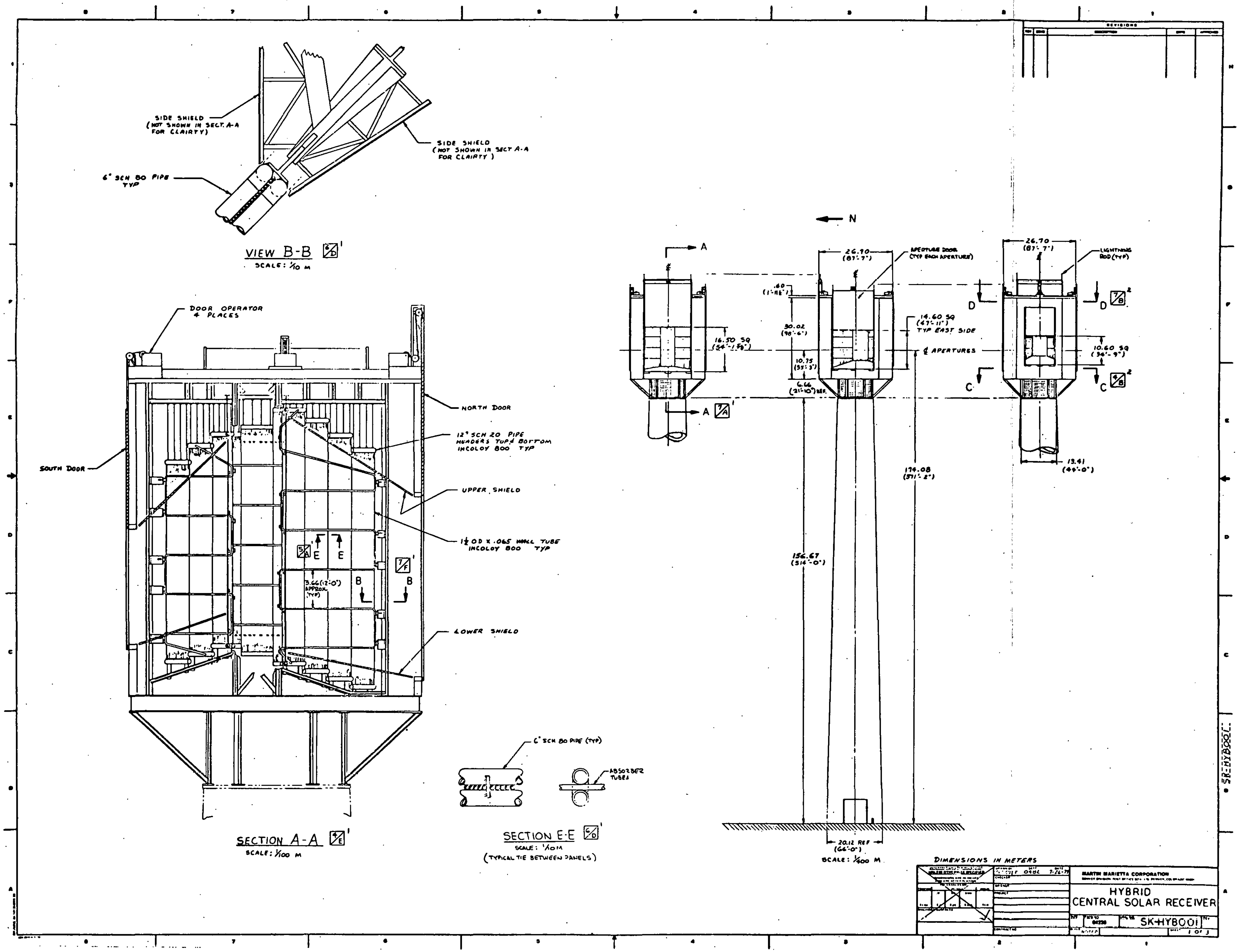
Storage charging is 100% efficient.

13) D1, D2, D3 - Quadratic coefficients for storage loss function during discharge = 1,0,0.

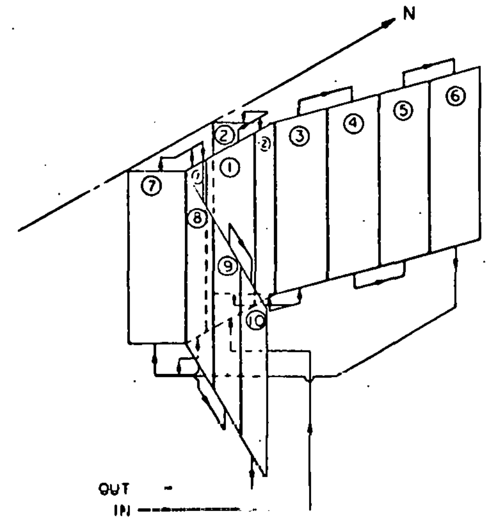
Storage discharging is 100% efficient.

14) LS - Storage flag (1 = non-thermocline tanks, 2 = thermocline tanks) = 1.

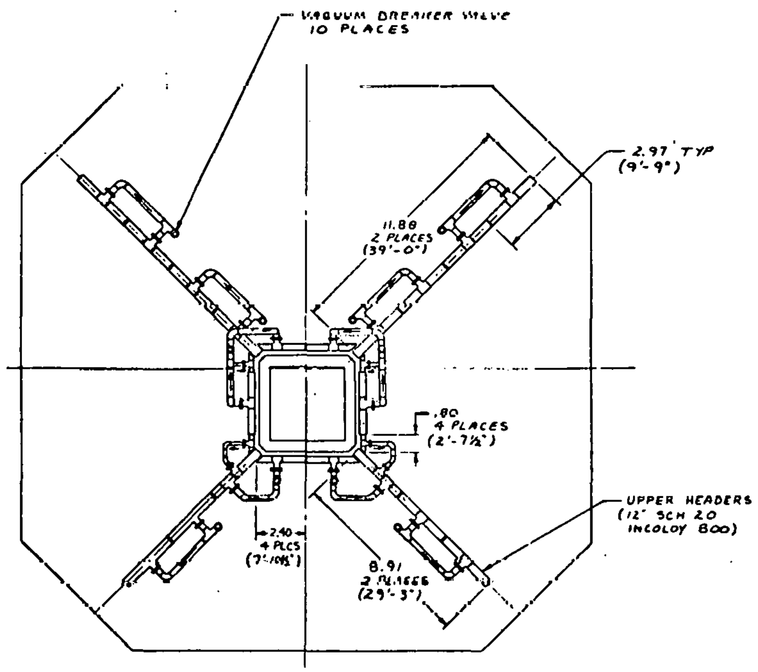
Non-thermocline tanks option was used since the hybrid system uses separate hot and cold salt tanks.



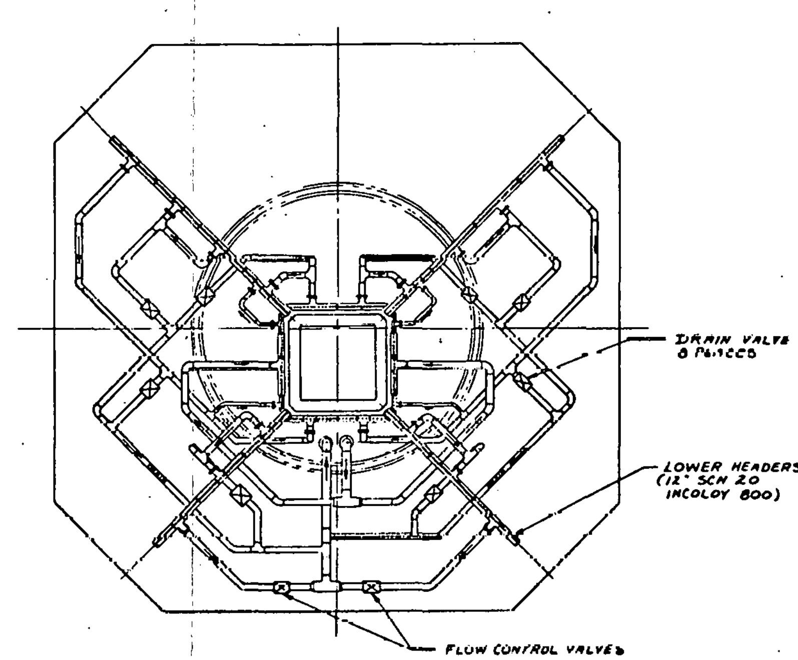
SIDE SHIELD (NOT SHOWN IN SECT. A-A FOR CLAIRTY)
SIDE SHIELD (NOT SHOWN IN SECT A-A FOR CLARITY)
6" SCH 80 PIPE TYP
VIEW B-B
SCALE: 1/10 M
DOOR OPERATOR 4 PLACES
NORTH DOOR
12" SCH 20 PIPE HEADERS TOP & BOTTOM INCOLOY 800 TYP
SOUTH DOOR
UPPER SHIELD
1 1/2 OD X .065 WALL TUBE INCOLOY 800 TYP
3.66 (12'-0") APPROX (TYP)
LOWER SHIELD
SECTION A-A
SCALE: 1/100 M
6" SCH 80 PIPE (TYP)
ABSORBER TUBES
SECTION E-E
SCALE: 1/10 M
(TYPICAL TIE BETWEEN PANELS)
N
26.70 (87'-7")
APERTURE DOOR (TYP EACH APERTURE)
LIGHTNING ROD (TYP)
.60 (1'-11 5/8")
30.02 (98'-6")
16.50 SQ (54'-1 5/8")
14.60 SQ (47'-11") TYP EAST SIDE
℄ APERTURES
10.60 SQ (34'-9")
10.75 (35'-3")
6.66 (21'-10") REF
13.41 (44'-0")
174.08 (571'-2")
156.67 (514'-0")
20.12 REF (66'-0")
SCALE: 1/400 M
DIMENSIONS IN METERS
MARTIN MARIETTA CORPORATION
HYBRID CENTRAL SOLAR RECEIVER
SK-HYB001
1 OF 3



ABSORBER FLOW PATH
EAST SIDE SHOWN
WEST SIDE OPPOSITE
SCALE: NONE



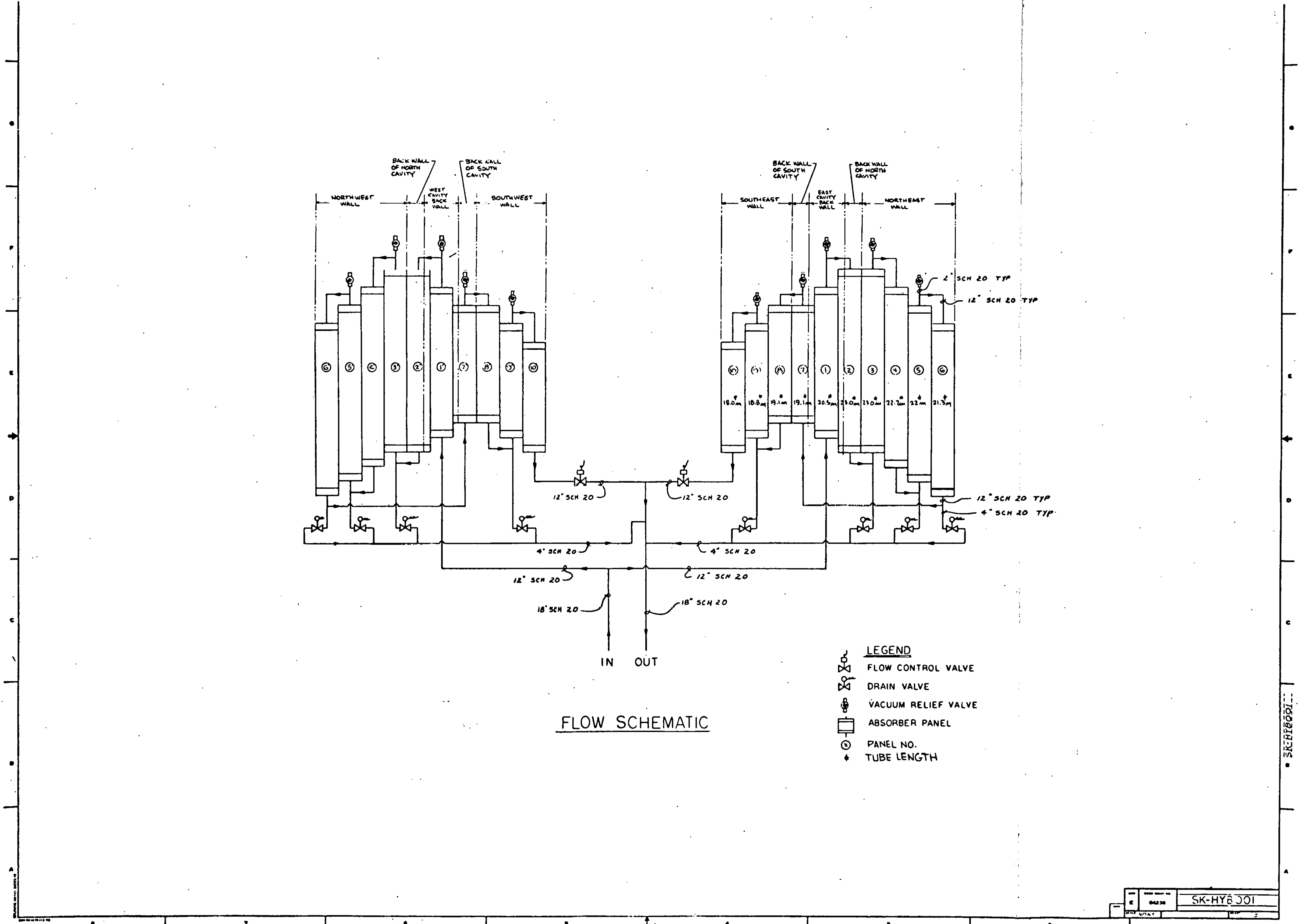
VIEW D-D
UPPER CROSSOVER PIPING



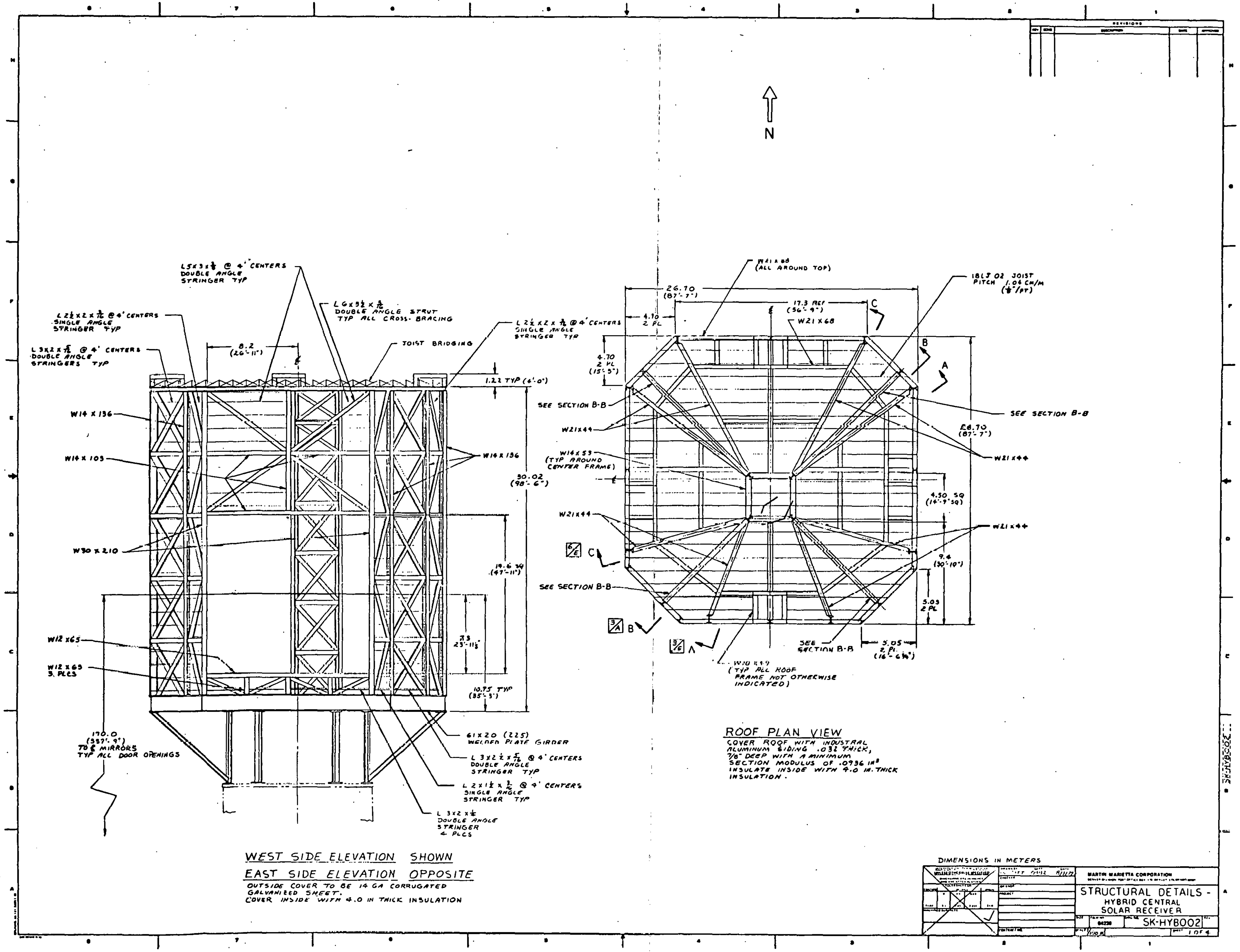
SECTION C-C
LOWER CROSSOVER, SUPPLY,
RETURN AND DRAIN PIPING

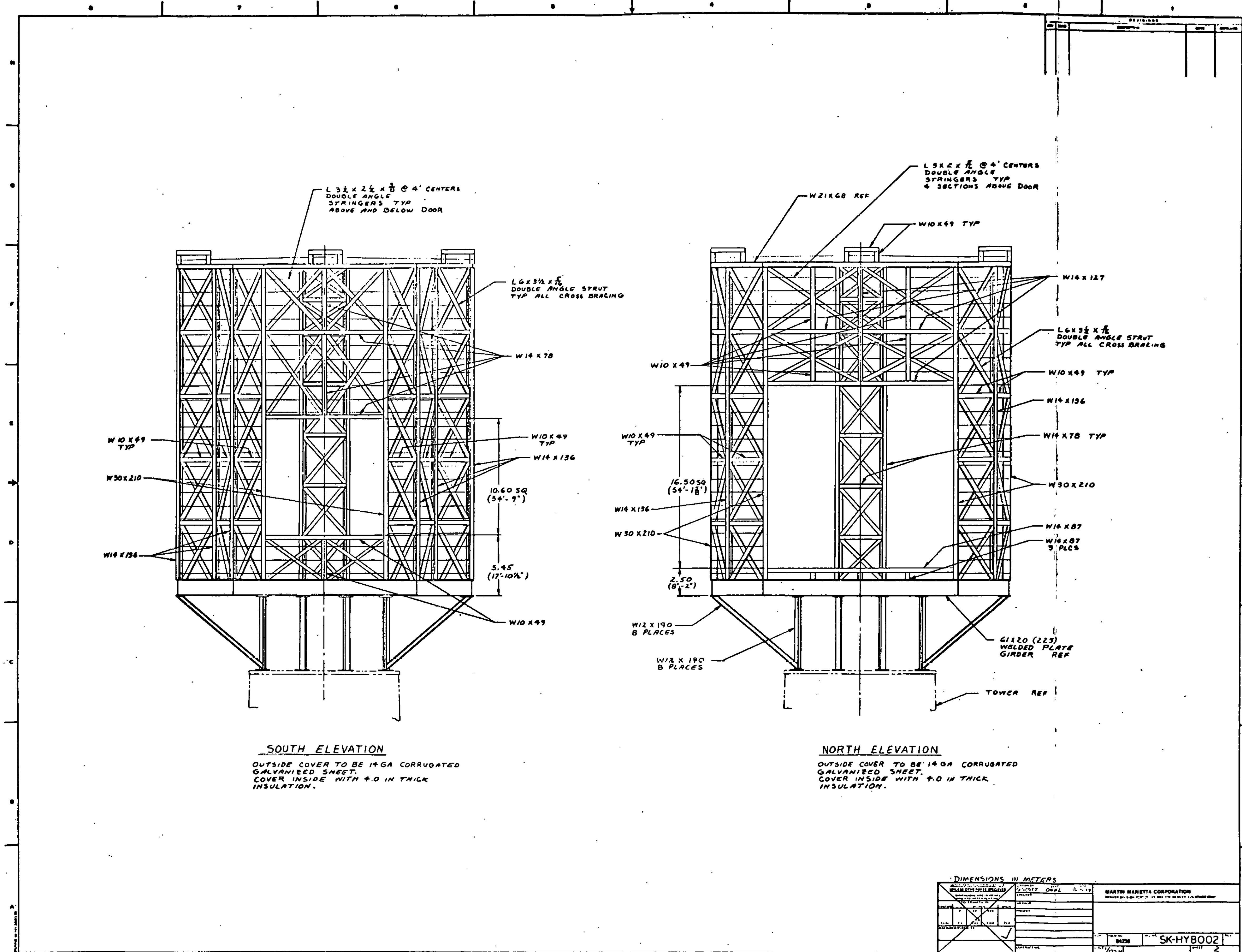
DIMENSIONS IN METERS

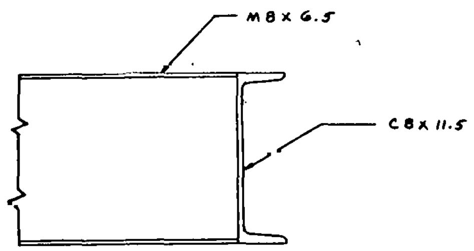
SK-HYE 301



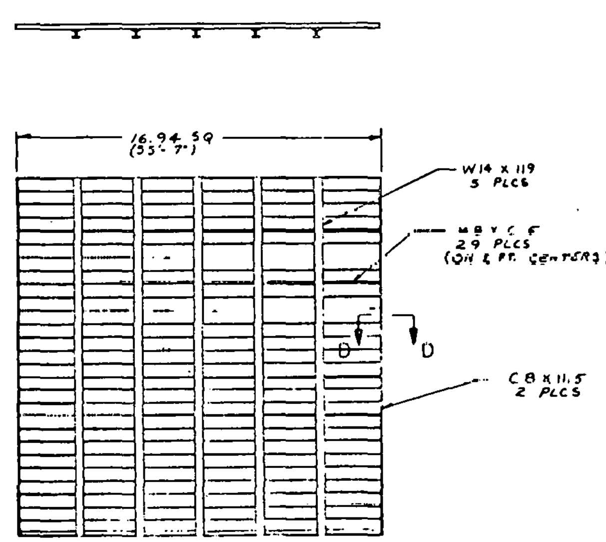
FLOW SCHEMATIC


N
WEST SIDE ELEVATION SHOWN
EAST SIDE ELEVATION OPPOSITE
OUTSIDE COVER TO BE 14 GA CORRUGATED GALVANIZED SHEET.
COVER INSIDE WITH 4.0 IN THICK INSULATION
ROOF PLAN VIEW
COVER ROOF WITH INDUSTRAL ALUMINUM SIDING .032 THICK, 7/8" DEEP WITH A MINIMUM SECTION MODULUS OF .0936 IN³ INSULATE INSIDE WITH 4.0 IN. THICK INSULATION.
L5x3x3/8 @ 4' CENTERS DOUBLE ANGLE STRINGER TYP
L6x5 1/2 x 7/16 DOUBLE ANGLE STRUT TYP ALL CROSS-BRACING
JOIST BRIDGING
W14 X 136
W14 X 105
W30 X 210
W12 X65
W12 X65 5 PLCS
61X20 (225) WELDED PLATE GIRDER
SEE SECTION B-B
W21X44
W21X68
W10 X49 (TYP ALL ROOF FRAME NOT OTHERWISE INDICATED)
DIMENSIONS IN METERS
MARTIN MARIETTA CORPORATION
STRUCTURAL DETAILS - HYBRID CENTRAL SOLAR RECEIVER
SK-HYB002
1 OF 4

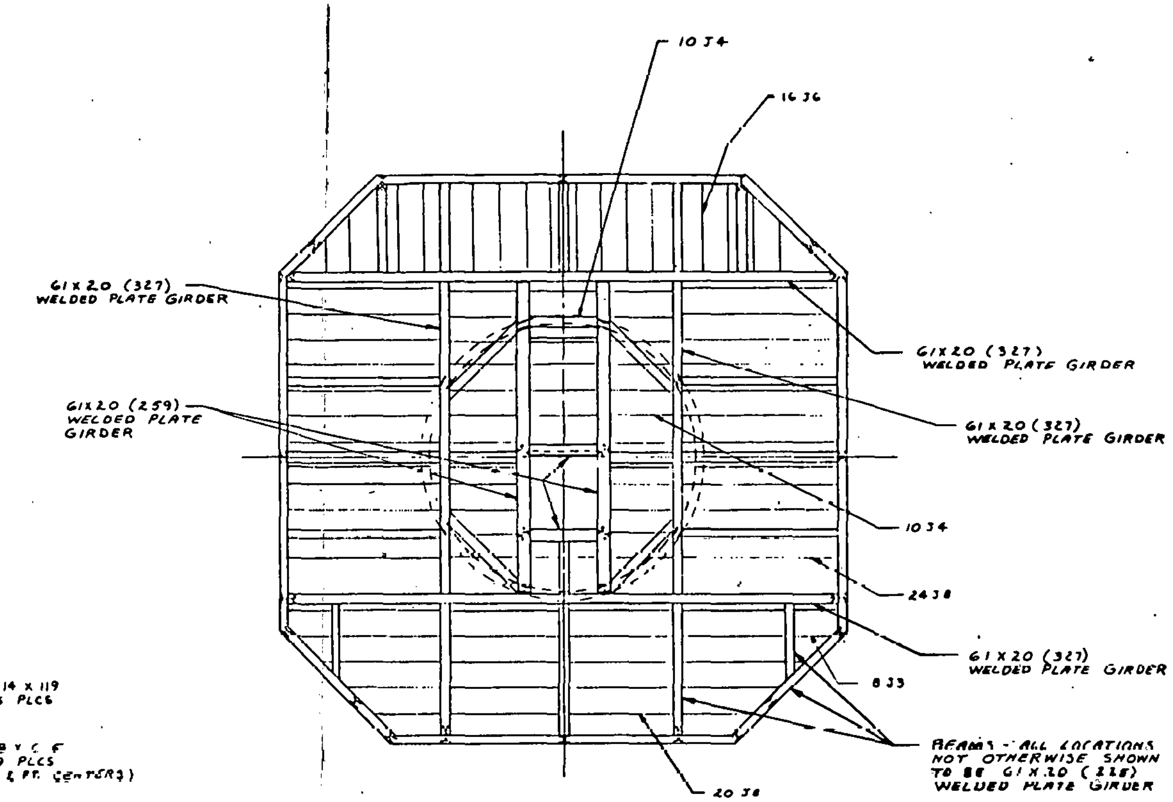

L 3½ x 2½ x ⅜ @ 4' CENTERS DOUBLE ANGLE STRINGERS TYP ABOVE AND BELOW DOOR
L 6 x 3½ x 5/16 DOUBLE ANGLE STRUT TYP ALL CROSS BRACING
W14 x 78
W10 x 49 TYP
W30 x 210
W14 x 136
W10 x 49 TYP
W14 x 136
10.60 SQ (34'-9")
5.45 (17'-10½")
W10 x 49
SOUTH ELEVATION
OUTSIDE COVER TO BE 14 GA CORRUGATED GALVANIZED SHEET. COVER INSIDE WITH 4.0 IN THICK INSULATION.
L 5 x 2 x 5/16 @ 4' CENTERS DOUBLE ANGLE STRINGERS TYP 4 SECTIONS ABOVE DOOR
W21 x 68 REF
W10 x 49 TYP
W14 x 127
L 6 x 3½ x 5/16 DOUBLE ANGLE STRUT TYP ALL CROSS BRACING
W10 x 49
W10 x 49 TYP
W14 x 136
W14 x 78 TYP
W10 x 49 TYP
16.50 SQ (54'-1⅝")
W14 x 136
W30 x 210
W30 x 210
W14 x 87
W14 x 87 3 PLCS
2.50 (8'-2")
W12 x 190 8 PLACES
W12 x 190 8 PLACES
61 x 20 (225) WELDED PLATE GIRDER REF
TOWER REF
NORTH ELEVATION
OUTSIDE COVER TO BE 14 GA CORRUGATED GALVANIZED SHEET. COVER INSIDE WITH 4.0 IN THICK INSULATION.
DIMENSIONS IN METERS
MARTIN MARIETTA CORPORATION
SK-HYB002



SECTION D-D
SCALE: 1cm = 1 INCH



DOOR FRAME
NORTH DOOR SHOWN
OTHER DOORS SIMILAR



FLOOR PLAN VIEW
COVER WITH 5/16 STL PL
COVER PLATE WITH 4 IN. INSULATION

DIMENSIONS IN METERS

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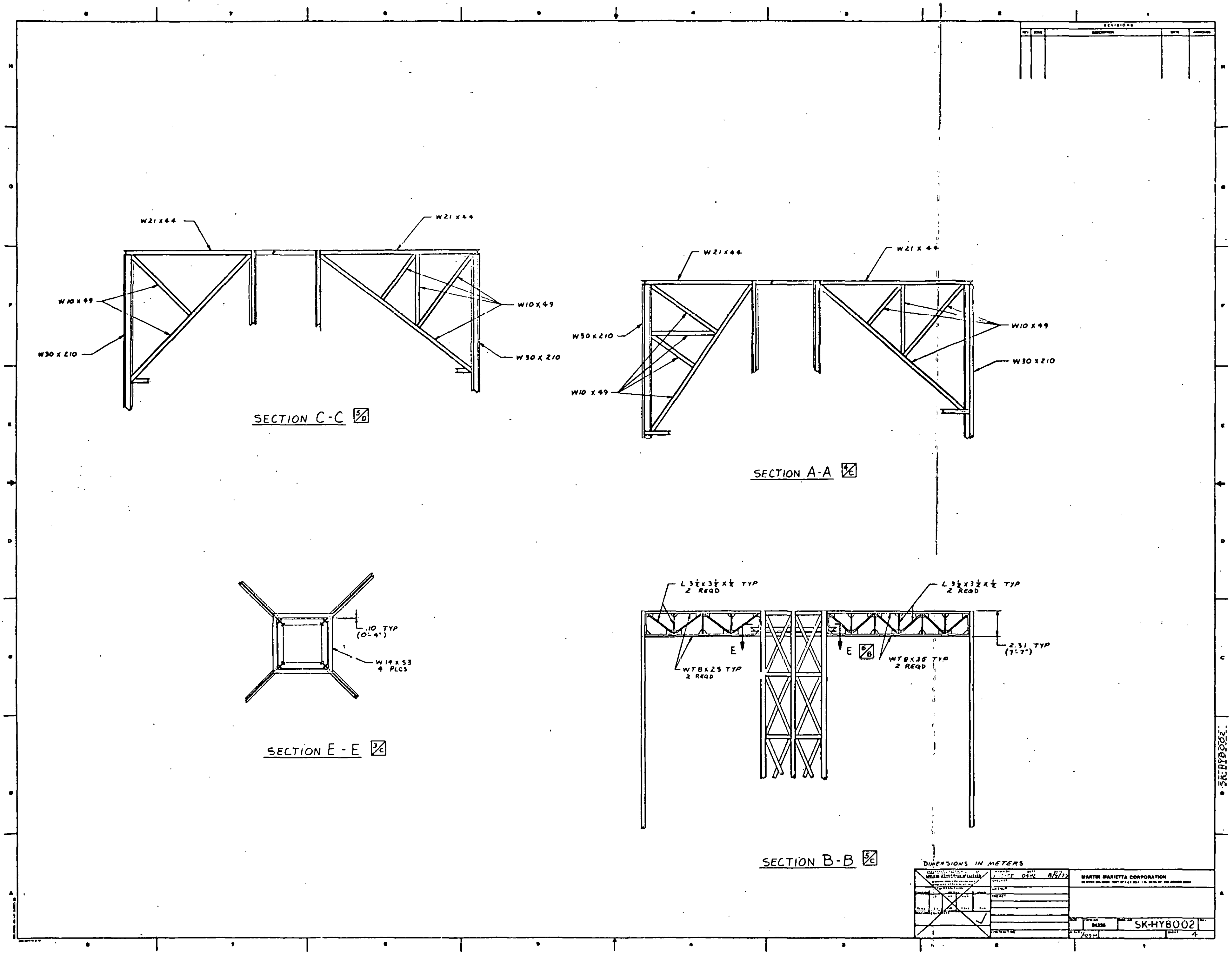
SK-HYB002


W21 x 44
W21 x 44
W10 x 49
W10 x 49
W30 x 210
W30 x 210
SECTION C-C
W21 x 44
W21 x 44
W30 x 210
W10 x 49
W10 x 49
W30 x 210
SECTION A-A
.10 TYP
(0'-4")
W14 x 53
4 PLCS
SECTION E-E
L 3½ x 3½ x ½ TYP
2 REQD
L 3½ x 3½ x ½ TYP
2 REQD
E
E
2.31 TYP
(7'-7")
WT8 x 25 TYP
2 REQD
WT8 x 25 TYP
2 REQD
SECTION B-B
DIMENSIONS IN METERS
MARTIN MARIETTA CORPORATION
04236
SK-HY8002
4
SK-HY8002

APPENDIX H: HYBRID RECEIVER ABSORBER TUBE THERMAL MATH MODEL

This appendix contains the Martin Marietta Interactive Thermal System (MITAS) computer program analysis model used to determine the receiver absorber tube and salt steady state temperature profiles presented in Figure 5.3-33 through 5.3-35. This 26 node model represents one absorbing panel (front and back) and is diagramed in Figure 5.3-32. By stacking computer runs, and inputting the salt temperature out of the previous panel as the inlet salt temperature for the succeeding panel, all 10 panels of a receiver zone are represented.

The appropriate flux values shown in Figures 5.3-27 through 5.3-29 are input on the front and back of each panel node. The program calculates the salt-to-tube heat transfer coefficient for front and back of the five tube segments based on the salt temperature, tube temperature, and salt velocity. The salt velocity is a function of the input mass flow rate and is calculated for each tube segment based on the salt temperature and resulting salt density. Incoloy conductance is varied in the program as a function of the tube temperature.

```
BCD 3TITLE DATA
BCD 9HYBRID RECEIVER TUBE SECTION MODEL - PASS 1
END
BCD 3NODE DATA
-1, 550., 0.              $ SALT INLET TEMP
GEN 2,5,1,550.,-1.        $ SALT NODES
GEN 11,5,1,550.,-1.       $ TUBE FRONT INSIDE NODES
GEN 21,5,1,550.,-1.       $ TUBE BACK INSIDE NODES
GEN 111,5,1,550.,-1.      $ TUBE FRONT OUTSIDE NODES
GEN 121,5,1,550.,-1.      $ TUBE BACK OUTSIDE NODES
END
BCD 3CONDUCTOR DATA
 1,1,2,1.                 $ SALT FLOW CONDUCTORS
 2,-2,3,1.
 3,-3,4,1.
 4,-4,5,1.
 5,-5,6,1.
GEN 11,5,1,11,1,2,1,1.  $ HA COND,FRONT TUBE TO SALT(CALC IN EXEC)
GEN 21,5,1,21,1,2,1,1.  $ HA COND,BACK TUBE TO SALT(CALC IN EXEC)
CGS 111,111,11,A3,1.$ FRONT TUBE OUTSIDE TO INSIDE (CALC IN VAR1)
CGS 112,112,12,A3,1.
CGS 113,113,13,A3,1.
CGS 114,114,14,A3,1.
CGS 115,115,15,A3,1.
CGS 121,121,21,A3,1.$ BACK TUBE OUTSIDE TO INSIDE (CALC IN VAR1)
CGS 122,122,22,A3,1.
CGS 123,123,23,A3,1.
CGS 124,124,24,A3,1.
CGS 125,125,25,A3,1.
END
BCD 3CONSTANTS DATA
1 = 1.5              $ TUBE OD (INCHES)
2 = .065             $ TUBE WALL (INCHES)
3 = 78.              $ NO OF TUBES PER SECTION
4 = 1.               $ SALT FLOW/TUBE (LBM/HR),CALC IN EXEC
5 = 1.               $ TUBE NODE AREA TOUCHING SALT(FT2),CALC IN EX
6 = 3460929.         $ TOTAL SALT FLOW/ZONE (LBM/HR)
7 = .371             $ SPECIFIC HEAT OF SALT (BTU/LBM-F)
8 = 59.06            $ LENGTH OF TUBE SECTION (FT)
9 = 1.                 $ TUBE ID (FT),CALC IN EXEC
10= 1.               $ TUBE FLOW CROSS SECT (FT2),CALC IN EXEC
11= .234             $ CONDUCTIVITY OF SALT (BTU/HR-FT-F)
12= 1.               $ EXT PROJECTED AREA OF TUBE NODE(FT2),CALC IN
13= .07              $ RAD,COND,REFL,AND CONV LOSSES.FRACT OF ABS
14= 1                $ PASS FLAG, 1=FIRST
NDSTOR=200
ITEROT=21
ITERMX=150
ARLXCA=.01
DRLXCA=.01
END
BCD 3ARRAY DATA
1  $ FRONT SIDE FLUX (*1000 BTU/HR-FT2)
    37.,164.,168.,114.,30.,END
2  $ BACK SIDE FLUX (*1000 BTU/HR-FT2)
    0.,0.,0.,0.,0.,END
3  $ INCOLOY 800 CONDUCTIVITY (BTU/HR-FT-F)
    70.,7.25, 200.,8.08, 400.,9.00, 600.,10.00, 800.,11.08
    1000.,12.00, 1200.,12.92, 1400.,13.92,END
END
BCD 3EXECUTION
IF(K14.GT.1)T1=ETEST
```

```
      R4=R6/R3                  $ FLOW/TUBE (LBM/HR)
      R5=3.1416*(R1-2.*R2)*R8/120.$ TUBE NODE AREA TOUCHING SALT (FT2)
      R9=(R1-2.*R2)/12.         $ TUBE ID (FT)
      R10=3.1416*R9**2./4.      $ TUBE CROSS SECTIONAL AREA (FT2)
      G1=R4*R7                  $ M DOT CP CONDUCTOR (BTU/HR-F)
      R12=R1*R8*12./(5.*144.) $ NODE PROJECTED AREA (FT2)
      G2=G1
      G3=G1
      G4=G1
      G5=G1
      STDSTL
C     CALCULATE THE HEAT ABSORBED BY THE SALT FOR THIS SECTION
      QABS=R4*R3*R7*(T6-T1)*.293*1.0E-06  $ MEGA WATTS
      WRITE(6,1)QABS
F   1 FORMAT(4X,E10.3,* MEGA WATTS TOTAL ABS IN THIS SECTION*)
      VELI=ATEST/3600.  $ FT/SEC
      VELO=BTEST/3600.  $ FT/SEC
      WRITE(6,2)VELI
F   2 FORMAT(4X,*VELOCITY AT ENTRANCE TO SECT=*,E10.3,* FT PER SEC*)
      WRITE(6,3)VELO
F   3 FORMAT(4X,*VELOCITY AT OUTLET OF SECT=*,E10.3,* FT PER SEC*)
      WRITE(6,4)CTEST
F   4 FORMAT(4X,*H=*,E12.3,*BTU/HR-FT2-F AT PASS ENTRANCE*)
      WRITE(6,5)DTEST
F   5 FORMAT(4X,*H=*,E12.3,*BTU/HR-FT2-F AT PASS EXIT*)
      ETEST=T6
      END
      BCD 3VARIABLES 1
      VARGS
F     DIMENSION VIS(15),ROE(15),VEL(15),VIST(15),COEF(15)
C  CALCULATE THE HA CONDUCTORS BETWEEN THE TUBE WALL AND SALT
      DO 10 I=1,5
F     VIS(I)=(577.644*T(I)**(-1.97469))*3600.
F     ROE(I)=131.524-.022543*T(I)
F     VEL(I)=R(4)/(ROE(I)*R(10))
F     COEF(I+5)=(.023*R(11)/R(9))*(R(9)*VEL(I)*ROE(I)/VIS(I))**.8*
F     (VIS(I)*R(7)/R(11))**.4
F     COEF(I+10)=COEF(I+5)
F     G(I+5)=COEF(I+5)*R(5)
F     G(I+10)=COEF(I+10)*R(5)
C  CALCULATE THE INCOLOY TUBE OUTSIDE TO INSIDE CONDUCTORS
F     G(15+I)=G(15+I)*3.1415927*R(8)/(5.*ALOG(R(1)/(R(1)-2.*R(2))))
F     G(20+I)=G(20+I)*3.1415927*R(8)/(5.*ALOG(R(1)/(R(1)-2.*R(2))))
   10 CONTINUE
      ATEST=VEL(1)
      BTEST=VEL(5)
      CTEST=COEF(6)
      DTEST=COEF(15)
      Q111=A1+1*1000.*(1.-R13)*R12
      Q112=A1+2*1000.*(1.-R13)*R12
      Q113=A1+3*1000.*(1.-R13)*R12
      Q114=A1+4*1000.*(1.-R13)*R12
      Q115=A1+5*1000.*(1.-R13)*R12
      Q121=A2+1*1000.*(1.-R13)*R12
      Q122=A2+2*1000.*(1.-R13)*R12
      Q123=A2+3*1000.*(1.-R13)*R12
      Q124=A2+4*1000.*(1.-R13)*R12
      Q125=A2+5*1000.*(1.-R13)*R12
      END
      BCD 3VARIABLES 2
      END
      BCD 3OUTPUT CALLS
```

```
TPRINT
END
BCD 3FINAL PARAMETERS
BCD 3TITLE DATA
BCD 9PASS 2
END
BCD 3CONSTANTS DATA
8 = 72.83
14= 2
END
BCD 3ARRAY DATA
1,41.,129.,167.,156.,22.,END
2,0.,0.,0.,0.,0.,END
END
BCD 3FINAL PARAMETERS
BCD 3TITLE DATA
BCD 9PASS 3
END
BCD 3CONSTANTS DATA
8 = 70.87
END
BCD 3ARRAY DATA
1,22.,136.,140.,123.,46.,END
2,7.,112.,135.,88.,2.,END
END
BCD 3FINAL PARAMETERS
BCD 3TITLE DATA
BCD 9PASS 4
END
BCD 3CONSTANTS DATA
8 = 67.59
END
BCD 3ARRAY DATA
1,84.,167.,156.,104.,17.,END
2,3.,110.,165.,118.,6.,END
END
BCD 3FINAL PARAMETERS
BCD 3TITLE DATA
BCD 9PASS 5
END
BCD 3CONSTANTS DATA
8 = 63.98
END
BCD 3ARRAY DATA
1,7.,53.,76.,70.,42.,END
2,2.,50.,83.,74.,5.,END
END
BCD 3FINAL PARAMETERS
BCD 3TITLE DATA
BCD 9PASS 6
END
BCD 3CONSTANTS DATA
8 = 61.68
END
BCD 3ARRAY DATA
1,3.,14.,25.,14.,0.,END
2,0.,2.,11.,7.,0.,END
END
BCD 3FINAL PARAMETERS
BCD 3TITLE DATA
BCD 9PASS 7
```

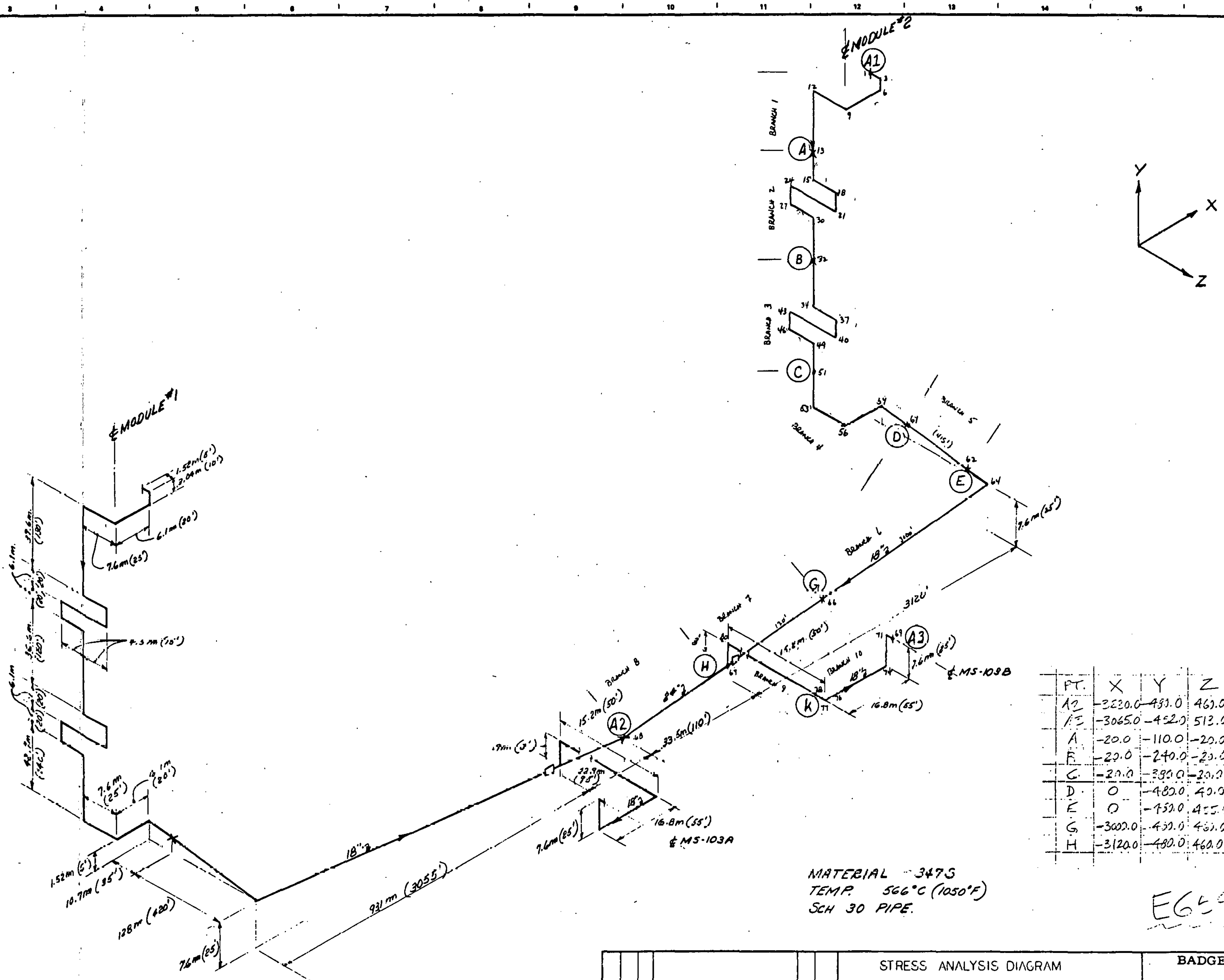
```
END
BCD 3CONSTANTS DATA
8 = 52.82
END
BCD 3ARRAY DATA
1,49.,126.,124.,85.,22.,END
2,0.,0.,0.,0.,0.,END
END
BCD 3FINAL PARAMETERS
BCD 3TITLE DATA
BCD 9PASS 8
END
BCD 3CONSTANTS DATA
8 = 58.73
END
BCD 3ARRAY DATA
1,36.,106.,160.,149.,26.,END
2,13.,77.,116.,63.,2.,END
END
BCD 3FINAL PARAMETERS
BCD 3TITLE DATA
BCD 9PASS 9
END
BCD 3CONSTANTS DATA
8 = 56.10
END
BCD 3ARRAY DATA
1,9.,75.,96.,80.,32.,END
2,0.,33.,81.,80.,22.,END
END
BCD 3FINAL PARAMETERS
BCD 3TITLE DATA
BCD 9PASS 10
END
BCD 3CONSTANTS DATA
8 = 54.13
END
BCD 3ARRAY DATA
1,2.,13.,28.,16.,.5,END
2,.5,9.,16.,4.,0.,END
END
BCD 3END OF DATA
```

APPENDIX I: PIPING STRESS ANALYSIS

This appendix contains the computer printout of the stress analysis program run on the hot salt network piping. The first 4 pages of the printout contain the moments, forces and stresses for different points along the piping (at each change in direction); the next 4 pages list the rotations and deflections at most of these points.

The figure details the branches and some of the points used in the stress analysis. As the piping is symmetrical about point A2, the piping of one module is detailed.

The maximum stress occurs at point 81 in Branch 9, in the piping from the main east-west line to the hot salt tanks. From page 7 of the printout, the stress computes to 3868 kPa (56,091 psi) for this point. The maximum deflection occurs at point 65 of Branch 6, or at the end of the main east-west run. Page 10 shows this deflection to be 9.97 m (392 in.) in the X-direction.



PT.	X	Y	Z
A2	-3220.0	-480.0	460.0
A3	-3065.0	-452.0	513.0
A	-20.0	-110.0	-20.0
B	-20.0	-240.0	-20.0
C	-20.0	-390.0	-20.0
D	0	-480.0	40.0
E	0	-450.0	455.0
G	-3000.0	-480.0	460.0
H	-3120.0	-480.0	460.0

MATERIAL 347S
TEMP. 566°C (1050°F)
SCH 30 PIPE.

E6591-1A

STRESS ANALYSIS DIAGRAM

SOLAR CENTRAL RECEIVER HYBRID SYSTEM
PHASE I

MARTIN MARIETTA CORP.

BADGER AMERICA, INC.
CAMBRIDGE, MASS.

DWG NO E6591-1A

REACTIONS AND SYSTEM STRESSES

RESTRAINING REACTIONS AT 'TO' END ARE REFERRED TO EACH POINT IN BRANCH

CONDITION 1

BRANCH 1, FROM A1 TO A

		MOMENTS IN FOOT POUNDS			FORCES IN POUNDS			STRESS
BR.	PT.	MX	MY	MZ	FX	FY	FZ	PSI
1	1	6356.	6376.	-14304.	344.	1945.	356.	4375.
1	2	11704.	5432.	-14304.	344.	1945.	356.	19131.
1	3	15033.	4885.	-14530.	344.	1945.	356.	24274.
1	4	16882.	4659.	-15077.	344.	1945.	356.	32946.
1	5	18841.	4659.	-16966.	344.	1945.	356.	36900.
1	6	19407.	4424.	-16231.	344.	1945.	356.	28530.
1	7	19642.	3857.	-13363.	344.	1945.	356.	20861.
1	8	19642.	-1663.	16782.	344.	1945.	356.	25052.
1	9	18361.	-2004.	19876.	344.	1945.	356.	7739.
1	10	13266.	-1692.	21158.	344.	1945.	356.	23004.
1	11	-24603.	5350.	21158.	344.	1945.	356.	37031.
1	12	-27463.	5896.	20931.	344.	1945.	356.	43117.
1	13	-28178.	6123.	20385.	344.	1945.	356.	50614.
1	13	6640.	6123.	-13192.	344.	1945.	356.	4138.

BRANCH 2, FROM A TO B

		MOMENTS IN FOOT POUNDS			FORCES IN POUNDS			STRESS
BR.	PT.	MX	MY	MZ	FX	FY	FZ	PSI
2	13	6640.	6123.	-13192.	-277.	1945.	-107.	2546.
2	14	3672.	6123.	-5507.	-277.	1945.	-107.	4296.
2	15	4783.	6305.	-5066.	-277.	1945.	-107.	3330.
2	16	7807.	6746.	-4884.	-277.	1945.	-107.	6569.
2	17	28228.	9654.	-4884.	-277.	1945.	-107.	18875.
2	18	31252.	10094.	-4701.	-277.	1945.	-107.	19972.
2	19	32363.	10277.	-4261.	-277.	1945.	-107.	20700.
2	20	30706.	10277.	32.	-277.	1945.	-107.	19479.
2	21	29254.	10094.	473.	-277.	1945.	-107.	19024.
2	22	26089.	9654.	655.	-277.	1945.	-107.	17585.
2	23	-23505.	2591.	655.	-277.	1945.	-107.	14949.
2	24	-26669.	2151.	838.	-277.	1945.	-107.	16873.
2	25	-28121.	1968.	1279.	-277.	1945.	-107.	17798.
2	26	-29779.	1963.	5571.	-277.	1945.	-107.	19154.
2	27	-28667.	2151.	6012.	-277.	1945.	-107.	18491.
2	28	-25644.	2591.	6194.	-277.	1945.	-107.	16323.
2	29	-5223.	5500.	6194.	-277.	1945.	-107.	4895.
2	30	-2199.	5940.	6377.	-277.	1945.	-107.	5679.
2	31	-1087.	6123.	6818.	-277.	1945.	-107.	4472.
2	32	-7264.	6123.	22812.	-277.	1945.	-107.	3935.

REACTIONS AND SYSTEM STRESSES
RESTRAINING REACTIONS AT 'TO' END ARE REFERRED TO EACH POINT IN BRANCH

CONDITION 1

BRANCH 3, FROM B TO C

		MOMENTS IN FOOT POUNDS			FORCES IN POUNDS			STRESS
BR.	PT.	MX	MY	MZ	FX	FY	FZ	PSI
3	32	-7264.	6123.	22812.	466.	1945.	117.	3935.
3	33	-533.	6123.	-4087.	466.	1945.	117.	2762.
3	34	935.	5316.	-4828.	466.	1945.	117.	1407.
3	35	4106.	5075.	-5135.	466.	1945.	117.	4207.
3	36	24527.	184.	-5135.	466.	1945.	117.	15526.
3	37	27698.	-557.	-5442.	466.	1945.	117.	17722.
3	38	29165.	-864.	-6183.	466.	1945.	117.	18847.
3	39	30971.	-864.	-13402.	466.	1945.	117.	21333.
3	40	29875.	-557.	-14143.	466.	1945.	117.	19907.
3	41	26858.	184.	-14450.	466.	1945.	117.	17134.
3	42	-22736.	12061.	-14450.	466.	1945.	117.	16432.
3	43	-25753.	12802.	-14757.	466.	1945.	117.	20417.
3	44	-26850.	13109.	-15498.	466.	1945.	117.	19709.
3	45	-25043.	13109.	-22718.	466.	1945.	117.	21476.
3	46	-23576.	12802.	-23459.	466.	1945.	117.	16170.
3	47	-20405.	12061.	-23766.	466.	1945.	117.	15454.
3	48	16.	7171.	-23766.	466.	1945.	117.	5905.
3	49	3187.	6430.	-24073.	466.	1945.	117.	9835.
3	50	4654.	6123.	-24814.	466.	1945.	117.	15989.
3	51	9054.	6123.	-42397.	466.	1945.	117.	6972.

BRANCH 4, FROM C TO D

		MOMENTS IN FOOT POUNDS			FORCES IN POUNDS			STRESS
BR.	PT.	MX	MY	MZ	FX	FY	FZ	PSI
4	51	9054.	6123.	-42397.	-823.	1945.	-760.	5072.
4	52	-65258.	6123.	38033.	-823.	1945.	-760.	27485.
4	53	-65136.	6665.	39342.	-823.	1945.	-760.	26636.
4	54	-62593.	7974.	39885.	-823.	1945.	-760.	23413.
4	55	-22723.	24842.	39885.	-823.	1945.	-760.	13089.
4	56	-19629.	25650.	38603.	-823.	1945.	-760.	17715.
4	57	-18347.	24933.	35509.	-823.	1945.	-760.	15936.
4	58	-18347.	13199.	5364.	-823.	1945.	-760.	5602.
4	59	-17066.	12532.	2269.	-823.	1945.	-760.	6854.
4	60	-13971.	13340.	988.	-823.	1945.	-760.	7028.
4	61	49722.	40287.	988.	-823.	1945.	-760.	7415.

BRANCH 5, FROM D TO E

		MOMENTS IN FOOT POUNDS			FORCES IN POUNDS			STRESS
BR.	PT.	MX	MY	MZ	FX	FY	FZ	PSI
5	61	49722.	40287.	988.	140.	-122.	-9.	7415.

REACTIONS AND SYSTEM STRESSES

RESTRAINING REACTIONS AT 'TO' END ARE REFERRED TO EACH POINT IN BRANCH

CONDITION 1

BRANCH 5, FROM D TO E

		MOMENTS IN FOOT POUNDS			FORCES IN POUNDS			STRESS
BR.	PT.	MX	MY	MZ	FX	FY	FZ	PSI
5	62	-815.	-17861.	988.	140.	-122.	-9.	2074.

BRANCH 6, FROM E TO G

		MOMENTS IN FOOT POUNDS			FORCES IN POUNDS			STRESS
BR.	PT.	MX	MY	MZ	FX	FY	FZ	PSI
6	62	-815.	-17861.	988.	140.	-0.	-9.	2074.
6	63	-817.	-18246.	988.	140.	-0.	-9.	6645.
6	64	-817.	-18463.	988.	140.	-0.	-9.	6718.
6	65	-818.	-18541.	987.	140.	-0.	-9.	6755.
6	66	-818.	8849.	-428.	140.	-0.	-9.	1031.

BRANCH 7, FROM G TO H

		MOMENTS IN FOOT POUNDS			FORCES IN POUNDS			STRESS
BR.	PT.	MX	MY	MZ	FX	FY	FZ	PSI
7	66	-818.	8849.	-428.	140.	-15.	139.	1031.
7	83	-818.	-7643.	-2166.	140.	-15.	139.	926.
7	67	-818.	-7736.	-2181.	140.	-15.	139.	1046.

BRANCH 8, FROM A2 TO H

		MOMENTS IN FOOT POUNDS			FORCES IN POUNDS			STRESS
BR.	PT.	MX	MY	MZ	FX	FY	FZ	PSI
8	63	84.	123782.	5212.	-5607.	142.	-2565.	6275.
8	67	84.	-158339.	-10447.	-5607.	142.	-2565.	20413.

BRANCH 9, FROM H TO K

		MOMENTS IN FOOT POUNDS			FORCES IN POUNDS			STRESS
BR.	PT.	MX	MY	MZ	FX	FY	FZ	PSI
9	67	-734.	-166124.	-12626.	-5467.	-490.	-2426.	49025.
9	79	1086.	-166124.	-16727.	-5467.	-490.	-2426.	20188.
9	80	4624.	-162522.	-25425.	-5467.	-490.	-2426.	38515.
9	81	5443.	-153824.	-29027.	-5467.	-490.	-2426.	56091.
9	78	-16842.	94920.	-29027.	-5467.	-490.	-2426.	11663.

BRANCH 10, FROM A3 TO K

		MOMENTS IN FOOT POUNDS			FORCES IN POUNDS			STRESS
BR.	PT.	MX	MY	MZ	FX	FY	FZ	PSI
10	69	-35662.	9815.	80320.	5467.	1552.	2426.	10244.
10	70	-35826.	13915.	80320.	5467.	1552.	2426.	17078.
10	71	-37697.	22513.	75717.	5467.	1552.	2426.	21164.
10	72	-34860.	26215.	68019.	5467.	1552.	2426.	27969.
10	73	14875.	26215.	-44052.	5467.	1552.	2426.	17184.

REACTIONS AND SYSTEM STRESSES
RESTRAINING REACTIONS AT 'TO' END ARE REFERRED TO EACH POINT IN BRANCH

CONDITION 1

BRANCH 10, FROM 43 TO K

		MOMENTS IN FOOT POUNDS			FORCES IN POUNDS			STRESS
BR.	PT.	MX	MY	MZ	FX	FY	FZ	PSI
10	74	18735.	24617.	-51726.	5467.	1552.	2426.	19208.
10	75	20334.	20757.	-52860.	5467.	1552.	2426.	20792.
10	76	20334.	-101762.	25535.	5467.	1552.	2426.	38238.
10	77	19311.	-102017.	28004.	5467.	1552.	2426.	37375.
10	78	16841.	-94920.	29028.	5467.	1552.	2426.	35228.

SUM OF RESTRAINING REACTIONS AT EACH BRANCH POINT

POINT	MX	MY	MZ	FX	FY	FZ
A	-0.	-0.	0.	620.5	0.0	463.1
B	0.	0.	-0.	-742.7	0.0	-223.5
C	-0.	-0.	0.	1288.6	0.0	876.8
D	0.	-0.	-0.	-962.9	2066.6	-751.1
E	0.	0.	0.	0.0	-121.3	0.0
G	0.	-0.	0.	0.0	14.1	-147.8
H	0.	-1.	-2.	0.0	617.5	0.0
K	-1.	0.	1.	0.0	1062.6	-0.0

MAX STRESS = 56091. PSI AT POINT 81

SYSTEM DEFLECTIONS

CONDITION 1

BRANCH 1, FROM A1 TO A

		ROTATIONS IN RADIANS			TRANSLATIONS IN INCHES		
BRANCH	POINT	XROT	YROT	ZROT	XLIN	YLIN	ZLIN
1	1	0.0	0.0	0.0	0.0	0.0	0.0
1	2	0.000303	0.000198	-0.000624	0.0036	-0.0034	0.3343
1	4	0.016723	-0.001724	-0.007571	-0.0781	-0.4308	0.3316
1	5	0.017926	-0.001317	-0.008645	-0.6122	-1.0989	-0.8109
1	7	0.027655	-0.005366	-0.026278	-1.3016	-0.8247	-1.5698
1	8	0.032482	-0.005158	-0.025955	-3.1855	4.1277	-2.5312
1	10	0.035911	-0.007262	-0.021132	-3.2834	5.6142	-2.9643
1	11	0.034744	-0.006804	-0.014256	-1.5157	14.5173	-5.4560
1	13	0.004632	-0.010501	-0.004129	-1.5909	14.8976	-6.1593
1	13	-0.008205	-0.001014	0.000158	0.0000	3.0228	-0.0000
	MOVEMENTS AT END POINT A FROM SOLUTION AS CHECK						
1	13	-0.008205	-0.001014	0.000158	-0.0000	3.0228	-0.0000

BRANCH 2, FROM A TO B

		ROTATIONS IN RADIANS			TRANSLATIONS IN INCHES		
BRANCH	POINT	XROT	YROT	ZROT	XLIN	YLIN	ZLIN
2	13	-0.008205	-0.001014	0.000158	-0.0000	3.0228	-0.0000
2	14	-0.007131	0.000643	-0.001788	-0.3167	-0.3492	2.5359
2	16	-0.005056	0.001465	-0.002190	-0.3519	-0.4610	2.9857
2	17	-0.003637	0.002110	-0.002690	-0.1295	0.1061	4.2620
2	19	0.008926	0.003747	-0.002500	-0.1099	-0.1876	4.4219
2	20	0.012593	0.005301	-0.002746	-0.6060	-2.0711	2.4174
2	22	0.024358	0.007438	-0.003867	-0.8599	-1.7971	1.6837
2	23	0.024605	0.008609	-0.003704	-3.3504	5.9425	-1.4161
2	25	0.013890	0.009015	-0.003743	-3.6922	6.2335	-2.1745
2	26	0.010523	0.009313	-0.003345	-4.3597	4.3500	-4.4481
2	28	-0.000989	0.010529	-0.001797	-4.1592	3.9951	-4.3417
2	29	-0.002205	0.010848	-0.001162	-2.8152	4.2158	-3.0654
2	31	-0.003231	0.012880	0.000977	-2.4987	4.0168	-2.7106
2	32	-0.005040	0.016328	0.007395	0.0001	-3.0006	-0.0004
	MOVEMENTS AT END POINT B FROM SOLUTION AS CHECK						
2	32	-0.005040	0.016328	0.007395	0.0	-3.0005	-0.0000

BRANCH 3, FROM B TO C

		ROTATIONS IN RADIANS			TRANSLATIONS IN INCHES		
BRANCH	POINT	XROT	YROT	ZROT	XLIN	YLIN	ZLIN
3	32	-0.005040	0.016328	0.007395	0.0	-3.0005	-0.0000

SYSTEM DEFLECTIONS

CONDITION 1

BRANCH 3, FROM B TO C

		ROTATIONS IN RADIANS			TRANSLATIONS IN INCHES		
BRANCH	POINT	XROT	YROT	ZROT	XLIN	YLIN	ZLIN
3	33	-0.006729	0.019777	0.011452	7.2069	-10.0179	4.2470
3	35	-0.006231	0.020434	0.011129	8.0479	-10.1129	4.7019
3	36	-0.005103	0.020641	0.010503	10.6404	-9.3794	5.9784
3	38	0.006030	0.019927	0.009285	11.4621	-9.6190	6.2029
3	39	0.009526	0.019797	0.008146	13.0972	-11.5024	4.7597
3	41	0.021529	0.021400	0.005149	12.7107	-11.3076	4.1071
3	42	0.021924	0.022571	0.001855	6.0426	-4.4111	1.0074
3	44	0.011595	0.027086	-0.003264	5.3524	-4.1892	0.3154
3	45	0.008578	0.029068	-0.005486	4.5526	-6.0727	-1.5572
3	47	-0.000881	0.029060	-0.009088	5.1137	-6.4098	-1.4178
3	48	-0.001584	0.029018	-0.011521	8.8277	-6.2287	-0.1414
3	50	-0.000507	0.028438	-0.016117	9.2667	-6.4630	0.1620
3	51	0.001434	0.030693	-0.025635	-0.0000	-11.0501	-0.0002
		MOVEMENTS AT END POINT C FROM SOLUTION AS CHECK					
3	51	0.001434	0.030692	-0.025635	0.0	-11.0500	0.0000

BRANCH 4, FROM C TO D

		ROTATIONS IN RADIANS			TRANSLATIONS IN INCHES		
BRANCH	POINT	XROT	YROT	ZROT	XLIN	YLIN	ZLIN
4	51	0.001434	0.030692	-0.025635	0.0	-11.0500	0.0000
4	52	-0.013560	0.034939	-0.026798	-34.9532	-22.9291	3.2286
4	54	-0.026939	0.038046	-0.021882	-34.6152	-22.6037	4.0014
4	55	-0.031772	0.039882	-0.016081	-25.0704	-15.2798	6.4930
4	57	-0.036407	0.045153	-0.010561	-23.6686	-14.7219	5.5991
4	58	-0.038425	0.045768	-0.008832	-21.7846	-16.4832	-2.9661
4	60	-0.040431	0.049421	-0.007467	-20.2030	-15.6401	-3.9813
4	61	-0.037236	0.054214	-0.007237	0.0010	0.0002	-0.0005
		MOVEMENTS AT END POINT D FROM SOLUTION AS CHECK					
4	61	-0.037236	0.054214	-0.007238	0.0	0.0	0.0

BRANCH 5, FROM D TO E

		ROTATIONS IN RADIANS			TRANSLATIONS IN INCHES		
BRANCH	POINT	XROT	YROT	ZROT	XLIN	YLIN	ZLIN
5	61	-0.037236	0.054214	-0.007238	0.0	0.0	0.0
5	62	0.018155	0.079613	-0.004329	387.8943	-0.0016	50.4470
		MOVEMENTS AT END POINT E FROM SOLUTION AS CHECK					
5	62	0.018155	0.079613	-0.004329	387.8933	0.0000	50.4469

BRANCH 6, FROM E TO G

		ROTATIONS IN RADIANS			TRANSLATIONS IN INCHES		
BRANCH	POINT	XROT	YROT	ZROT	XLIN	YLIN	ZLIN
6	62	0.018155	0.079613	-0.004329	387.8933	0.0000	50.4469

SYSTEM DEFLECTIONS

CONDITION 1

BRANCH 6, FROM E TO G

		ROTATIONS IN RADIANS			TRANSLATIONS IN INCHES		
BRANCH	POINT	XROT	YROT	ZROT	XLIN	YLIN	ZLIN
6	63	0.018143	0.079342	-0.004310	390.5161	-0.5989	50.7812
6	65	0.018105	0.075515	-0.004242	392.3474	-0.9721	53.1313
6	66	0.000714	-0.003778	0.000331	27.9534	0.0028	-0.0260
		MOVEMENTS AT END POINT G FROM SOLUTION AS CHECK					
6	66	0.000714	-0.003777	0.000331	27.9519	0.0000	0.0

BRANCH 7, FROM G TO H

		ROTATIONS IN RADIANS			TRANSLATIONS IN INCHES		
BRANCH	POINT	XROT	YROT	ZROT	XLIN	YLIN	ZLIN
7	66	0.000714	-0.003777	0.000331	27.9519	0.0000	0.0
7	83	0.000024	-0.003387	-0.000511	13.4868	-0.0064	-3.8319
7	67	0.000022	-0.003401	-0.000515	13.3652	-0.0002	-3.8727
		MOVEMENTS AT END POINT H FROM SOLUTION AS CHECK					
7	67	0.000022	-0.003401	-0.000515	13.3652	0.0	-3.8796

BRANCH 8, FROM A2 TO H

		ROTATIONS IN RADIANS			TRANSLATIONS IN INCHES		
BRANCH	POINT	XROT	YROT	ZROT	XLIN	YLIN	ZLIN
8	68	0.0	0.0	0.0	0.0	0.0	0.0
8	67	0.000021	-0.003401	-0.000515	13.3582	0.0027	-3.8892
		MOVEMENTS AT END POINT H FROM SOLUTION AS CHECK					
8	67	0.000022	-0.003401	-0.000515	13.3652	0.0	-3.8796

BRANCH 9, FROM H TO K

		ROTATIONS IN RADIANS			TRANSLATIONS IN INCHES		
BRANCH	POINT	XROT	YROT	ZROT	XLIN	YLIN	ZLIN
9	67	0.000022	-0.003401	-0.000515	13.3652	0.0	-3.8796
9	79	0.000022	-0.004285	-0.000575	13.3697	0.0912	-3.8800
9	81	0.000386	-0.021400	0.006216	13.0026	0.3501	-3.5962
9	78	-0.000530	-0.028714	-0.003155	-3.5292	0.0028	1.9189
		MOVEMENTS AT END POINT K FROM SOLUTION AS CHECK					
9	78	-0.000529	-0.028714	-0.003155	-3.5121	-0.0000	1.9292

BRANCH 10, FROM A3 TO K

		ROTATIONS IN RADIANS			TRANSLATIONS IN INCHES		
BRANCH	POINT	XROT	YROT	ZROT	XLIN	YLIN	ZLIN
10	69	0.0	0.0	0.0	0.0	0.0	0.0
10	70	-0.000148	0.000049	0.000427	0.0002	-0.0004	-0.0905
10	72	-0.007841	-0.002087	0.007727	0.1132	-0.3450	-0.2145
10	73	-0.003953	0.001726	0.009068	2.4474	-2.8288	1.9801

SYSTEM DEFLECTIONS

CONDITION I

BRANCH 10, FROM A3 TO K

		ROTATIONS IN RADIANS			TRANSLATIONS IN INCHES		
BRANCH	POINT	XROT	YROT	ZROT	XLIN	YLIN	ZLIN
10	75	-0.008346	0.003363	-0.001436	2.3213	-3.1721	2.2670
10	76	-0.001060	-0.007802	-0.005202	-3.8020	-0.0573	2.6433
10	78	-0.000528	-0.028715	-0.003154	-3.4948	0.0218	1.9618
MOVEMENTS AT END POINT K FROM SOLUTION AS CHECK							
10	78	-0.000529	-0.028714	-0.003155	-3.5121	-0.0000	1.9292

APPENDIX J: 100 MWe - 18 HOUR CAPITAL COST WORKSHEETS

The appendix contains the cost worksheets for the capital cost of the 100 MWe-18 hours of storage Solar Central Receiver Hybrid Power System. All estimates are in 1979 $, first plant costs, and use Barstow, CA as the plant site.

Attachment 1 shows the construction cost codes used, with the estimating responsibility. MM denotes Martin Marietta, B denotes Badger Plants, G&H denotes Gibbs and Hill, and FW denotes Foster Wheeler.

Attachment 2 provides clarification as to the major hardware elements in each subsystem cost account. Similarly, Attachment 3 contains the definitions for the various indirect cost accounts.

Following Attachment 3 are the cost worksheets for each cost account shown in Attachment 1. A summary worksheet has been provided for each major cost account.

ATTACHMENT 1

CONSTRUCTION COST CODES FOR SOLAR CENTRAL RECEIVER
HYBRID POWER SYSTEM

5000 Plant Cost (4000)

5100 Land, General Site Preparation (4110)

MM 5110 Land (4111)

G&H 5120 Yard Work (Balance of plant) (4112)

MM 5130 Yard Work (Collector fields)

5200 Administrative Areas

G&H 5210 Operations

5211 Administration Buildings (4122)

5212 Control Building (4124)

5213 Communications Equipment (4132)

5220 Security

5230 Storage and Maintenance (4125)

5231 Storage and Maintenance Buildings (4123)

5232 Transportation and Lifting Equipment (4131)

G&H 5233 Miscellaneous Equipment (4133)

5300 Collector Subsystem (4400)

MM 5310 Reflective Unit (4410)

5320 Drive Unit (4420)

5321 Azimuth or Horizontal Drive (4421)

5322 Elevation or Vertical Drive (4422)

5323 Motors (4423)

5324 Position Indicators or Encoders (4424)

MM 5325 Power Distribution and Emergency Supply (4425)

MM 5330 Control and Instrumentation (4430)

5331 Sensor or Calibration Equipment (4431)

5332 Field Control Electronics (4432)

5333 Control Signal Distribution Equipment (4433)

5340 Foundations and Site Preparation (4440)

5350 Heliostat Support and Protection (4450)

5351 Heliostat Support Structure (4451)

5352 Heliostat Protective Enclosure (4452)

5354 Lightning Protection (4453)

5360 Field Assembly and Checkout (4460)

MM 5370 Design and Engineering (4470)

5400 Receiver Subsystem (4500)

5410 Receiver Unit (4510)

MM 5411 Absorber Unit (4511)

MM 5412 Support Structure (4512)

B 5413 Receiver Circulation Equipment (4513)

5414 Instrumentation and Control (4514)

MM

B 5420 Riser, Downcomer and Horizontal Piping (4520)

5421 Vertical Piping

5422 Variable Horizontal

5430 Working Media Cost (4530)

5431 Working Media Cost

B 5432 Working Media Processing Equipment

G&H 5440 Tower (4540)

G&H		5450	Tower Foundation (4550)
		5460	Salt/Steam Generator and Related Piping (4560)
B			5461 Salt/Steam Generator
B			5462 Salt/Steam Circulation Equipment
G&H			5463 Steam/Water Circulation Equipment
G&H			5464 Foundations
MM/B/G&H		5470	Design and Engineering (4570)
	5500		Master Control Subsystem (4350)
MM		5510	Hardware (4351)
↓		5520	Hardware Design and Engineering (4352)
MM		5530	Software Design, Development, and Tests (4353)
	5600		Non-Solar Energy Subsystem (4700)
G&H		5610	Fuel Oil Supply System
↓			5611 Fuel Oil Storage
G&H			5612 Fuel Oil Preparation/Feed
B		5620	Salt Pipes and Pumps
G&H		5650	Foundations (4740)
	5700		Energy Storage Subsystem (4600)
B		5710	Media Containment Equipment (4610)
B		5720	Media Circulation Equipment (4620)
G&H		5750	Foundations (4660)
B		5760	Media (4680)
B		5770	Design and Engineering (4670)

	5800	Electric Power Generation Subsystem
G&H	5810	Turbine Building (4121)
	5820	Steam Turbine Generator (4220)
	5830	Feed Heating and Condensing System (4240)
	5840	Water Treatment and Condensate Makeup System (4260)
	5850	Cooling Tower System (4250)
	5860	Electric Plant Equipment (4300)
	5861	Switchgear (4310)
	5862	Station Service Equipment (4320)
	5863	Protective Equipment (4330)
	5864	Power Wiring, Electrical Structures, and Wiring Containers (4340)
G&H	5870	Air Quality Control (4270)
	5890	Oil Fired Salt Heater System (4230)
FW	5891	Oil Fired Salt Heater
FW	5892	Air Preheater and Forced Draft Fans
G&H	5893	Heater System Foundations
FW	5894	Instrumentation and Control
FW	5895	Design and Engineering
	5900	Indirect Costs (4800)
MM/B/G&H/FW	5910	Indirect Field Construction Costs
	5920	Engineering & Management
	5930	Contingency

ATTACHMENT 2

CONSTRUCTION COST CODES DEFINITIONS

5100 Land, General Site Preparation

5110 Land cost for entire site (MM)

5120 Includes general grading, roads, etc. for balance of plant area (G&H)

5130 Includes general grading, roads for collector fields (MM)

5200 Administrative Areas

5210 Administration & Control buildings will be costed as portion of turbine building

5220 Includes fencing, gates around site (MM), lighting, guard shack, etc., in BOP area (G&H)

5231 Storage and maintenance areas will be costed as part of the turbine building (G&H)

5232 Transportation and lifting equipment is the necessary equipment required for plant operation (G&H)

5233 Miscellaneous equipment (G&H)

5300 Collector Subsystem (MM)

5400 Receiver Subsystem

5411 Absorber unit includes all active surface areas, headers, and header guides (MM)

5412 Support structure includes tower/receiver interface structure, active surface support structure, external enclosure and necessary insulation (MM)

5413 Receiver circulation equipment includes booster pumps (and check & gate valves and recirc. piping around pumps) at base of tower; main circulation pumps (and associated valves) (B)

5414 Includes instrumentation and controls for absorber unit, aperture doors (MM); booster pumps and main circulation pump (B)

5421 Vertical piping includes riser and downcomer to connection with horizontal piping at base of tower. Includes insulation and installation (B)

5422 Horizontal piping includes piping, insulation, tracers, installation and supports for hot and cold piping from base of tower to junction of field piping from the 2 modules.

5431 Working media cost in this account is the salt in the receivers, riser, downcomer, horizontal piping and heat exchangers at the design point (one instant of time) (B)

5432 Working media processing equipment includes startup melter equipment and processing equipment (B)

5440 Tower includes tower cost, elevators, aircraft lighting, etc. (G&H)

5450 Tower foundation includes excavation, foundation construction and final grading around foundation (G&H)

5460 Salt/Steam Generator and Related Piping

5461 Salt/steam heat exchangers includes heat exchanger cost and installation (not including foundations), and insulation.(B)

5462 Salt/steam circulation equipment includes the salt piping from the junction of the horizontal piping in 5422 thru the heat exchanger area. This account also includes the BFW circulation pump and all steam piping between the heat exchangers. The cost should include insulation, trace heating (of salt lines), valves and controls and installation of the piping and BFW circ. pump. (B)

5463 Steam/water circulation equipment is defined as the water/steam piping from the outlet of the boiler feed pump (5830) to the heat exchange area; from the HP turbine extraction to the reheater; and from the reheater and superheater flanges to the turbine inlets. Includes insulation and installation. (G&H)

5464 Heat exchanger foundations includes all foundations, tube layout area, etc. (G&H)

5470 Design and Engineering for all equipment in 5400 (MM/B/G&H)

5500 Master Control (MM)

5600 Nonsolar Energy Subsystem

5611 Fuel storage includes the cost of the main fuel day tank, oil tank, and installation only. (G&H)

5612 Fuel feed includes the cost of the transfer pump and feed pump, valves and controls, and piping to provide the fuel oil from the storage tank to the salt heater. Also includes fuel preparation, i.e., the fuel oil heater, condensate tank, oily water tank and the steam lines for the fuel oil heater. (G&H)

5620 Salt piping/pumps includes the cold salt piping from the main cold salt line in 5462 to the salt heater; the off-temp bypass line to cold storage tank; and the cold salt booster pumps, controls and valves (if required); and the hot salt piping from the salt heater to the main hot salt line in 5462. Insulation, heat tracing and installation for salt piping should be included. (E)

5650 Foundations in this account are only those foundations required for the fuel storage tank and fuel feed subsystem. (G&H)

5700 Energy Storage Subsystem

5710 Media containment equipment consists of the cold storage tank(s), hot storage tank(s) and the drain tank(s). Included in this account is the field erection of the tanks and the internal/external insulation and installation. (B)

5720 Media circulation equipment includes cantilever hot salt pumps and sumps, valves and controls. Salt piping in this account includes the salt piping that is necessitated by having storage and is not included in 5462. This would include the piping from the hot tank to the hot salt pumps. Insulation and installation of pumps and piping is also included. (B)

5750 Foundations - Foundations for the storage tanks and cantilever pumps are in this account. (G&H)

5760 Media - Storage media cost includes that amount of salt in the storage tanks; the hot line to the sump and the sump at the design point. (B)

5800 Electric Power Generation Subsystem

5810 Turbine building - This account is for the cost of the turbine building and foundation. The turbine building includes administrative offices (5211), control room (5212) and storage and maintenance areas (5231). (G&H)

5820 Steam Turbine Generator, including accessories. (G&H)

5830 Feed Heating and Condensing System consists of: the feedwater heaters, the FW heater drain pump, the boiler feed pump, the condenser and condensate pump; piping from the turbine extraction points through the FW heaters to the boiler feed pump, and piping from the turbine extraction points thru the condenser to the FW heaters; all instrumentation and controls, valves, insulation and installation. (G&H)

5840 Water treatment and condensate makeup system. Includes such equipment as clarifiers, demineralizers, water pretreatment, etc. (G&H)

5850 Cooling tower system includes the cooling towers, circulating water pump(s), and piping to and from the condensers. (G&H)

5860 Electric Plant Equipment

5861 Switchgear (G&H)

5862 Station Service Equipment (G&H)

5863 Protective Equipment (G&H)

5864 Power Wiring, Electrical Structures and Wiring Containers (G&H)

5870 Air Quality Control

This account includes all equipment associated with air quality from the salt heater; i.e., electrostatic precipitator, fans, controls, instrumentation, the stack, stack foundation, stack lighting, waste removal, etc. (G&H)

5890 Oil Fired Heater System

5891 Oil fired salt heater includes only the cost of the heater, heat tracing, and field erection. (FW)

5892 Air preheater and FD fans includes all auxiliary equipment such as preheaters and FD fans that are not part of 5891 (FW)

5893 Heater system foundations include all foundations required for 5891 and 5892.(G&H)

5894 Instrumentation and controls associated with operation of the oil fired heater. (FW)

ATTACHMENT 3

DEFINITION OF INDIRECT COST (5900)

5910 Indirect Field Construction Costs

5911 Temporary Construction Facilities

Includes: Temporary buildings, sheds, trailers, work areas, bays, roads, walks, parking, signs, railroads, unloading docks, utilities, personnel protection, camps, cleaning services, maintenance services, utility bills, and site maintenance.

5912 Construction Services, Supplies and Expenses

Services:

Includes: Cleanup, nonproductive time, medical examinations, doctor's fees, move on and off, and construction equipment maintenance and servicing.

Supplies:

Includes: Welding rod, oxygen, acetylene, rags and other consumables.

Field Office Supplies:

Includes: Office machines, telephone, telegraph, postage, computer rental, stationery and furniture.

5913 Field Staff, Labor Expenses

Field Staff:

Includes: Superintendents, field engineers, cost engineers, field administration, warehouseman, purchaser, nurse, safety engineer, timekeeper, accountant, clerks, Q/A control, watchmen, and security service.

Field Staff Subsistence:

Includes: travel, subsistence, transportation, and relocation for field staff.

Field Staff Burdens:

Includes: Vacation, sick leave, and holiday allowance.

5914 Field Craft Benefits, Payroll Burdens and Insurance

Field Craft Benefits:

Includes: Required contributions to funds for vacation, welfare, education, apprentice, retirement, holidays, etc.

Field Craft Travel, Transportation or Subsistence

Payroll Burdens for Field Craft and Field Staff:

Includes: Social security, workmen's compensation, comprehensive PL & PD, state unemployment insurance, federal unemployment insurance.

Insurance:

Includes: Builder's risk, performance bonds, and marine insurance.

5915 Equipment Rental

Construction Equipment Rental

Special Equipment Rental

Small Tools

NOTE: Special rigging equipment included in the Direct Field accounts.

5920 Engineering & Management

5921 Engineering

Plant Engineering - prime contractor to design plant, subcontract construction, and startup plant.

5922 Equipment Procurement by Prime Contractor

5923 Construction Management by Prime Contractor

5930 Contingency

5931 Construction Cost Contingency:

These represent normal construction uncertainties in an estimate which is based on a given design.

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CONSTRUCTION COSTS

CLIENT ____________________

LOCATION Barstow

PROJECT 100 MWe - 18 hr SCRHPS 1st plant

BY ________ CHKD. ________ APVD. ________

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS (1979$ x10^3) LABOR	SUB CONTRACT	MATERIAL	TOTAL
5000	Plant Cost, Summary												
	5100 Land, General Site preparation									37	1562	1224	2823
	5200 Administrative Areas									103	601	782	1486
	5300 Collector @ $160/m²·R												176,354
	@ $80/m²·R												(88,177)
	5400 Receiver Subsystem									8835	7462	13,459	29,756
	5500 Master Control Subsystem										750	344	1094
	5600 Non-solar Energy Supply									397	374	465	1,236
	5700 Thermal Storage Subsystem									2169	5799	12,036	20,004
	5800 Electric power generation subsystem									5528	3853	17,236	26,617
	5900 Indirects												21,261
	Total plant	($160/m²	R)							17,069	20,401	45,546	280,631
		($65/m²	R)										(192,454)

DATE __________ REVISION NO. __________ REVISION DATE __________ PAGE NO. ______ OF ______

REVISION NO. __________ REVISION DATE __________

CONSTRUCTION COSTS

CLIENT ______

LOCATION ______

PROJECT 100 MWe - 12 hour

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5100	Land, General Site Preparation (Summary)												
	5110 Land											1,164,000	1,164,000
	5120 Yard work (BOP)									37,000	62,000	60,000	159,000
	5130 Yard work (Collector Field)										1,500,000		1,500,000
										37,000	1,562,000	1,224,000	2,823,000

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CONSTRUCTION COSTS

CLIENT ______
LOCATION Barstow
PROJECT 100 MWe - 18 hour storage

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5110	LAND												
A	Site												
	TOTAL RECTANGULAR LAND AREA: 3.88 km x 1.80 km = 6.984 km² (1,724.4 acres)	LAND COST RANGE = $350-1000/AC. USED AVERAGE OF $675/AC.											
		1724.4	AC						$675			$1,163,970	$1,163,970
										–	–	1,163,970	$1,163,970
5120	YARD WORK (BALANCE OF PLANT)												
A1	ROAD 20'W x 3600' = 72000 SF / 9	8000	SY					4			32,000		32,000
A2	FIRE LOOP INCL. EARTHWORK, PIPING, HYDRANTS, HOSE HOUSES, ETC	3000	LF	.7	2100	17.50	12.25		20.	37,000		60,000	97,000
A3	RAIL INCL. BUMPERS	470	LF					63.80			30,000		30,000
										37,000	62,000	60,000	159,000

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CONSTRUCTION COSTS

CLIENT ______

LOCATION Barstow

PROJECT 100 MWe - 18 hour

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5130	YARD WORK (COLLECTOR FIELDS)												
A1	CLEARING W/DOZER	6.36×10^6	YD^2					.16			1,038,998		1,038,998
	AREA = 2.66 km^2/MODULE x 2 = 5.32 km^2 (6,362,667 yd^2)												
A2	ROUGH GRADING												
	1/6 LAND ± 3 FT GRADE												
	1/12 x 6.36×10^6 SY x 3/3 = 530,000 yd^2												
	grading	530,000	SY					.72			383,279		383,279
	compacting	500	HR					37.80			20,412		20,412
											1,442,689		1,442,689

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CONSTRUCTION COSTS

CLIENT ____________
LOCATION Barstow
PROJECT 100 MWe-18 hr

BY ________ CHKD. ________ APVD. ________

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5200	ADMINISTRATIVE AREAS (SUMMARY)												
	5210 OPERATIONS									12 000		7000	19 000
	5220 SECURITY									33,000	356,000	50,000	439,000
	5230 STORAGE AND MAINTENANCE									58,000	245,000	725,000	1,028,000
										103,000	601,000	782,000	1,486,000

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Gibbs & Hill, Inc.
ENGINEERS, DESIGNERS, CONSTRUCTORS
NEW YORK

JOB NO. 11-2772-001 DESCR. 100 MW SOLAR PLANT

CLIENT MMSHPP LOCATION BARSTOW, CALIF

EST. BY NJS PAGE NO. 2
CHKD. BY SHEET NO. OF
DATE 8-13-79 APPROVED BY

ESTIMATE

ITEM OR ACCT. NO.	DESCRIPTION	QUANTITY	UNIT	COST PER UNIT MAT'L. $	COST PER UNIT SUBC. $	LABOR MH'S	LABOR $/HR	TOTAL MH'S	COST MATERIALS & EXPENSES	COST SUB-CONTRACTS	COST LABOR	COST TOTAL
5200	Administrative Areas											
5210	Operations											
5211	Administration Building			Part of Turbine Building								
5212	Control Building			Part of Turbine Building								
5213	Communications Equipment											
	Outdoor, Indoor P/A System & Speakers	20	EA	350AV		35 AV	16.55	700	7000		12000	19000
5220	Security (Fencing)											
	FENCE 6'H + 3 STRANDS	2100	LF		10					21000		
	GATES	1	LOT							2000		
	YARD LIGHTING											
	3600/100 = 36 + 4	40	FIX	1250		50	16.55	2000	50000		33000	
	FENCING (COLLECTOR FIELDS)	33,300	LF		10					333000		
									50000	356,000	33,000	439,000

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F-825, 2-79

Gibbs & Hill, Inc.
ENGINEERS, DESIGNERS, CONSTRUCTORS
NEW YORK

JOB NO. 11-2772-001 DESCR. 100 MW SOLAR PLANT

CLIENT MMSHPP LOCATION BARSTOW, CALIF

EST. BY A/C PAGE NO. 3
CHKD. BY ______ SHEET NO. ____ OF ____
DATE 8-13-79 APPROVED BY ______

ESTIMATE

ITEM OR ACCT. NO.	DESCRIPTION	QUANTITY	UNIT	COST PER UNIT MAT'L. $	COST PER UNIT SUBC. $	LABOR MH'S	LABOR $/HR	TOTAL MH'S	COST MATERIALS EXPENSES	COST SUB-CONTRACTS	COST LABOR	COST TOTAL
5230	Storage & Maintenance											
5231	Storage & Maintenance											
	Building 6000 SF	6000	SF		35					210000		
	(BUTLER-TYPE, 1 STORY)											210,000
5232	Transportation & Lifting											
	Equipment 40^T Bridge Crane											
	in Turbine Bldg 50' Span	1	EA	150000		400	17.50	400	150000		9000	
	Cherry Picker 10T	1	EA	50000		100		100	50000			
												209,000
5233	Miscellaneous Equipment											
	Machine Shop Crane											
	Misc. Cranes & Hoists											
	Machine Shop Equipment											
	Lab & Store Room Equip.											
	Sump Pumps	1	LOT				17.50	1700	150000		30000	
	Welding System											
	Air Compressor											
	Instrument Repair											
	A/C 5233 (Cont. next page)											

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Gibbs & Hill, Inc.
ENGINEERS, DESIGNERS, CONSTRUCTORS
NEW YORK

JOB NO. 11-2772-001 DESCR. 100 MW SOLAR PLANT

EST. BY AJC PAGE NO. 4

CHKD. BY SHEET NO. OF

CLIENT MMSHPP LOCATION BARSTOW, CALIF

ESTIMATE

DATE 8-23-79 APPROVED BY

ITEM OR ACCT. NO.	DESCRIPTION	QUANTITY	UNIT	COST PER UNIT MAT'L. $	COST PER UNIT SUBC. $	LABOR MH'S	LABOR $/HR	TOTAL MH'S	COST MATERIALS & EXPENSES	COST SUB-CONTRACTS	COST LABOR	COST TOTAL
5233 (cont)	Diesel Generator 2500 kW	1	EA	375000			17.50	1100	375000		19000	
	Diesel Generator Building 20' x 30'	1	EA		35000					35000		
									375000	35000	19000	429000
									150000		30000	
							TOTAL a/c	5233	525000	35000	49000	609000

F-875, 2-79

CONSTRUCTION COSTS

CLIENT ______
LOCATION Barstow
PROJECT 100 MWe -18 Loop

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5300	Collector												
	12,484 heliostats/module x 2 modules =												
	= 24,968 heliostats												
	24,968 x 49.05 m² = 1,224,680 m²												
	Per K. Battleson, 6/27/79												
	1st plant = $160/m² x .90 = $144/m²												
	$144/m² x 1,224,680 m² =	1,224,680	SM					144					$ 176,354,000
	80th plant = $80/m² x .90 = $72/m²												
	$72/m² x 1,224,680 m² =	1,224,680	SM					72					$ 88,177,000

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CONSTRUCTION COSTS

CLIENT ______
LOCATION ______
PROJECT ______

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5400	RECEIVER SUBSYSTEM SUMMARY												
	5410 RECEIVER UNIT				135,355					2,675,891	570,000	5,296,312	8,542,203
	5420 RISER, DOWNCOMER & VERTICAL PIPING				126,169					2,245,520	686,460	4,100,220	7,032,200
	5430 WORKING MEDIA COST				1362					22,247	750,000	715,150	1,487,397
	5440 TOWER										2,359,000		2,359,000
	5450 TOWER FOUNDATION										2,246,800		2,246,800
	5460 SALT/STEAM GENERATOR AND PIPING				80,231					1,364,600	250,000	3,347,145	4,963,745
	5470 DESIGN AND ENGINEERING									2,525,000	600,000		3,125,000
	TOTAL A/C 5400				343,117					8,835,258	7,462,260	13,458,827	29,756,345

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CONSTRUCTION COSTS

CLIENT __________
LOCATION __________
PROJECT __________

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS			COST/UNIT			COSTS ( )			
				PER UNIT	TOTAL	RATE	LABOR	SUB CONTR.	MAT'L.	LABOR	SUB CONTRACT	MATERIAL	TOTAL
5410	Receiver Cost Summary												
	Absorber Panels	2	LOT	31,910	63,820		638,200	30,000	882,748	1,276,400	60,000	1,765,496	3,101,896
	Pipe & Plumbing	2	LOT	7,225	14,450		144,590	40,000	551,310	289,180	80,000	1,102,620	1,471,800
	Total 5411	2	EA	39,135	78,270		782,790	70,000	1,434,058	1,565,580	140,000	2,868,116	4,573,696
	Structural Support												
	Total 5412	2	LOT	25,234	50,468		416,512	40,000	724,841	833,024	80,000	1,449,682	2,362,706
	Total Receiver Units (5411, 5412)	2	EA	64,369	128,738		1,199,302	110,000	2,158,899	2,398,604	220,000	4,317,798	6,936,402
							$ 3,468,201						
	Receiver Circulation Equip Total 5413				6050					268,000	200,000	874,366	1,342,366
	Receiver I&C												
	Total 5414				567					9,287	150,000	104,148	263,435
	Total 5410				135,355					2,675,891	570,000	5,296,312	8,542,203

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CONSTRUCTION COSTS

CLIENT

LOCATION Barstow

PROJECT 100-MWe, 18 hour

BY CHKD. APVD.

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5411	ABSORBER UNIT (1 UNIT COST)			NOTE: LABOR ASSOCIATED WITH MATERIALS EXCLUDES STORAGE, HANDLING, CUTTING, FITTING AND ALIGNING ON PIPE RACKS (SEE F1A)									
F1	ABSORBER PANELS												
F1A	1½" OD. INCOLOY 800	117800	LF	.15	17670	20.00	3	-	4.89	353,400	-	576,042	939,442
	(LABOR EXCLUDES STORAGE, HANDLING, CUTTING, FITTING, ALIGNING ON PIPE RACKS)												
	WELD TUBES TO HEADERS												
	78 tubes/panel x 20 panels x 2 = 3120	3120	EA	1.5	4680	20.00	30	-	-	93,600	-		93,600
F1B	UPPER HEADERS: 12" sch 20 INCOLOY 800	200	LF	.75	150	20.00	15		236.09	3,000		47,218	50,218
	WELDS	40	EA	7.5	300	20.00	150			6000			6,000
	MACHINING - ALLOW				1000	20.00				20,000			20,000
F1C	LOWER HEADERS: 12" sch 20 INCOLOY 800	200	LF	.75	150	20.00	15		236.09	3,000		47,218	50,218
	WELDS	40	EA	7.5	300	20.00	150			6,000			6,000
	MACHINING - ALLOW				1000	20.00				20,000			20,000
F1D	LATERAL SUPPORT PIPES												
	6" sch 40 INCOLOY 800	2120	LF	.5	1060	20.00	10		100.00	21,200		212,000	233,200
	WELDS	100	EA	6	600	20.00	120			12,000			12,000
	TOTAL FABRICATED PANELS				26,910					538,200	-	882,478	1,420,678

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A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5411	ABSORBER UNIT (CONT)												
	TOTAL FABRICATED PANELS				24,910					538,200		882,478	1,420,678
	TRANSPORTATION 160 K lb × .1875/lb										30,000		
	FIELD ERECTION: ALLOW	20	PAN.	250	5000	20.00	5000			100,000			
	TOTAL INSTALLED PANELS				31,910					638,200	30,000	882,748	1,550,678
F2	ABSORBER UNIT PLUMBING & VALVES												
F2A	4" PIPE & FITTINGS												
	PIPE (sch 10) 347 CRES	360	LF	.225	81	20.00	4.50		32.44	1,620		11,678	13,298
	TEE "	6	EA	1.5	9	20.00	30.00		396.25	180		2377	2557
	90° ELBOW "	2	EA	1.5	3	20.00	30.00		140.70	60		281	341
	45° ELBOW	4	EA	1.5	6	20.00	30.00		130.50	120		522	642
	WELDS	50	EA	1.5	75	20.00	30.00			1500			1500
					174					3,480	-	14,858	18,338

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A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5411 (CONT)													
F2B	8" PIPE & FITTINGS												
	PIPE (SCH 20) INCOLOY 800	15	LF.	.5	7.5	20.00	10.00		151.32	150.		2268	2418
	TEE "	8	EA	3.75	30	20.00	75.00		1812.00	600		14,496	15,096
	150 lb FLANGE "	12	EA	1.90	22.8	20.00	38.00		331.50	456		3978	4434
	PIPE (SCH 20) 347 CRES	45	LF.	.33	14.85	20.00	6.60		56.41	297		2538	2835
	90° ELBOW "	10	EA	1.5	15.0	20.00	30.00		926.35	300		9263	9563
	45° ELBOW "	6	EA	3.75	22.50	20.00	75.00		758.50	450		4551	5001
	150 lb FLANGE "	12	EA	1.90	22.8	20.00	38.00		255.02	456		3060	3516
	WELDS	100	EA	3.75	375.	20.00	75.00		–	7500			7500
					511					10,290	–	40,154	50,444
F2C	12" PIPE & FITTINGS												
	TEE (STRAIGHT) INCOLOY 800	40	EA	4.5	180	20.00	90.00		2994.17	3600		119,766	
	TEE (REDUCING) "	4	EA	4.5	18	20.00	90.00		3110.18	360		12,440	
	150 lb FLANGE "	40	EA	2.25	90	20.00	45.00		774.80	1800		30,992	
	PIPE (SCH 20) 347 CRES	520	LF.	.50	260	20.00	10.00		75.43	5200		39,223	
	TEE (STRAIGHT) "	12	EA	4.5	54	20.00	90.00		2,274.60	1080		27,295	
	TEE (REDUCING) "	4	EA	4.5	18	20.00	90.00		2,410.19	360		9,640	
	90° ELBOW "	54	EA	2.25	121.50	20.00	45.00		1,771.40	2430		70,856	
	45° ELBOW "	22	EA	4.5	99.	20.00	90.00		1,319.10	1980		29,018	
	FLANGE (150 lb) "	40	EA	2.25	90	20.00	45.00		596.11	1800		23,884	
	WELDS	200	EA	7.5	1500	20.00	150.00			30,000			
					2430					48,610	–	363,114	411,724

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CONSTRUCTION COSTS

CLIENT
LOCATION
PROJECT

BY CHKD. APVD.

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A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L	COSTS LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5411 (CONT)													
F2D	18" PIPE & FITTINGS												
	PIPE (SCH 20) 347 CRES	80	LF.	1.2	96	20.00	24		125.49	1920		10,039	
	TEE (STRAIGHT) "	2	EA.	6	12	20.00	120		5,310.00	240		10,620	
	TEE (REDUCING) "	2	EA	6	12	20.00	120		5,716.00	240		11,432	
	90° ELBOW "	2	EA	4.5	9	20.00	90		4,314.00	180		8,628	
	REDUCER "	4	EA	6	24	20.00	120		1854.00	480		7,416	
	150 lb FLANGE "	2	EA	3.75	7.5	20.00	75		1,274.90	150		2,549	
	WELDS	20	EA	15	300	20.00	300			6000			
					460					9,210	-	50,684	59,894
F2E	4" MOTOR OPERATED DRAIN VALVE (SS)	8	EA	75	600	20.00	1500		4500	12,000		36,000	48,000
F2F	12" MOTOR OPERATED DRAIN VALVE (SS)	2	EA	75	150	20.00	1500		20,000	3000		40,000	43,000
F2G	2" VACUUM RELIEF VALVES (SS)	10	EA	40	400	20.00	800		650	8000		6,500	14,500
F2	TOTAL DRAINING & PIPING				4725					94,590		551,310	645,900
	HEAT TRACING (INSTALLED)										40,000		
	FIELD ERECTION - ALLOW				2500	20.00				50,000			
					7225					144,590	40,000	551,310	735,900
5411	ABSORBER UNIT TOTAL EACH	1	EA		39,135					782,790	70,000	1,434,058	2,286,848

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PROJECT ______ BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
54/2	Receiver Unit Support Structure (1 unit)	NOTES:		ALL STRUCTURE A36 STRUCTURAL STEEL; LABOR @ $16.50/hr, BASED ON MEANS CONSTRUCTION DATA & LITERATURE SEARCH								COST IS FOR 1 RECEIVER	
C	STRUCTURAL STEEL												
C1	ROOF												
	a) 18LJ02 JOISTS	26,811	lb		162.5		.10		.26	2,681		6,970	9,651
	b) ROOF FRAME A36 STEEL												
	W21 x 68 46'	3,112	lb										
	W21 x 44 298'	13,108											
	W10 x 49 1300'	63,616											
	WT 8 x 25 620'	15,486											
	L 3½ x 3½ x ½ 313'	3,431											
	ALLOW FOR PLATES, ETC	9,880											
		108,685	lb		1,120		.17		.44	18,476		47,821	66,927
	c) .032 ALUMINUM COVERING	8235	SF		220		.44		.79	3,623		6,505	10,129
C2	WALLS												
	a) NORTH WALL - FRAME												
	W30 x 210 188'	39,375	lb										
	W21 x 68 99'	6739											
	W14 x 136 188'	25,520											
	W14 x 127 141'	17,920											
	W14 x 87 76'	5,820											
	W10 x 49 234'	10,966											
	ALLOW FOR PLATES, CONNECTIONS	10,632											
		116,952	lb		1,205		.17		.44	19,381		51,549	71,340

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A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
C2	North wall (cont)												
	Frame Bracing												
	L6 x 3½ x 5/16 1816'	17,794	lb										
	Allow for plates	2,669	lb										
		20,463	lb		248		.20		.44	4,092		9,003	13,095
	Stringers												
	3 x 2 x 5/16 579'	5788	lb										
	2½ x 2 x 3/16 124'	341											
	3 x 2 x 5/16 700'	6982											
		13,114	lb		159		.20		.42	2,622		5,506	8,128
	Covering												
	14 ga galv sht'g	7194	SF		436		1.00		1.20	7194		8632	15,826
	b) South wall - Frame												
	W21 x 68 100'	6,805	lb										
	W30 x 210 187'	39,375											
	W14 x 136 562'	76,500											
	W14 x 78 112'	8,705											
	W10 x 49 258'	12,632											
	Allow 10% for attachments	14,400											
		158,408	lb		1632		.17		.44	26,929		69,699	96,628

DATE ________ REVISION NO. ________ REVISION DATE ________ PAGE NO. ____ OF ____

REVISION NO. ________ REVISION DATE ________

CONSTRUCTION COSTS

CLIENT

LOCATION

PROJECT

BY CHKD. APVD.

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
C2	South Wall (cont)												
	- Frame Bracing												
	L6 x 3½ x 5/16 2486'	24,360	lb										
	Allow 15% for plates	3654	lb										
		28,014	lb		340		.20		.44	5,602		12,326	17,928
	Stringers												
	3 x 2½ x 5/16 1243'	6791	lb										
	2 x 1½ x 3/16 260'	551											
	2½ x 2 x 3/16 347'	953											
	5 x 3 x 3/8 870'	8526											
	3 x 2 x " 89'	366											
		17,188	lb		208		.20		.42	3437		7,218	10,655
	Covering												
	14 ga. galv sht	10,860	SF		658		1.00		1.20	10,860		13,032	23,892
	c) East Wall												
	Frame												
	W30 x 210 188'	35,375	lb										
	W21 x 68 55'	3,771											
	W14 x 103 171'	17,484											
	W12 x 65 71'	4,585											
	W10 x 49 18'	900											
	Allow for attach	3106											
		65,221	lb		672		.17		.44	11,089		28,697	39,786

DATE REVISION NO. REVISION DATE PAGE NO. OF

REVISION NO. REVISION DATE

CONSTRUCTION COSTS

CLIENT ____________________

LOCATION ____________________

PROJECT ____________________ BY ________ CHKD. ________ APVD. ________

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
	EAST WALL (CONT)												
	FRAME BRACING												
	L6 x 3½ x 5/16 515'	5043	lb										
	ALLOW FOR PLATES	757	lb										
		5800	lb		70		.20		.44	1160		2552	3538
	STRINGERS												
	2 x 1½ x 3/16 260'	550	lb										
	5 x 3 x 3/8 756'	7408											
	3 x 2 x 1/4 89'	366											
		8325	lb		101		.20		.42	1665		3496	5161
	COVERING												
	14 GA GALV SHT	3369	SF		206		1.00		1.20	3396		4043	7439
	d) WEST WALL (SAME AS EAST)												
	FRAME	65,221	lb		672		.17		.44	11,089		20,697	32,786
	BRACING	5800	lb		70		.20		.44	1160		2552	3538
	STRINGERS	8325	lb		101		.20		.42	1665		3496	5161
	COVERING	3369	SF		206		1.00		1.20	3396		4043	7439

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DATE ________ REVISION NO. ________ REVISION DATE ________ PAGE NO. ________ OF ________

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CONSTRUCTION COSTS

CLIENT ______________________

LOCATION ______________________

PROJECT ______________________ BY ________ CHKD. ________ APVD. ________

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS ( ) SUB CONTRACT	COSTS ( ) MATERIAL	COSTS ( ) TOTAL
	e) Floor & Floor Support												
	Welded Plate Girders												
	61x20 266' (327#/ft)	87,118	lb										
	61x20 128' (259#/ft)	33,099	lb										
	61x20 678' (225#/ft)	152,591	lb										
	Allow for conn.	13,640	lb										
		286,448	lb		2951		.17		.25	48,696		71,362	120,058
	Covering												
	5/16 plate = 7162 ft²	91,316	lb		2767		.50		.40	45,158		35,526	82,184
	Floor joist w/ bridging	11,291	lb		198		.20		.29	3258		4724	7982
	f) Super structure												
	W12 x190 420'	79,800	lb										
	Allow for plates	7,980	lb										
		87,780	lb		905		.17		.44	14,937		38,662	53,600
	g) Center section												
	W14 x 78 702'	50,054	lb										
	Allow for connection	2734	lb										
		52,788	lb		543		.17		.44	8973		23,266	32,239
	L6 x 3½ x 9/16 2021'	17,802	lb										
	Allow for plates	2971	lb										
		20,973	lb		216		.17		.44	3565		9210	12,775

DATE ________ REVISION NO. ________ REVISION DATE ________ PAGE NO. ____ OF ____

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J-32

CONSTRUCTION COSTS

CLIENT ______________________

LOCATION ______________________

PROJECT ______________________

BY ________ CHKD. ________ APVD. ________

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
	h) SIDE SHIELDS												
	L 2×2×1/4 1440'	4710	lb										
	20 GA (.0359) sht 2359 ft²	3518	lb										
		8228	lb		250		.50		.50	4114		4114	8228
	i) Roof shields												
	10 lb/ft² × 7612 ft²	76,120	lb		2300		.50		.50	38,060		38,060	76,120
	j) FLOOR SHIELDS												
	10 lb/ft² × 6430 ft²	64,300	lb		1950		.50		.50	32,150		32,150	64,300
	k) DOORS												
	North: W14×119 278'	33,070	lb										
	M 8×6.5 1611'	10,477											
	C 8×11.5 111'	1278											
		44,825	lb		1086		.40		.44	17,933		19,723	37,656
	West: 44,825 lb × 2294 ft²/2930 ft²	35,096	lb		850		.40		.44	14,038		15,422	29,460
	East:	35,096	lb		850		.40		.44	14,038		15,422	29,460
	South: 44,825 lb × 1209 ft²/2930 ft²	18,499	lb		450		.40		.44	7,399		8139	15,538

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DATE ________ REVISION NO. ________ REVISION DATE ________ PAGE NO. ____ OF ____

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CONSTRUCTION COSTS

CLIENT ____________
LOCATION ____________
PROJECT ____________

BY ________ CHKD. ________ APVD. ________

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5412	Receiver Support Structure (cont)												
K	Insulation												
	Roof: 4#/ft³ x .33 ft x 7161 ft²	9548	lb										
	North wall: " " 6851 ft²	9134											
	South wall: " " 10,343 ft²	13,791											
	West wall: " " 3,208 ft²	4,277											
	East wall: " " 3,208 ft²	4,277											
	Center wall: " " 4410 ft²	5880											
	North Door: " " 3089 ft²	4118											
	East door: " " 2423 ft²	3231											
	West door: " " 2423 ft²	3231											
	South door: " " 1277 ft²	1702											
	(44,393 ft²)	59,190	lb		1434		.40		$1.275	23,676		75,467	99,143
	Installation Hardware												
	[illegible] 4 per s.f. x 44,393 sf	177,572	ea						.10			17,757	
					1434					23,676		93,224	116,900
E	Misc. Equipment (Structural												
	Door mechanisms (winch type)	4	ea					10,000			40,000		

All receiver insulation is Fiberfrax Duraback

Source: Carborundum Co.
P.O. Box 808
Niagara Falls, N.Y 14302

DATE ________ REVISION NO. ________ REVISION DATE ________ PAGE NO. ____ OF ____
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CONSTRUCTION COSTS

CLIENT
LOCATION
PROJECT

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5412	Receiver Unit Support Structure (cont) SUMMARY												
C	STRUCTURAL - STEEL & COVERING				23,800					392,836		631,617	1,024,453
E	MISC EQUIPMENT				–						40,000		40,000
K	INSULATION				1434					23,676		93,224	116,900
	TOTAL RECEIVER SUPPORT STRUCTURE FOR ONE RECEIVER	1	LOT		25,234					416,512	40,000	724,841	1,181,353

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CONSTRUCTION COSTS

CLIENT ____________

LOCATION ____________

PROJECT ____________ BY ________ CHKD. ________ APVD. ________

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L	COSTS ( ) LABOR	COSTS ( ) SUB CONTRACT	COSTS ( ) MATERIAL	COSTS ( ) TOTAL
5413	Receiver Circulation Equipment												
E1	Booster pumps / 2000 hp												
	Quote: Pacific Pump - $ 130,935												
	Quote: United - $ 81,632												
	Quote: Bingham - $ 108,387												
	Quote: Ingersol-Rand $ 132,778												
	Avg: $ 113,426	6	EA	1500	9000	17.00	25,250	--	113,426	153,000		680,556	833,556
G2	Main circulation pumps: 300 hp												
	Quote: Pacific Pump: $ 27,914												
	Quote: United: $ 33,403												
	Quote: Bingham: $ 28,279												
	Quote: Ingersoll-Rand: $ 29,452												
	Ave: 29,762	5	EA	200	1000	17.00	3,400		29,762	17,000		148,810	165,810
G	Electrical for pumps												
	Elect: Allow	2	LOTS					100,000			200,000		200,000
F1	Piping around pumps	1	LOTS		6050	16.28				98,000		47,000	143,000
	(See 5413 piping breakdown)												
	Total 5413				16050					268,000	200,000	874,366	1,342,376

DATE ________ REVISION NO. ________ REVISION DATE ________ PAGE NO. ____ OF ____

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BADGER

1	2	3	4	5	6	7	8	9	10	11	12	DESCRIPTION	Unit	Quantity	H (Hours)	M (Mat'l)$	L (Labor)	Total $
												TOTAL CARRIED FORWARD						
												LARGE BORE 3" + UP incl els			2333	21176		
												SMALL BORE 2½" + DOWN						
												CONTROL & SAFETY VALVES			7	—		
C	J											BELOW GRADE PIPING			—	—		
C	S											STEAM TRACING			—	—		
												SUB-TOTAL			2340	21176		
C	M				F							MISC.			895	8755		
C	M											SPECIALS			–			
												SUB-TOTAL			3235	29931		
C	H											HANGERS & SUPPORTS			1130	15800		
C	D							5				TESTING			160	—		
C	G							1				UNLOAD & STORAGE HANDLE			165	–		
C	K											REWORK			120	—		
C	X											X-RAY ~~& STRESS RELIEVE~~			30	250		
C	G											SPECIAL CLEANING & PICKLING						
C	W											FREIGHT				400		
												JOB FACTOR 25% 4840			1210			
												TOTAL SHEET we 16.28 MHr			6050	46931	98494	

TOTAL ACCOUNT		47,000	98,500	145,500
DIRECT				
SUBCONTRACT				

"C" ACCOUNT SUMMARY SHEET

Client Martin Marietta
Plant Solar Hybrid
Subject Acct # 5413

Issue	Date	By	Chkd
	1/25/77	VJP	

Est. No. C 6591

Page C) 1 of 5

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BADGER

MISCELLANEOUS CALCULATION

	WGT. #	MANHOURS	MATERIAL $
SUB-TOTAL 265 c/s		2340	21176
DESIGN DEVELOPMENT 20%		470	4235
TAKE-OFF FACTOR 10%		235	2120
OSHA + QUALITY CONTROL FACTOR 5%		120	1060
MISC.: PUMP PIPING, VENTS, 2%		45	425
DRAINS, NIPPLES, ETC.			
FIELD DETAILER		—	—
WELDER QUALIFICATION		25	165
19. ST mmm = 25 / 13 = 3 x 55			
BOLTS & GASKETS		—	750
14 AIG [illegible] e			
END PROTECTORS		—	—
SPOOLS			
/SPOOL			
TOTAL MISC		895	8755

Issue	Date	By	Chkd
1	9/15/74	[illegible]	

Est. No. E6591

Acct./Sheet C 4 of 5

Martin Marietta
Acct # 5413

<u>BADGER</u>

SUMMARY SHEET CALCULATIONS	WGT.	MANHOURS	MATERIAL $
HANGERS & SUPPORTS incl. Spec. Supports			
35 % OF SUB-TOTAL + MISC. + MM ~~WGT~~ .MHRS		1130	15800
Mat'l # @ 12 MHR			
@ MH'S/TON			
SHOP PAINTING Allowance		—	—
COLOR BANDING			
FREIGHT		—	400
FIELD X-RAY		30	850
STRESS RELIEVE		—	—
PICKLING		—	—
TESTING 5% S.T. MHR 3235		160	—
STEAM TRACING		—	—
UNLOAD & STORAGE HANDLING 7% of ST 2340		165	—
REWORK 5% of ST 2340		120	—

Issue	Date	By	Chkd

Est. No. E 6591

Acct./Sheet C 5 of 5

HC 6 (5413) ✓

QUANTITY	SIZE	DESCRIPTION	WEIGHT		MATERIAL		FAB. LABOR COST		FIELD M H	
			UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
80	6	SCH 60 PIPE			10.50	840			.98	78
55	10	10			13.26	729			1.10	61
35	10	60			25.50	893			1.24	43
30	12	10			13.26	398			1.32	40
15	18	10			22.32	335			2.15	32
15	18	60			48.37	726			2.64	40
35	24	10			34.37	1203			2.82	99
265						5124				393
14	6	60 BW 90° ELL			110.00	1540			10.68	150
9	10	10			57.00	513			13.77	124
5	10	60			280.00	1400			19.07	95
5	12	10			73.00	365			15.38	77
1	18	10 TEE			492	492			29.40	29
1	18	60			1007.	1007			59.04	59
7	24	10			901.	6307			39.01	273
4	10×6	10 RED.			45.00	180			11.92	48
1	12×10	10			67.00	67			15.00	15
1	18×10	10			215.	215			19.90	20
1	18×10	60			350.	350			32.43	32
3	24×12	10			630	1890			24.97	75
2	10	10 NOZZLE WELDS			13	26			7.63	15
2	10	60			26	52			11.07	22
4	18	10			22	88			13.36	53
4	18	60			48	192			29.25	117
2	6	600# FLGS			82.00	164			9.19	18
8	10	300#			90.00	720			12.21	98
4	12				121.00	484			14.91	60
						16,052				1380
						21,176				1773

FILE NO.: E 6591

C.O. #:

SHEET NO.:

CLASS:

AREA:

DATE:

MAT'L: C/S

UNIT: 5413

SIGNATURE:

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CONSTRUCTION COSTS

CLIENT ______________________

LOCATION ______________________

PROJECT ______________________

BY ________ CHKD. ________ APVD. ________

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5414	RECEIVER INSTRUMENTATION AND CONTROL												
41	INSTRUMENTATION FOR RECEIVER FLOW (CONTROL VALVES IN A/C 5411)	2	LOT					50,000			100,000		100,000
42	FLOW CONTROL FOR BOOSTER PUMPS AND MAIN CIRCULATION PUMPS (SEE BACKUP SHEET)	1	LOT		567	16.38	9287		104,148	9287		104,148	113,435
43	INSTRUMENTATION FOR PUMPS	1	LOT					50,000			50,000		50,000
	TOTAL A/C 5414									9287	150,000	104,148	263,435

DATE ________ REVISION NO. ________ REVISION DATE ________ PAGE NO. ____ OF ____

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He 6

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QUANTITY	SIZE	DESCRIPTION	WEIGHT UNIT	WEIGHT TOTAL	MATERIAL UNIT	MATERIAL TOTAL	FAB. LABOR COST UNIT	FAB. LABOR COST TOTAL	FIELD M H UNIT	FIELD M H TOTAL
8	10	300# SCH 10 GATE V.			2490	19920			14.51	116
4	10	600# 60			5365	21460			21.11	84
4	12	300# 10			3162	12648			16.39	66
4	10	600# 60 CHECK V			3580	14320			21.11	84
4	12	300# 10			2950	11800			16.39	66
						80,148				410
24		MOTOR OPERATORS			1000	24000			6.00	144
1	6	600# FLGD GATE V.			—	—			6.46	7
2		[illegible]								

104,148

567

FILE NO.: E6591

C.O. #:

SHEET NO.:

CLASS:

AREA:

DATE.

MAT'L: C/S

UNIT: 5414

SIGNATURE:

67-61

CONSTRUCTION COSTS

CLIENT

LOCATION

PROJECT

BY CHKD. APVD.

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS ( ) SUB CONTRACT	COSTS ( ) MATERIAL	COSTS ( ) TOTAL
5420	RISER, DOWNCOMER AND VERTICAL PIPING												
5421	RISER AND DOWNCOMER												
F1	PIPING, INCL SUPPORTS	1	LOT		14,167		421,600		675,400	421,600		675,400	1,097,000
	(SEE FOLL. PAGES FOR BREAKDOWN)												
K	INSULATION												
	6" thick, 18" pipe (COLD)	1554	LF	1.75	2720	16.38	28.42		28.42	44,164		44,164	88,329
	9" thick, 18" pipe (HOT)	1554	LF	2.65	4118	16.38	43.42		43.42	67,474		67,474	134,949
	FROM RECENT BADGER DATA												
G	ELECTRIC HEAT TRACING	3108	LF					30.00			93,240		93,240
	(3 TRACES)												
	THERMON QUOTE									533,238	93,240	787,538	1,413,900
	TOTAL A/C 5421				21,005								

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DATE REVISION NO. REVISION DATE PAGE NO. OF

REVISION NO. REVISION DATE

BADGER

1	2	3	4	5	6	7	8	9	10	11	12	DESCRIPTION	Unit	Quantity	H (Hours)	M (Mat'l)$	L (Labor)	Total $
												TOTAL CARRIED FORWARD 1440' c/s						
												LARGE BORE 3" + UP 1440' c/s 2880'			9911	414 373		
												SMALL BORE 2½" + DOWN						
												CONTROL & SAFETY VALVES						
C	J											BELOW GRADE PIPING			—	—		
C	S											STEAM TRACING			—	—		
												SUB-TOTAL			9911	414 373		
C	M				F							MISC.			3770	154 760		
C	M											SPECIALS			—	—		
												SUB-TOTAL			13681	569 133		
C	H											HANGERS & SUPPORTS			4730	67000		
C	D							5				TESTING			655	—		
C	G							1				UNLOAD & STORAGE HANDLE			695	—		
C	R											REWORK			495			
C	X											X-RAY ~~& STRESS RELIEVE~~			380	11300		
C	G											SPECIAL CLEANING & PICKLING						
C	W											FREIGHT				28000		
												JOB FACTOR 25% 20716			5180			
												TOTAL SHEET			25896	675 433	421 587	

TOTAL ACCOUNT		675 400	421 600	1,097,00[illegible]
DIRECT				
SUBCONTRACT				

"C" ACCOUNT SUMMARY SHEET

Client Martin Marietta
Plant Solar Hybrid
Subject Acct # 5421

Issue	Date	By	Chkd
1	[illegible]	[illegible]	

Est. No. C 6591

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BADGER

MISCELLANEOUS CALCULATION

	WGT. #	MANHOURS	MATERIAL $
SUB-TOTAL		9911	414 373
DESIGN DEVELOPMENT 20 %		1985	82 875
TAKE-OFF FACTOR 10%		990	41 440
OSHA + QUALITY CONTROL FACTOR 5%		495	20,720
MISC.: PUMP PIPING, VENTS, 2%		200	8290
DRAINS, NIPPLES, ETC.			
FIELD DETAILER			
—			
WELDER QUALIFICATION 1%		100	715
100/8 = 13 × 55			
BOLTS & GASKETS 5 ea 16		—	720
END PROTECTORS		—	
SPOOLS			
/SPOOL			
MISC. TOTAL		3770	154 760

Issue	Date	By	Chkd
1	9/25/7?	[illegible]	

Est. No. E 6591

Acct./Sheet C 4 of 5

Martin Marietta
Acct # 5421

BADGER

SUMMARY SHEET CALCULATIONS	WGT.	MANHOURS	MATERIAL $
HANGERS & SUPPORTS			
35% OF SUB-TOTAL + MISC. + MM ~~WGT~~ MHRS		4780	67000
MATL # @ 14 MIL			
@ MH'S/TON			
SHOP PAINTING		—	—
COLOR BANDING			
FREIGHT		—	28000
FIELD X-RAY		380	11300
STRESS RELIEVE			
PICKLING			
TESTING 5% S.T MHRS 13681		685	—
STEAM TRACING			
UNLOAD & STORAGE HANDLING 7% ST 9911		695	
REWORK 5% ST 9911		495	

Issue	Date	By	Chkd
1	9/25/[illegible]	[illegible]	

Est. No. E6591

Acct./Sheet C 5 of 5

Martin Marietta
Acct # 5421

Hc 9 ET 5421 ✓

QUANTITY	SIZE	DESCRIPTION	WEIGHT UNIT	WEIGHT TOTAL	MATERIAL UNIT	MATERIAL TOTAL	FAB. LABOR COST UNIT	FAB. LABOR COST TOTAL	FIELD M H UNIT	FIELD M H TOTAL
									FIELD	
400	18	SCH. 10 PIPE			124.	49600			1.93	772
400	18	20			143.	57200			2.04	816
640	18	30			215.	137600			2.28	1459
1440						244,400				3047
12	18	SCH. 10 BW 90° ELL			1305.	15660			46.80	562
8	18	20			1567.	12536			48.50	388
18	18	30			2004.	36072			58.26	1049
2	18	10 NOZZLE WELDS			124	248			29.72	59
2	18	10 STUBENDS			673	1346			27.48	55
4	18	20			673	2692			29.18	117
2	18	30			1000	2000			34.06	68
8	18	300# SO FLGS C/S			265	2120			9.80	78
						72674				2376

317074 5423

FILE NO.: E6591

SHEET NO.:

C.O. #

CLASS:

AREA:

DATE

MAT'L: 347 SS

UNIT: 5421

SIGNATURE:

67-61

HC6 ET 5421 ✓

QUANTITY	SIZE	DESCRIPTION	WEIGHT		MATERIAL		FAB. LABOR COST		FIELD M H	
			UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
									FIELD	
1440	18	SCH. 60 PIPE			48.37	69653			1.92	2765
38	18	BW 90° ELL			725	27550			43.78	1664
2	18	NOZZLE WELDS			48	96			29.35	59
						27646				1723
						97299				4488

FILE NO.: E 6591

C.O. #: J-48

SHEET NO.:

CLASS:

AREA:

DATE:

MAT'L: C/S

UNIT: 5421

SIGNATURE:

67-61

CONSTRUCTION COSTS

CLIENT ______
LOCATION ______
PROJECT ______

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5420	(CONT)												
.5422	VARIABLE HORIZONTAL PIPING												
F1	PIPING, INCL SUPPORTS (SEE BACKUP SHEETS)	1	LOT		72,951					1,187,600		2,788,000	3,975,600
K	INSULATION:												
	6" THICK, 4" PIPE (COLD)	221	LF	.91	201	16.38	14.92		14.92	3297		3297	6594
	18" PIPE (COLD)	7220	LF	1.75	12,635	16.38	28.24		28.24	203,892		203,892	407,784
	24" PIPE (COLD)	10	LF	2.00	20	16.38	33.03		33.03	330		330	660
	9" THICK, 4" PIPE (HOT)	97	LF	1.29	125	16.38	21.08		21.08	2045		2045	4090
	18" PIPE (HOT)	7031	LF	2.65	18,632	16.38	43.42		43.42	305,286		305,286	610,572
	24" PIPE (HOT)	195	LF	3.08	600	16.38	50.42		50.42	9832		9832	19,664
G	ELECTRIC HEAT TRACING THERMON QUOTE: 3 TRACES	14,774	LF					30.00			443,220		443,220
A	CIVIL: FOUNDATIONS FOR SUPPORTS, ETC	1	LOT								150,000		150,000
	TOTAL A/C 5422				105,164					1,712,282	593,220	3,312,682	5,618,184

DATE ______ REVISION NO. ______ REVISION DATE ______ PAGE NO. ______ OF ______

REVISION NO. ______ REVISION DATE ______

524,682

BADGER

CODE POSITION 1	2	3	4	5	6	7	8	9	10	11	12	DESCRIPTION	Unit	Quantity	H (Hours)	M (Mat'l)$	L (Labor)	Total $
												TOTAL CARRIED FORWARD						
												LARGE BORE 3" + UP			27 976	1 787 571		
												SMALL BORE 2½" + DOWN						
												CONTROL & SAFETY VALVES						
C	J											BELOW GRADE PIPING			—	—		
C	S											STEAM TRACING			—	—		
												SUB-TOTAL			27976	1787571		
C	M				F							MISC.			10 635	661 445		
C	M											SPECIALS			—	—		
												SUB-TOTAL			38 611	2 449 016		
C	H											HANGERS & SUPPORTS			13 500	157000		
C	D							5				TESTING			1930	—		
C	G							1				UNLOAD & STORAGE HANDLE			1960	—		
C	R											REWORK			1600	—		
C	X											X-RAY ~~& STRESS RELIEVE~~			960	28000		
C	C											SPECIAL CLEANING & PICKLING						
C	W											FREIGHT				122 000		
												JOB FACTOR 25% 58361			14 590			
												TOTAL SHEET			72951	2788016	1187642	

TOTAL ACCOUNT		2 788 000	1 187 600	3975600
DIRECT				
SUBCONTRACT				

"C" ACCOUNT SUMMARY SHEET

Client Martin Marietta

Plant Solar Hybrid

Issue	Date	By	Chkd
1	[illegible]	[illegible]	

Est. No. E 6591

Page C 1 of 5

J-50

BADGER

MISCELLANEOUS CALCULATION

	WGT. #	MANHOURS	MATERIAL $
SUB-TOTAL		27 976	1 787 571
DESIGN DEVELOPMENT 20%		5595	357 515
TAKE-OFF FACTOR 10%		2800	178 760
OSHA + QUALITY CONTROL FACTOR 5%		1400	89 380
MISC.: PUMP PIPING, VENTS, 2%		560	35 750
DRAINS, NIPPLES, ETC.			
FIELD DETAILER		—	—
WELDER QUALIFICATION 1%		280	
BOLTS & GASKETS 4		—	40
END PROTECTORS		—	—
SPOOLS			
/SPOOL			
MISC. TOTAL		10635	661,445

Issue	Date	By	Chkd
1	9/25/70	[illegible]	

Est. No. E 6591

Acct./Sheet C 4 of 5

Martin Marietta
Acct # 5422

BADGER

SUMMARY SHEET CALCULATIONS

	WGT.	MANHOURS	MATERIAL $
HANGERS & SUPPORTS			
35 % OF SUB-TOTAL + MISC. + MM ~~WGT.~~ MHRS		13500	189 000
MAT'L # 6 14, MHR			
@ MH'S/TON			
SHOP PAINTING		—	—
COLOR BANDING			
FREIGHT			122 000
FIELD X-RAY 28-4" S/S 0-4" C/S 33 @ 15 1; 7-18" S/S 74-18" C/S 431 @ 60 2; 21-24" 21 @ 72 3; 28		960	28 000
STRESS RELIEVE		—	—
PICKLING		—	—
TESTING 5% ST MHR 38611		1930	—
STEAM TRACING			
UNLOAD & STORAGE HANDLING 7% ST 27976		1960	
REWORK 5% ST 27976		1400	

Martin Marietta
Acct # 5422

Issue	Date	By	Chkd
1	9/25/7[illegible]	[illegible]	

Est. No. E 6591

Acct./Sheet C 5 of 5

HC 9 ET 5422 /

QUANTITY	SIZE	DESCRIPTION	WEIGHT		MATERIAL		FAB. LABOR COST		FIELD M H	
			UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
										[illegible]
70	4	SCH.40 PIPE 34755			50.	3500			.76	53
7025	18	30			215.	151375			2.28	16017
195	24	30			376.	73320			3.01	587
7290						1,528195				1605
5	4	SCH40 BW 90° ELL			130.	650			10.65	53
2	18	30			2004	4008			58.26	117
2	4	40 TEE			200.	400			16.08	32
3	24	30			8440	25320			108.81	326
2	24x18	30 RED			2233	4466			60.81	122
4	4	40 STUB END			100.	400			5.69	22
4	4	300# SO FLGS C/S			18.	72			2.76	11
						35316				683

1622,511 17340

FILE NO: E6591

C.O #

SHEET NO.

CLASS:

AREA

DATE

MAT'L: 34755

UNIT 5422

SIGNATURE

67-61

HC 6 ET 5422

QUANTITY	SIZE	DESCRIPTION	WEIGHT		MATERIAL		FAB. LABOR COST		FIELD M H	
			UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
185	4	SCH. 60 PIPE			8.	1480			.77	142
7220	18	10 "			22.32	161150			1.42	10252
10	24	" 10 "			39.35	394			2.82	28
#15						163024				1042
12	4	SCH 60 BW 90° ELL			10.00	120			6.21	75
3	4	60 TEE			22.00	66			8.82	26
2	18	10 "			492.	984			29.40	59
2	24x18	" 10 RED.			433.	866			27.01	54
						2036				21.
						165060				10636

FILE NO.: E-6591

C.O. #:

SHEET NO.:

CLASS:

AREA:

DATE:

MAT'L: C/S

UNIT: 5422

SIGNATURE:

67-61

CONSTRUCTION COSTS

CLIENT
LOCATION
PROJECT

BY CHKD. APVD.

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS ( ) SUB CONTRACT	COSTS ( ) MATERIAL	COSTS ( ) TOTAL
5431	Working Media Cost												
	(Salt in receivers, piping, and heat exchangers, excluding storage)	6.231	lb x 10^6						0.1114			694,133	694,133
5432	Working Media Processing Equipment												
	(Includes mixers, bins and melter)												
	Based on Badger Plants files	1	LOT					750,000			750,000		750,000
	Salt transfer pump (PP 101)	1	EA	40	40	17.00	680		7550	680		7550	8,230
	Salt transfer piping (see backup)	1	LOT		897	16.38				14,600		6500	21,100
	Insulation, 6" thick, 4" pipe	467	LF	.91	425	16.38	14.92		14.92	6967		6967	13,934
	Total A/C 5432				1362					22,247	750,000	21,017	793,264
					1362					22,247	750,000	715,150	1,487,397

DATE REVISION NO. REVISION DATE PAGE NO. OF
REVISION NO. REVISION DATE

BADGER

CODE POSITION 1	2	3	4	5	6	7	8	9	10	11	12	DESCRIPTION	Unit	Quantity	H (Hours)	M (Mat'l)$	L (Labor)	Total $
												TOTAL CARRIED FORWARD						
												LARGE BORE 3" + UP 380' c/s			338	2787		
												SMALL BORE $2\frac{1}{2}$" + DOWN						
												CONTROL & SAFETY VALVES			4	-		
C	J											BELOW GRADE PIPING			-	-		
C	S											STEAM TRACING			-	-		
												SUB-TOTAL			342	2787		
C	N				F							MISC.			130	1100		
C	M											SPECIALS			-	-		
												SUB-TOTAL			472	3887		
C	H											HANGERS & SUPPORTS			165	2300		
C	T							5				TESTING			25	-		
C	C							T				UNLOAD & STORAGE HANDLE			25	-		
C	T											REWORK			20	-		
C	X											X-RAY ~~& STRESS RELIEVE~~			10	100		
C	G											SPECIAL CLEANING & PICKLING						
C	W											FREIGHT				200		
												JOB FACTOR 25% 717			180			
												TOTAL SHEET			897	6487	14603	

	H (Hours)	M (Mat'l)$	L (Labor)	Total $
TOTAL ACCOUNT		6500	14600	21100
DIRECT				
SUBCONTRACT				

"C" ACCOUNT SUMMARY SHEET

Issue	Date	By	Chkd
1	7/5/77	[illegible]	

Client Martin Marietta

Plant Sodium Hydroxide

Subject Acct # 5432

Est. No. E6571

Page C 1 of 5

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BADGER

MISCELLANEOUS CALCULATION

		WGT. #	MANHOURS	MATERIAL $
SUB-TOTAL			342	2787
DESIGN DEVELOPMENT	20%		70	560
TAKE-OFF FACTOR	10%		35	280
OSHA + QUALITY CONTROL FACTOR	5%		15	140
MISC.: PUMP PIPING, VENTS, DRAINS, NIPPLES, ETC.	2%		5	55
FIELD DETAILER				
WELDER QUALIFICATION	1%		5	55
5/8 - 1455				
BOLTS & GASKETS			—	10
END PROTECTORS			—	—
SPOOLS				
/SPOOL				
MISC TOTAL			130	1100

Issue	Date	By	Chkd
1	2/25/76	VA	

Est. No. E6591

Acct./Sheet C 4 of 5

Martin Marietta
Acct # 5432

BADGER

SUMMARY SHEET CALCULATIONS	WGT.	MANHOURS	MATERIAL $
HANGERS & SUPPORTS			
35% OF SUB-TOTAL + MISC. + MM ~~WGT~~. MHRS		165	2300
Mat'l # @ 14 mm			
@ MH'S/TON			
SHOP PAINTING		—	—
COLOR BANDING			
FREIGHT			200
FIELD X-RAY 10 4" ck. @ 10 #/mh		10	100
STRESS RELIEVE			
PICKLING			
TESTING 5% ST MH 472		25	—
STEAM TRACING			
UNLOAD & STORAGE HANDLING 7% ST 362		25	—
REWORK 5% ST 342		20	

Issue	Date	By	Chkd
1	[illegible]	[illegible]	

Est. No. E6591

Acct./Sheet C 5 of 5

Martin Marietta
Acct # 5432

Hc 6 ET 5432 ✓

QUANTITY	SIZE	DESCRIPTION	WEIGHT		MATERIAL		FAB. LABOR COST		FIELD M H	
			UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
380	4	SCH 40 Pipe C/S			4.40	1672			.61	232
12	4	" BW 90° ELL			6.65	80			6.33	76
3	4	300# FLGS			11.50	35			5.34	16
						115				92
1	4	300# SCH40 GATE V			540	540			6.70	7
1	4	" CHECK V			460	460			6.70	7
						1000				14
1	4	300# Flg'd Control V			—	—			4.21	4
						2787				342

FILE NO.: E 6591

C.O. #:

SHEET NO.:

CLASS:

AREA:

DATE

MAT'L: C/S

UNIT: 5432

SIGNATURE:

67-61

CONSTRUCTION COSTS

CLIENT ______________________
LOCATION Barstow
PROJECT 100 MWe - 1st plant

BY ________ CHKD. ________ APVD. ________

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5440	Tower												
	(1) Based on Sandia cost eqtn, see following pages	2	EA					1,179,500			2,359,000		2,359,000
	(2) Gibbs and Hill estimate see backup shts	2	EA					(3,200,000)			(6,400,000)		(6,400,000)

DATE ________ REVISION NO. ________ REVISION DATE ________ PAGE NO. ____ OF ____

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5440 TOWER REF: K.W. BATTLESON memo to DISTRIBUTION, March 2, 1979 "COSTS AND EARTHQUAKE LOADS FOR CONICAL, CONCRETE TOWERS FOR SOLAR CENTRAL RECEIVERS"

$$\text{TOWER COST} = 0.194 + 0.669 \times 10^{-6} H_T (H_T M_{MAX})^{0.4}$$

$$\text{ACCESSORIES} = 0.175 + .0002 H_T$$

WHERE
$$M_{WIND} = 1.72 \times 10^{-7} V^2 \left[H_T^3 - 0.027 H_T^{3.23} + 3.88 H_R D_R \left(H_T + \frac{H_R}{2} \right)^{1.23} \right]$$

$$M_{EQ} = 5.71 \times 10^{-3} (\ddot{X}_g)^{1.5} H_T \left[W_R (536 - H_T) + 5.34 H_T (H_T - 160) \right]$$

FOR SOLAR HYBRID SYSTEM:

$H_T = 514$ FT

$H_R = 98.6$ FT

$D_R = 87.7$ FT

$W_R = 2154$ kips

OTHER VARIABLES:

$V = 90$ mph (30 ft REF height)

$\ddot{X}_g = .25$ g's

therefore,

$$M_{WIND} = 1.72 \times 10^{-7} (90)^2 \left[(514)^3 - 0.027 (514)^{3.23} + 3.88 (98.6)(87.7)\left(514 + \frac{98.6}{2} \right)^{1.23} \right]$$

$$= 280,738 \text{ ft-lb}$$

$$* \; M_{EQ} = 5.71 \times 10^{-3} (.25)^{1.5} (514) \left[2154 (536 - 514) + 5.34 (514)(514 - 160) \right]$$

$$= 373,850 \text{ ft-lb}$$

$$M_{MAX} = M_{EQ} = 373,850$$

the tower cost thus becomes:

$$\text{TOWER COST} = 0.194 + 0.669 \times 10^{-6} (514)(514 \cdot 373,850)^{0.4}$$

$$= \$.901707 \text{ M}$$

$$\text{ACCESSORY COST} = 0.175 + .0002 (514)$$

$$= \$.2778 \text{ M}$$

TOTAL 544c : \$1,179,507 / tower

x2

\$2,359,000

ALTERNATE TOWER ESTIMATE, NOT USED

Gibbs & Hill, Inc.
ENGINEERS, DESIGNERS, CONSTRUCTORS
NEW YORK

JOB NO. 11-2772-001 DESCR. 100 MW SOLAR PLANT

CLIENT MMSHPP LOCATION BARSTOW, CALIF

EST. BY AJc PAGE NO. 5
CHKD. BY SHEET NO. OF
DATE 5-23-79 APPROVED BY

ESTIMATE

ITEM OR ACCT. NO.	DESCRIPTION	QUANTITY	UNIT	COST PER UNIT MAT'L. $	COST PER UNIT SUBC. $	LABOR MH'S	LABOR $/HR	TOTAL MH'S	COST MATERIALS EXPENSES	COST SUB-CONTRACTS	COST LABOR	COST TOTAL
5440	Tower 165 m. H x44' dia. x											
	70' dia.											
	Concrete-Floor Slab & Ring											
	Beam 100 cy											
	Wall 6280 cy											
	6380 cy	6380	CY	40		3		19140	255200			
	Rebar 200 lb/CY	638	TN	550		50		31900	350900			
	Slipforms Including							25000	167000			
	Scaffolding							(40)				
	SUB TOTAL						17.50	76000	773100		1333000	2103100
	Indirect Costs											826000
	Elevator											150000
	Gratings & Supports	22	T	2000		100	17.50	2200	44000		39000	83000
	Obstruction Lights, Etc.	ALLOW										38000
												(100)
	SINGLE TOWER TOTAL											3200000
5470	Design Engineering											250000

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CONSTRUCTION COSTS

CLIENT

LOCATION

PROJECT

BY CHKD. APVD.

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5450	TOWER FOUNDATION												
	(1) FROM 5440, $M_{MAX} = 373,850$												
	SANDIA COST EQTN,												
	$\$_{FOUND} = 0.60 + 1.4 \times 10^{-6} M_{MAX}$	2	EA					1,123,400			2,246,800		2,246,800
	(2) GIBBS AND HILL ESTIMATE, SEE FOLLOWING SHEET	2	EA					(1,450,000)			(2,900,000)		(2,900,000)

DATE REVISION NO. REVISION DATE PAGE NO. OF

REVISION NO. REVISION DATE

ALTERNATE TOWER FOUNDATION ESTIMATE, NOT USED.

Gibbs & Hill, Inc.
ENGINEERS, DESIGNERS, CONSTRUCTORS
NEW YORK

JOB NO. 11-2772-001 DESCR. 100 MW SOLAR PLANT

EST. BY elc PAGE NO. 6

CHKD. BY SHEET NO. OF

CLIENT MMSHPP LOCATION BARSTOW, CALIF

ESTIMATE

DATE 8-13-79 APPROVED BY

ITEM OR ACCT. NO.	DESCRIPTION	QUANTITY	UNIT	COST PER UNIT MAT'L. $	COST PER UNIT SUBC. $	COST PER UNIT LABOR MH'S	COST PER UNIT LABOR $/HR	TOTAL MH'S	COST MATERIALS EXPENSES	COST SUB-CONTRACTS	COST LABOR	COST TOTAL
5450	Tower Foundation 180'											
	Across Flats											
	Concrete 7890 CY	7890	CY	40		1	17.50	7890	315600		139075	
	Rebar 150*/CY, Anchor Bolts	590	TN	550		35	17.50	20650	324500		361375	
	Forms (Reuse)	25000	SF	100		0.35	17.50	8750	25000		153125	
	Excav. & Backfill	15400	CY			.5	12.50	7700	–		96250	
	Premoulded Expansion Joints	1	LS	–			17.50	860	20000		15000	
									(100)		(175)	
	TOTAL	9380	CY						685000		765000	1,450,000

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F-825 2-79

CONSTRUCTION COSTS

CLIENT ______
LOCATION ______
PROJECT ______

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS			COST/UNIT			COSTS ( )			
				PER UNIT	TOTAL	RATE	LABOR	SUB CONTR.	MAT'L.	LABOR	SUB CONTRACT	MATERIAL	TOTAL
5460	SALT/STEAM GENERATOR SUMMARY												
	5461				1600					27,200	250,000	1,573,310	1,850,510
	5462				31,761					519,400		835,835	1,355,235
	5463				41,370					724,000		883,000	1,607,000
	5464				5500					96,000		55,000	151,000
	TOTAL A/C 5460				80,231					1,366,600	250,000	3,347,145	4,963,745

DATE ______ REVISION NO. ______ REVISION DATE ______ PAGE NO. ______ OF ______

REVISION NO. ______ REVISION DATE ______

CONSTRUCTION COSTS

CLIENT ______
LOCATION ______
PROJECT ______ BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5461	SALT/STEAM GENERATOR					NOTE: QUOTES ARE FOR CONSTRUCTED UNIT, FOB BARSTOW							
E1	TT101 BFW PREHEATER (21,386 ft^2)												
	QUOTE: INDUSTRIAL FABRICATORS	1	EA						199,735				
	QUOTE: WYATT IND	1	EA						245,969				
	AVERAGE DELIVERED COST:	1	EA						222,852			222,852	222852
	INSTALLATION: (BADGER FILES)			200	200	17.00	3400			3400			3400
													226,252
E2	TT102 STEAM GENERATOR (24,190 ft^2)												
	QUOTE: INDUSTRIAL FABRICATORS	1	EA						393,105				
	QUOTE: WYATT IND.	1	EA						466,900				
	AVE. DELIVERED COST:	1	EA						430,000			430,000	430,000
	INSTALLATION: (BADGER FILES)			400	400	17.00	6800			6800			6800
													436,800

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CONSTRUCTION COSTS

CLIENT ____________
LOCATION ____________
PROJECT ____________

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5461	(CONT)												
E3	TT-103 STEAM SUPERHEATER (14,300 FT²)												
	QUOTE: INDUSTRIAL FABRICATORS	1	EA						535,315	–			
	QUOTE: WYATT IND.	1	EA						483,913				
	AVE. DELIVERED COST	1	EA						509,614			509,614	509,614
	INSTALLATION (BADGER FILES)			400	400	17.00	6800			6800			6800
													516,414
E4	TT-104 STEAM REHEATER (11,925 FT²)												
	QUOTE: INDUSTRIAL FABRICATORS	1	EA						311,035				
	QUOTE: WYATT IND	1	EA						350,652				
	AVE. DELIVERED COST	1	EA						330,844			330,844	330,844
	INSTALLATION (BADGER FILES)			300	300	17.00	5100			5100			5100
													335,944

DATE ______ REVISION NO. ______ REVISION DATE ______ PAGE NO. ______ OF ______
REVISION NO. ______ REVISION DATE ______

CONSTRUCTION COSTS

CLIENT ______
LOCATION ______
PROJECT ______ BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS ( ) SUB CONTRACT	COSTS ( ) MATERIAL	COSTS ( ) TOTAL
5461	(CONT)												
ES	MS103 STEAM DRUM												
	QUOTE: INDUSTRIAL FABRICATORS	1	EA						80,000			80,000	80,000
	INSTALLATION			300	300	17.00	5100			5100			5100
													85,100
	HEATING BLANKETS TO 500°F												
	QUOTE: BRISK-HEAT, INC	1	LOT					50,000			50,000		50,000
	Hx RACKS AND STRUCTURES												
	ALLOW (BADGER ELLIS)	1	LOT					200,000			200,000		200,000
	TOTAL 5461				1600					27,200	250,000	1,573,310	1,850,510

DATE ______ REVISION NO. ______ REVISION DATE ______ PAGE NO. ______ OF ______
REVISION NO. ______ REVISION DATE ______

CONSTRUCTION COSTS

CLIENT ____________________

LOCATION ____________________

PROJECT ____________________ BY ________ CHKD. ________ APVD. ________

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5462	SALT / STEAM CIRCULATION EQUIP.												
E1	PP107 BFW pump 5 hp												
	QUOTE: PACIFIC PUMP - $39,105												
	QUOTE: UNITED PUMP - 11,030												
	AVE: $25,067	2	EA	200	400	17.50	3500		25,067	7000		50,135	57,135
F1	PIPING (SEE BACKUP SHEETS)	1	LOT		12,427	16.38				202,300		225,700	428,000
K	INSULATION	1	LOT		1840	16.38	30,100		30,000	30,100		30,000	60,100
G	ELECTRICAL *	1	LOT		4384	16.38	80,000		100,000	80,000		100,000	180,000
H	INSTRUMENTS AND CONTROL *	1	LOT		12,210	11.38	200,000		400,000	200,000		400,000	1,200,000
	* BASED ON BADGER DATA												
	TOTAL A/C 5462				31,761					519,400		835,835	1,355,235

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DATE ________ REVISION NO. ________ REVISION DATE ________ PAGE NO. ________ OF ________

REVISION NO. ________ REVISION DATE ________

BADGER

CODE POSITION (1–12)	DESCRIPTION	Unit	Quantity	H (Hours)	M (Mat'l)$	L (Labor)	Total $
	TOTAL CARRIED FORWARD 340 415						
	LARGE BORE 3" + UP			4561	124 833		
	SMALL BORE 2½" + DOWN						
	CONTROL & SAFETY VALVES			21			
C J	BELOW GRADE PIPING				—		
C S	STEAM TRACING				—		
	SUB-TOTAL			4582	124 833		
C N F	MISC.			1740	47 280		
C M	SPECIALS			—			
	SUB-TOTAL			6322	172 163		
C H	HANGERS & SUPPORTS			2210	31,000		
C D 5	TESTING			315	—		
C G 1	UNLOAD & STORAGE HANDLE			320	—		
C R	REWORK			2[illegible]0	—		
C X	X-RAY & STRESS RELIEVE			545	13 900		
C G	SPECIAL CLEANING & PICKLING						
C W	FREIGHT				8600		
	JOB FACTOR 25% 9942			2485			
	TOTAL SHEET			12 427	225,663	202,312	
	TOTAL ACCOUNT				225,700	202,300	428,000
	DIRECT						
	SUBCONTRACT						

"C" ACCOUNT SUMMARY SHEET

Client: Martin Marietta
Plant: Solar Hybrid
Subject: Acct # 5462

Issue	Date	By	Chkd
1	7/15/[illegible]	LJC	

Est. No. E 6591

Page C 1 of 5

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BADGER

MISCELLANEOUS CALCULATION

		WGT. #	MANHOURS	MATERIAL $
SUB-TOTAL			4582	124 853
DESIGN DEVELOPMENT	20%		915	24 975
~~TAKE-OFF FACTOR~~	10%		~~460~~	12 490
OSHA + QUALITY CONTROL FACTOR	5%		230	6245
MISC.: PUMP PIPING, VENTS,	2%		90	2495
DRAINS, NIPPLES, ETC.				
FIELD DETAILER				
WELDER QUALIFICATION			45	275
45/8 = 5 x 55				
BOLTS & GASKETS			–	800
END PROTECTORS			–	
SPOOLS				
/SPOOL				
			1740	47280

Martin Marietta
Acct # 5462

Issue	Date	By	Chkd
1	[illegible]	[illegible]	

Est. No. E 6591

Acct./Sheet C 4 of 5

BADGER

SUMMARY SHEET CALCULATIONS	WGT.	MANHOURS	MATERIAL $
HANGERS & SUPPORTS			
35 % OF SUB-TOTAL + MISC. + MM ~~HOP~~ .mm		2210	31000
MATL # @ 14. mm			
@ MH'S/TON			
SHOP PAINTING		—	—
COLOR BANDING			
FREIGHT		—	8600
# MH			
FIELD X-RAY 17-2 [illegible] 14 [illegible] 31 @ 10 1; 9-16" 9 50 2		175	3900
51-16 [illegible] 3 16" [illegible] 35 50 2; 4-18" 4 60 2			
2-20" 2 60 3			
STRESS RELIEVE 19-12" [illegible] MTL # 120 MH 6		370	10000
16-18" 240 9			
15 24" 360 10			
PICKLING			
TESTING 5% ST MHR 6322		315	—
STEAM TRACING			
UNLOAD & STORAGE HANDLING 7% ST 4582		320	—
REWORK 5% ST 4582		230	—

Issue	Date	By	Chkd
1	[illegible]	[illegible]	

Est. No. E6591

Acct./Sheet C 5 of 5

Martin Marietta
Acct # 5462

HC 9 ET 5462

QUANTITY	SIZE	DESCRIPTION	WEIGHT UNIT	WEIGHT TOTAL	MATERIAL UNIT	MATERIAL TOTAL	FAB. LABOR COST UNIT	FAB. LABOR COST TOTAL	FIELD M H UNIT	FIELD M H TOTAL
60	6	SCH 10 PIPE =347SS			50.	3000			.92	55
5	14	↓			200.	1000			1.93	10
275	16	↓			112.	30800			2.37	652
340						34800				717
7	6	SCH 10 FW 90° ELL			175	1225			16.80	118
2	14	↓			750.	1500			34.36	69
17	16	↓			942.	16014			39.97	679
3	16×14	RED			570.	1710			37.67	113
2	14	STUB END			405.	810			20.28	41
2	16	NOZZLE WELDS			112.	224			26.98	54
2	14	300# SO FLGS C/S			245.	490			7.69	15
						21973				1089

56773 1806

FILE NO.: 6591

C.O. # J-74

SHEET NO.:

CLASS:

AREA:

DATE.

MAT'L: 347SS

UNIT: 5462

SIGNATURE.

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HC 6 J462

QUANTITY	SIZE	DESCRIPTION	WEIGHT UNIT	WEIGHT TOTAL	MATERIAL UNIT	MATERIAL TOTAL	FAB. LABOR COST UNIT	FAB. LABOR COST TOTAL	FIELD M H UNIT	FIELD M H TOTAL
—										
40	4	Sch.120 Pipe			9.65	386			1.03	41
20	6	120			15.70	314			1.34	27
90	10	120			38.40	3456			2.56	230
20	16	Sch.10			19.11	382			1.90	38
75	18	120			105.	7875			5.23	392
50	24	120			185.	9250			6.80	340
295						21663				1068
6	4	Sch.120 BW 90° Ell			25.	150			11.30	68
3	6	120			65.	195			15.47	46
6	10	120			270	1620			39.59	238
4	16	Sch.10			173.	692			21.00	84
6	18	120			1275.	7650			87.38	524
3	24	120			2625.	7875			118.51	356
1	4	120 TEE			33	33			15.68	16
1	6	120			95	95			21.51	22
2	4x3	120 RED.			20	40			10.04	20
2	6x4	120			51.	102			13.81	28
1	24	120 Nozzle welds			185.	185			80.11	80
2	4	1500# WN FLG			115.	230			7.92	16
2	6				200.	400			10.69	21
2	10				540.	1080			24.79	50
2	16	300#			310.	620			15.68	31
						20 927				1660
2	4	1500# BW GATE V.			3325.	6650			12.87	26
2	6				6800.	13600			17.30	35
2	4	CHECK V			2615	5230			12.87	26
						25 480				87
1	4	1500# FLGD Control Valve			—	—			6.56	7
1	16	300#			—	—			13.88	14
										21

68 110 2776

FILE NO.: E 6591

C.O. # J-75

SHEET NO.:

CLASS:

AREA:

DATE

MAT'L: C/S

UNIT: J462

SIGNATURE

67-61

Gibbs & Hill, Inc.
ENGINEERS, DESIGNERS, CONSTRUCTORS
NEW YORK

JOB NO. 11-2772 DESCR. 100 MW SOLAR PLANT

CLIENT MMSHPP LOCATION BARSTOW, CA.

EST. BY AJC PAGE NO. 7

CHKD. BY ______ SHEET NO. ____ OF ____

DATE 7-23-79
Rev. 8-30-79

ESTIMATE

ITEM OR ACCT. NO.	DESCRIPTION	QUANTITY	UNIT	COST PER UNIT: MAT'L. $	SUBC. $	LABOR: MH'S	$/HR	TOTAL MH'S	COST: MATERIALS & EXPENSES	SUB-CONTRACTS	LABOR	TOTAL
5463	PIPING, FITTINGS, HANGERS											
	FABRICATED	1	LOT				17.50	32000	350000		560000	910000
	VALVES	1	LOT					INCL.	466000		-	466000
	INSULATION	1	LOT				17.50	5370	54000		94000	148000
	PAINT	1	LOT				17.50	4000	13000		70000	83000
	TOTAL A/C 5463							41370	883000		724000	1607000
5464	FOUNDATIONS											
	70' x 70' x 3' = 544 CY	550	CY	100		10		5500	55000		96000	151000
	Data by Badger											

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F-825 8-75

CONSTRUCTION COSTS

CLIENT ______________________

LOCATION ______________________

PROJECT ______________________

BY ________ CHKD. ________ APVD. ________

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5470	DESIGN AND ENGINEERING												
	5410 RECEIVER UNIT												
	DESIGN: 300 dwg shts x 55 mh/sht				16,500	30.00				495,000			495,000
	STRESS: 30% OF DESIGN				5000	30.00				150,000			150,000
	THERMAL: 20 %				3333	30.00				100,000			100,000
										750,000			750,000
	MMC COST ANALYSIS DATA												
	5420 FIELD PIPING (1)									775,000			775,000
	5430 WORKING MEDIA				—	—							—
	5440-5450 TOWER										600,000		600,000
	SANDIA TOWER COST EQTN												
	5460 SALT-STEAM GENERATOR (1)									1,000,000			1,000,000
	(1) BADGER, GIBBS AND HILL INTERNAL DATA												
	TOTAL 5470									2,525,000	600,000		3,125,000

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DATE ________ REVISION NO. ________ REVISION DATE ________ PAGE NO. ____ OF ____

REVISION NO ________ REVISION DATE ________

CONSTRUCTION COSTS

CLIENT ______
LOCATION ______
PROJECT ______

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5500	MASTER CONTROL SUBSYSTEM												
						NOTE: HAC NOT INCLUDED IN 5500 per K. BATTLESON, 9/7/79							
H	INSTRUMENTS												
H1	PLANT CONTROL SUBSYSTEM (PCS)	1	ea						211,820			211,820	211,820
H2	DATA ACQUISITION SUBSYSTEM (DAS)	1	ea						132,355			132,355	132,355
H3	HELIOSTAT ARRAY CONTROLLER (HAC)	1	ea						(146,185)			(146,185)	
													344,175
H4	SOFTWARE - PCS } ALLOW												
H5	SOFTWARE - DAS } ALLOW	1	LOT					750,000			750,000		750,000
	TOTAL 5500										750,000	344,175	1,194,175

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DATE ______ REVISION NO. ______ REVISION DATE ______ PAGE NO. ______ OF ______
REVISION NO. ______ REVISION DATE ______

Master Control Hardware Equipment List

Model No.	Description	Cost ($) PCS	DAS	HAC
	MODCOMP			
1862	Classic Computer (131 KB Memory)	45,850	45,850	45,850
3765-27	Disc/Console Controller	12,400	12,400	12,400
4850	Multifunction Controller (2)	3,610	3,610	3,610
4852-1	Card Reader Controller	3,970	-	-
4862	Port Option for Card Reader	825	-	-
4906	Peripheral Controller Switch	3,090	3,090	3,090
4911	Peripheral Control. Sw. Encl.	2,500	2,500	2,500
4701	Interval Timer	1,030	1,030	1,030
4611	CRT Console Device	2,010	2,010	2,010
4411-2	Card Reader (300 CPM)	5,310	-	-
4426	Online Card Punch	22,600	-	-
4217-1	Electrostatic Printer/Plotter	-	16,500	-
4157-1	Magnetic Tape Unit (9-track)	19,800	19,800	19,800
4137	Rotating Disc (10 MB)	9,275	9,275	9,275
4820	MODCOMP-MODCOMP Parallel Link (DMA)	-	4,120	-
1300-1	Analog Input Subsystem	6,300	-	-
1309	Analog Input Expander	5,680	-	-
1310	MUX Gate Card	930	-	-
1905	MUX Controller	1,240	-	1,240
1910-XXXX	Communications MUX (12)	30,960	-	30,960
0001	Cabinets (Misc.)	1,190	1,190	1,190
-	Standard Software	2,500	2,500	2,500
-	Licensed Software	-	2,100	-
02XX	Cabling	2,000	2,000	2,000
820	KSR with Printer	1,900	1,900	1,900
	AYDIN			
-	Color CRT with Graphics	1,850	-	1,850
	CONRAC			
-	Digital Displays (CRT)	25,000	-	25,000
	TOTALS	211,820	132,355	146,185
	Specialized Software	750,000		

CONSTRUCTION COSTS

CLIENT ______
LOCATION ______
PROJECT ______

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS ( ) SUB CONTRACT	COSTS ( ) MATERIAL	COSTS ( ) TOTAL
5600	NON-SOLAR ENERGY SUBSYSTEM SUMMARY												
	5610				2100					36,800	335,000	57,000	428,800
	5620				19,025					311,500	39,000	382,740	733,240
	5650				2810					49,000		24,950	73,950
	TOTAL A/C 5600				23,935					397,300	374,000	464,690	1,235,990

DATE ______ REVISION NO. ______ REVISION DATE ______ PAGE NO. ______ OF ______
REVISION NO ______ REVISION DATE ______

Gibbs & Hill, Inc.
ENGINEERS, DESIGNERS, CONSTRUCTORS
New York

JOB NO. 11-2772-001 DESCR. 100 MW SOLAR PLANT

CLIENT MMSHPP LOCATION BARSTOW, CALIF

EST. BY AJc PAGE NO. 8

CHKD. BY SHEET NO. OF

DATE 8-22-79 APPROVED BY

ESTIMATE

ITEM OR ACCT. NO.	DESCRIPTION	QUANTITY	UNIT	COST PER UNIT: MAT'L. $	COST PER UNIT: SUBC. $	COST PER UNIT: LABOR: MH'S	COST PER UNIT: LABOR: $/HR	TOTAL MH'S	COST: MATERIALS EXPENSES	COST: SUB-CONTRACTS	COST: LABOR	COST: TOTAL
5610	Fuel Oil Supply System											
5611	Fuel Oil Storage											
	625,000 Gal Cap 55'dia x36'H	2	EA		125000					250000		
	In-House Data											
5612	Fuel Oil Pump House 20'x25'	500	SF		50					25000		
5612	Fuel Oil Preparation & Feed											
	Fuel Oil Pumps 70 GPM w/5HP Motor	2	EA	2000		75	17.50	150	4000		2600	
	Fuel Oil Transfer Pumps 140 GPM w/10 HP Motor	2	EA	4000		150	17.50	300	8000		5300	
	Fuel Oil Heat Exchanger 1000 SF	1	EA	25000		150	17.50	150	25000		2600	
5611	Fuel Oil Day Tank 100,000 Gal, In-House Data	1	EA		60000					60000		
5612	Piping Valves Fttgs, Supports & Oil Heaters	1	LOT				17.50	1500	20000		26300	
	TOTAL 5610							2100	57,000	335,000	36,800	428,800

F-825, 2-79

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CONSTRUCTION COSTS

CLIENT ______
LOCATION ______
PROJECT ______
BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5620	SALT PIPES AND PUMPS												
	PP104A SALT HEATER BOOSTER PUMP 600 hp												
E1	QUOTE: PACIFIC PUMP: $36,413 UNITED PUMP: $54,911 BINGHAM : $34,467 INGERSOLL-RAND: $55,839												
		2	EA	750	1500	17.00	12,750		45,420	25,500		90,840	116,340
H	PIPING: (SEE BACKUP SHEETS)	1	LOT		11,250	16.38	183,200		191,200	183,200		191,200	374,400
K	INSULATION	1	LOT		3100	16.38	50,800		50,700	50,800		50,700	101,500
G	ELECTRIC TRACE HEATING QUOTE: THERMON	1300	LF					30.00			39,000		39,000
H	INSTRUMENTATION AND CONTROL	1	LOT		3175	16.38	52,000		50,000	52,000		50,000	102,000
	TOTAL A/C 5620				19,025					311,500	39,000	382,740	733,240

DATE ______ REVISION NO. ______ REVISION DATE ______ PAGE NO. ______ OF ______
REVISION NO. ______ REVISION DATE ______

1	2	3	4	5	6	7	8	9	10	11	12	DESCRIPTION	Unit	Quantity	H (Hours)	M (Mat'l)$	L (Labor)	Total $
												TOTAL CARRIED FORWARD 290' c/s						
												LARGE BORE 3" + UP 2015' c/s / 1305			4276	103234		
												SMALL BORE 2½" + DOWN			9	650		
												CONTROL & SAFETY VALVES			10	-		
C	J											BELOW GRADE PIPING			-	-		
C	S											STEAM TRACING			-	-		
												SUB-TOTAL			4315	103884		
C	M				F							MISC.			1640	41765		
C	M											SPECIALS			-	-		
												SUB-TOTAL			5955	150649		
C	H											HANGERS & SUPPORTS			2085	27200		
C	T							5				TESTING			300	-		
C	(							1				UNLOAD & STORAGE HANDLE			305	-		
C	R											REWORK			215	-		
C	X											X-RAY ~~& STRESS RELIEVE~~			140	3300		
C	C											SPECIAL CLEANING & PICKLING						
C	W											FREIGHT				7500		
												JOB FACTOR 25% 9000			2250			
												TOTAL SHEET			11250	191149	183150	

	H (Hours)	M (Mat'l)$	L (Labor)	Total $
TOTAL ACCOUNT		191200	183200	374400
DIRECT				
SUBCONTRACT				

"C" ACCOUNT SUMMARY SHEET

Client Martin Marietta
Plant Solar Hybrid
Subject Acct # 5620

Issue	Date	By	Chkd
1	[illegible]	[illegible]	

Est. No. E 6591

Page C 1 of 5

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BADGER

MISCELLANEOUS CALCULATION

		WGT. #	MANHOURS	MATERIAL $
SUB-TOTAL			4315	103,884
DESIGN DEVELOPMENT	20%		865	21 775
TAKE-OFF FACTOR	10%		430	10 890
OSHA + QUALITY CONTROL FACTOR	5%		215	5445
MISC.: PUMP PIPING, VENTS, DRAINS, NIPPLES, ETC.	2%		85	2180
FIELD DETAILER				
WELDER QUALIFICATION	1%		45	275
	45/P: C+55			
BOLTS & GASKETS	/6		—	1200
END PROTECTORS				
SPOOLS				
/SPOOL				
MISC TOTAL			1640	41765

Issue	Date	By	Chkd
1	[illegible]	[illegible]	

Est. No. EC591

Acct./Sheet C 4 of 5

MARTIN MARIETTA
ACCT # 5620

BADGER

SUMMARY SHEET CALCULATIONS

	WGT.	MANHOURS	MATERIAL $
HANGERS & SUPPORTS			
35 % OF SUB-TOTAL + MISC. + MM ~~WGT.~~ MH		2085	29200
MAT'L # @ 14, MHR			
@ MH'S/TON			
SHOP PAINTING		—	—
COLOR BANDING			
FREIGHT			7500
# MHR			
FIELD X-RAY 49-12" 315 13-12" 6/3 = 62 @ 60 1½ ; 13-16" 12 @ 50 2 ; 9-18" 9 @ 60 2 ; 2-24" 2 @ 90 3		140	3800
STRESS RELIEVE			
PICKLING			
TESTING 5% ST MHR 5955		300	—
STEAM TRACING			
UNLOAD & STORAGE HANDLING 7% ST 4315		305	
REWORK 5% ST 4315		215	

Issue	Date	By	Chkd
1	9/25/73	[illegible]	

Est. No. E6591

Acct./Sheet C 5 of 5

Martin Marietta
Acct# 5620

Hc9 ET 5620 1

QUANTITY	SIZE	DESCRIPTION	WEIGHT UNIT	WEIGHT TOTAL	MATERIAL UNIT	MATERIAL TOTAL	FAB. LABOR COST UNIT	FAB. LABOR COST TOTAL	FIELD M H UNIT	FIELD M H TOTAL
290	12	SCH-20 PIPE 347SS			85.65	24839			1.66	481
12	12	BW 90° ELL			564.	6768			31.78	381
2	12x10	RED			250.	500			29.54	59
4	12	STUB END			278.	1112			18.54	74
4	12	300# SO FLGS C/S			121.	484			6.68	27
1	12	ORIF SET			1000.	1000			9.33	9
2	3/4	300# SOCKOLET			40.	80			3.21	6
						9944				556
—	1/2	800# SOW/SCR GATE V			150.	300			1.27	3
—	3/4				150.	300			1.42	3
						600				6
1	12	300# SH20 BW CHECK V			18000	18000			32.79	33
1	12	300# FLGD CONTROL V.			—	—			10.34	10
1		MOTOR OPERATOR			1000	1000			6.0	6
						54383				1092

FILE NO.: E 6591

C.O. #: J-86

SHEET NO.:

CLASS:

AREA:

DATE

MAT'L: 347 SS

UNIT: 5620

SIGNATURE:

67-61

HC 6 ET 5620 ✓

QUANTITY	SIZE	DESCRIPTION	WEIGHT UNIT	WEIGHT TOTAL	MATERIAL UNIT	MATERIAL TOTAL	FAB. LABOR COST UNIT	FAB. LABOR COST TOTAL	FIELD M H UNIT	FIELD M H TOTAL
285	12	SCH 20 PIPE C/S			13.26	3779			1.32	376
40	12	SCH. 30 PIPE			18.90	756			1.32	53
390	16	10			19.11	7453			1.95	761
260	18	10			22.36	5814			2.15	559
10.15 40	24	10			29.35	1174	1176		2.82	113 15
6	12	SCH 20 BW 90° ELL			64.	384			15.38	92
6	12	SCH 30 BW 90° ELL			85.	510			15.38	92
16	16	10			173.	2768			20.99	336
14	18	10			206	2884			22.32	312
3	24	10			442.	1326			29.47	88
1	12	30 TEE			115.	115			20.42	20
1	16	10			300.	300			27.88	28
2	12x10	10 RED.			45.	90			15.00	30
4	12	300# SO FLGS			121.	484			14.91	60
4	16				245.	980			20.23	81
4	18				265.	1060			23.53	94
3	3/4	300# SW ELLS			10.	30			3.21	10
						10931				1243
2	3/4	300# SW/SCR GATE V			25.	50			1.42	3
2	12	300# SCH.20 BW GATE V			3161.	6322			16.39	33
2	12	30			3161	6322			16.39	33
2	12	30 CHECK V			2950	5900			16.39	33
						18544				99
6		MOTOR OPERATORS			1000	6000			6.	36

54501 3223

FILE NO.: E6591

C.O. # J-87 SHEET NO.:

CLASS: AREA: DATE.

MAT'L: C/S UNIT: 5620 SIGNATURE:

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CONSTRUCTION COSTS

CLIENT ______
LOCATION ______
PROJECT ______

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS			COST/UNIT			COSTS ( )			
				PER UNIT	TOTAL	RATE	LABOR	SUB CONTR.	MAT'L	LABOR	SUB CONTRACT	MATERIAL	TOTAL
5650	FOUNDATIONS												
	Fuel Oil Tanks - 38 cy												
	Daytank - 9 cy												
	Total	50	cy	25	1250	17.50	437.50		135	22,000		6750	28,760
	Earthen Dike	520	LF.	3	1560	17.50	52.50		35	27,000		18,200	45,200
					2810					49,000		24,950	73,950

DATE ______ REVISION NO. ______ REVISION DATE ______ PAGE NO. ______ OF ______
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CONSTRUCTION COSTS

CLIENT ______________________

LOCATION ______________________

PROJECT ______________________ BY ________ CHKD. ________ APVD. ________

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5700	ENERGY STORAGE SUBSYSTEM SUMMARY												
	5710 CONTAINMENT EQUIP.									475,000	4,732,965	781,541	5,989,506
	5720 CIRCULATION EQUIP				27,167					444,350	25,860	1,587,398	2,057,608
	5750 FOUNDATIONS										1,040,247		1,040,247
	5760 MEDIA											9,667,067	9,667,067
	5770 DESIGN AND ENG.									1,250,000			1,250,000
										2,169,350	5,799,072	12,036,006	20,004,428

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REVISION NO ________ REVISION DATE ________

CONSTRUCTION COSTS

CLIENT ____________________

LOCATION ____________________

PROJECT ____________________

BY ________ CHKD. ________ APVD. ________

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5710	MEDIA CONTAINMENT EQUIPMENT												
F1	HOT TANKS 96' DIA x 57' h												
	4.13×10^5 FT^3 x $1.75/FT^3	2	EA					722,012			1,444,024		1,444,024
	SOURCE: CB&I												
K1	INSULATING BRICK							379,617			759,234		759,234
	18,428 FT^3 x $20.6/FT^3												
	SOURCE: KAISER REFRACTORY												
	MTL: $17.40/FT^3												
	LAB: $3.15/FT^3												
	(KRILITE 30)												
K2	SS 316 LINER												
	31,667 FT^2/tank	63,334	FT^2	.5	31,667	15.00	7.50		12.34	475,000		781,541	1,256,541
	SOURCE: GLITSCH												
K3	EXTERNAL INSULATION												
	TOP: 7238 FT^2/TANK {6" DURABOARD, 6" FIBERGLASS}	14,476	FT^2					23.25			336,567		336,567
	SIDES: 17190 FT^2/tank, 8" FIBERGLASS	34,381	FT^2					4.47			153,683		153,683
K4	LAGGING												
	COST INCL IN TOP EXT INS.												
	SIDES: 17,335 FT^2/tank	34,670	FT^2					2.05			71,074		71,074

DATE ________ REVISION NO. ________ REVISION DATE ________ PAGE NO. ____ OF ____

REVISION NO. ________ REVISION DATE ________

CONSTRUCTION COSTS

CLIENT

LOCATION

PROJECT

BY CHKD. APVD.

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
F1	TOTAL HOT TANKS	2	EA							475,000	2,764,582	781,541	4,021,123
F2	COLD TANKS 86' DIA x 63' h												
	EA TANK 3.66 FT³ x 1.78 /FT³	7.32x10⁵	FT³					1.78			1,302,960		1,312,960
	CB&I QUOTE												
K4	EXTERNAL INSULATION												
	TOP: 2904 FT³/TANK (6" DURABOARD)	5808	CF					39.80			231,190		231,190
	SIDES: 8510 FT³/TANK (6" FIBERGLASS)	17,021	CF					6.70			114,041		114,041
K5	LAGGING (SIDES ONLY)												
	17,120 FT²/TANK	34,240	FT²					2.05			70,192		70,192
	TOTAL COLD TANKS	2	EA								1,718,383		1,718,383
F3	HOT SALT SUMP: ALLOW (BADGER FILES)										250,000		250,000
	TOTAL 5710									475,000	4,732,965	781,541	$5,989,506

DATE REVISION NO. REVISION DATE PAGE NO. OF

REVISION NO. REVISION DATE

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CONSTRUCTION COSTS

CLIENT ______
LOCATION ______
PROJECT ______

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5720	MEDIA CIRCULATION EQUIPMENT												
E1	PP103 Hot Salt Pump												
	Quote: Lawrence Pump $111,674	2	EA	450	900	17.00	7650		111,674	15,300		223,348	238,648
H1	Instrumentation and Control	1	LOT		12,210	16.38	200,000		500,000	200,000		500,000	700,000
F1	Piping: (see backup sheets)	1	LOT		11,795	16.38	192,000		827,000	192,000		827,000	1,019,000
K1	Insulation												
	9" thick, 16" pipe	90	LF	2.47	222	16.38	40.52		40.52	3646		3646	7292
	9" thick, 18" pipe	772	LF	2.64	2040	16.38	43.27		43.27	33,404		33,404	66,808
E	Electrical Tracing Quote: Thermon	862	LF					30.00			25,860		25,860
	Total 5720				27,167					444,350	25,860	1,587,398	2,057,608

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DATE ______ REVISION NO. ______ REVISION DATE ______ PAGE NO. ______ OF ______
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CODE POSITION 1 2 3 4 5 6 7 8 9 10 11 12	DESCRIPTION	Unit	Quantity	H (Hours)	M (Mat'l)$	L (Labor)	Total $
	TOTAL CARRIED FORWARD 725						
	LARGE BORE 3" + UP			4472	413256		
	SMALL BORE 2½" + DOWN			3	300		
	CONTROL & SAFETY VALVES			-	-		
	BELOW GRADE PIPING			-	-		
	STEAM TRACING				-		
	SUB-TOTAL			4475	413556		
	MISC.			1705	154190		
	SPECIALS			-	-		
	SUB-TOTAL			6180	567746		
	HANGERS & SUPPORTS			2165	30200		
	TESTING			310	-		
	UNLOAD & STORAGE HANDLE			315	-		
	REWORK			225	-		
	X-RAY ~~& STRESS RELIEVE~~			240	6500		
	SPECIAL CLEANING & PICKLING						
	FREIGHT				28,000		
	JOB FACTOR 25% 9425			2360			
	TOTAL SHEET			11795	632,846	192023	

	H (Hours)	M (Mat'l)$	L (Labor)	Total $
TOTAL ACCOUNT		632,900	192,000	824,900
DIRECT ADD	18" Valve	[illegible]		
SUBCONTRACT				

"C" ACCOUNT SUMMARY SHEET

Use 827,000

Client [illegible]
Plant [illegible]
Subject [illegible] 2720

Issue	Date	By	Chkd
2			

Est. No. [illegible] 65?

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BADGER

MISCELLANEOUS CALCULATION	WGT. #	MANHOURS	MATERIAL $
SUB-TOTAL		4475	413 556
DESIGN DEVELOPMENT 20 %		895	82 710
TAKE-OFF FACTOR 10 %		450	41 355
OSHA + QUALITY CONTROL FACTOR 5 %		225	20 680
MISC.: PUMP PIPING, VENTS, 2 %		90	8 270
DRAINS, NIPPLES, ETC.			
FIELD DETAILER			
—			
WELDER QUALIFICATION 1 %		45	275
4%: 5455			
BOLTS & GASKETS 9			900
END PROTECTORS			
SPOOLS			
/SPOOL			
MISC TOTAL		1705	154 190

Issue	Date	By	Chkd
1	5/2/77	[illegible]	

Est. No. E 6571

Acct./Sheet C 4 of 5

Martin Marietta
Acct # 5720

BADGER

SUMMARY SHEET CALCULATIONS	WGT.	MANHOURS	MATERIAL $
HANGERS & SUPPORTS			
35 % OF SUB-TOTAL + MISC. + MM ~~WGT.~~ MHR		2165	32300
mat'l # c-14, mhr			
@ MH'S/TON			
SHOP PAINTING		—	—
COLOR BANDING			
FREIGHT			28,000
FIELD X-RAY 36-16 315 / 12-18 ; # 50 / 60 ; m/m 2 / 2		240	6800
STRESS RELIEVE		—	—
PICKLING		—	—
TESTING 5% ST MHR 6180		310	—
STEAM TRACING			
UNLOAD & STORAGE HANDLING 7% ST 4475		315	
REWORK 5% ST 4475		225	

Issue	Date	By	Chkd
1			

Est. No. E 6591

Acct./Sheet C 5 of 5

Martin Marietta
Acct # 5720

HC 9 CT 5720

QUANTITY	SIZE	DESCRIPTION	WEIGHT UNIT	WEIGHT TOTAL	MATERIAL UNIT	MATERIAL TOTAL	FAB. LABOR COST UNIT	FAB. LABOR COST TOTAL	FIELD M H UNIT	FIELD M H TOTAL
30	16	SCH10 PIPE 347SS			112.	3360			2.37	71
270	18	20			143.	38610			2.77	748
425	18	30			215.	91375			3.60	1530
725						133345				2349
4	16	SCH10 BW90°ELL			942.	3768			39.97	160
9	18	20			1567.	14103			46.80	421
12	18	20			2004.	24048			56.56	679
3	16x12	10 RED.			500	1500			34.59	104
6	16	10 STUB ENDS			458.	2748			23.59	142
2	18	20			673.	1346			27.68	55
1	18	30			1000.	1000			32.36	32
2	16	10 NOZZLE WELDS			112	224			26.98	54
1	18	20			143	143			33.58	34
2	3/4	3000# SOCKLETS			40	80			6.12	12
6	16	200# SO FLGS C/S			245	1470			8.79	53
3	18				265.	795			9.80	29
						51225				1777
2	3/4	200# SOW/SCR GATE V 347SS			150.	300			1.42	3
3	16	200# SCH10 BW GATE V			35000	105000			41.45	124
3	16	CHECK V			22062	66186			41.45	124
1	18	SCH30 GATE V.			47000	47000			55.26	58
						218186				306
7		MOTOR OPERATORS			1500	10500			6.00	42
						413556				4475

FILE NO.: E 6591

C.O. # J-96

SHEET NO.:

CLASS:

AREA:

DATE:

MAT'L: 347 SS

UNIT: 5720

SIGNATURE:

CONSTRUCTION COSTS

CLIENT
LOCATION
PROJECT

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5750	FOUNDATIONS												
	HOT TANKS: 98 FT DIA (+ 1 FT OUTSIDE TANK WALL) 7543 FT^2/TANK	15,086	FT^2					29.00*			437,491		437,491
	COLD TANKS: 88 FT DIA 6082 FT^2/TANK	12,164	FT^2					29.00*			352,756		352,756
	* SEE BACKUP ON FOLLOWING PAGE												
	COOLING WATER AUXILIARIES ALLOW:										100,000		100,000
	DIKING ALLOW:										150,000		150,000
											1,040,247		1,040,247

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CONSTRUCTION COSTS

CLIENT ______
LOCATION ______
PROJECT ______

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
	FOUNDATION BACKUP -												
	BASED ON 134' DIA. ACTIVELY COOLED FOUNDATION												
	1. EXCAVATION BY MACHINE	800	CY	.3	240	13.43	4.03			3,224			
	EXCAVATION BY HAND	55	CY	3.25	179	13.43	43.65			2,400			
	2. BACKFILL	86	CY	.35	30	13.43	4.70			404			
	3. SANDFILL	1315	CY	.35	473	13.43	4.70		8.50	6180		11,484	
										12,208		11,484	23,692
	4. RING WALLS	77	CY	16	1,233	13.43	214.88		118	16,545		9,086	
	5. 12" CONCRETE	522	CY	9	4698	13.43	120.87		82	63,094		42,084	
	6. 4½" VERMICULITE CONCRETE	196	CY	7	1372	13.43	94.01		47	18,425		9,212	
	7. WASTE & OVERPOUR	40	CY	4	160	13.43	53.72		40	2,149		1,600	
										100,213		61,986	162,195
	8. 3" DIA CARBON STEEL PIPE ON 12" CENTERS	16000	LF	.84	13440	~~13.43~~ 14.50	12.18		1.00	194,890		16,000	210,890
										307,311		89,470	$396,781
											$\frac{\$396,781}{14,000\ FT^2} = \$28.34/FT^2 \Rightarrow \$29.00$		

DATE ______ REVISION NO. ______ REVISION DATE ______ PAGE NO. ______ OF ______
REVISION NO. ______ REVISION DATE ______

CONSTRUCTION COSTS

CLIENT ______
LOCATION ______
PROJECT ______

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS			COST/UNIT			COSTS ( )			
				PER UNIT	TOTAL	RATE	LABOR	SUB CONTR.	MAT'L.	LABOR	SUB CONTRACT	MATERIAL	TOTAL
5760	MEDIA	86.77	M lb						0.114			9,666,067	9,666,067
5770	DESIGN AND ENGINEERING												
	BADGER ESTIMATE									1,250,000			1,250,000

DATE ______ REVISION NO. ______ REVISION DATE ______ PAGE NO. ______ OF ______
REVISION NO. ______ REVISION DATE ______

CONSTRUCTION COSTS

CLIENT ______________

LOCATION ______________

PROJECT ______________ BY ________ CHKD. ________ APVD. ________

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5800	ELECTRIC POWER GENERATION SYSTEM - SUMMARY												
	5810 TURBINE BUILDING										1,573,000		1,573,000
	5820 STEAM TURBINE GENERATOR				60,100					1,050,000		9,003,250	10,053,000
	5830 FEEDHEATING AND CONDENSING				28,670					502,000		2,162,000	2,664,000
	5840 WATER TREATMENT AND CONDENSATE MAKEUP				14,285					250,000		500,000	750,000
	5850 COOLING TOWER SYSTEM				20,150					352,000	900,000	588,000	1,840,000
	5860 ELECTRIC PLANT EQUIP.				50,000					828,000		1,878,000	2,706,000
	5870 AIR QUALITY CONTROL				1950					34,000	600,000	565,000	1,199,000
	5890 OIL FIRED SALT HEATER				65,000					2,512,000	779,885*	2,539,900	5,831,785
					240,155					5,528,000	3,852,885	17,236,150	26,617,035
											*INCL. MARKUP		

DATE ________ REVISION NO. ________ REVISION DATE ________ PAGE NO. ______ OF ______

REVISION NO. ________ REVISION DATE ________

Gibbs & Hill, Inc.
ENGINEERS, DESIGNERS, CONSTRUCTORS
NEW YORK

JOB NO. 11-2772-001 DESCR. 100 MW SOLAR PLANT

CLIENT MMSHPP LOCATION BARSTOW, CALIF

ESTIMATE

EST. BY AJC PAGE NO. 9
CHKD. BY ______ SHEET NO. ___ OF ___
DATE 8-25-79 APPROVED BY ______

ITEM OR ACCT. NO.	DESCRIPTION	QUANTITY	UNIT	COST PER UNIT MAT'L. $	SUBC. $	LABOR MH'S	LABOR $/HR	TOTAL MH'S	COST MATERIALS EXPENSES	SUB-CONTRACTS	LABOR	TOTAL
5800	Electric Power Generation											
	System											
5810	Turbine Building											
	100' x 110' = 11000SF x 50'	550000	CF		2.70					1485000		
	Machine Shop & Warehouse	2500	SF			35				88000		
	50' x 50'											
										1,573,000		1,573,000
5820	Steam Turbine Generator											
	100 MW/120 MVA Straight											
	Condensing, 1800 psig,	1	EA	8500000		23000	17.50	23000	8500000		400000	
	1000°F											
	w/Reheat to 1000°F, 2.5"HgA											
	Exhaust 0.90 P.F.											
	Quote GE Co. 8,500,000											
	Concrete Foundation	950	CY	135		18	17.50	17100	128250		300000	
	(Pedestals & Mat)											
									8,628,250		700,000	9,328,000

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Gibbs & Hill, Inc.
ENGINEERS, DESIGNERS, CONSTRUCTORS
NEW YORK

ESTIMATE

JOB NO. 11-2772-001 DESCR. 100 MW SOLAR PLANT

CLIENT MMSHPP LOCATION BARSTOW, CALIF

EST. BY AJC PAGE NO. 12
CHKD. BY SHEET NO. OF
DATE 5-23-79 APPROVED BY

ITEM OR ACCT. NO.	DESCRIPTION	QUANTITY	UNIT	COST PER UNIT MAT'L. $	SUBC. $	LABOR MH'S	LABOR $/HR	TOTAL MH'S	COST MATERIALS EXPENSES	SUB-CONTRACTS	LABOR	TOTAL
5821	INSTRUMENTS AND CONTROL											
	I&C TUBING	1	LOT				17.50	5000	25 000		87,500	112,500
	I&C CONTROL BOARDS	1	LOT				17.50	12,500	250 000		218,750	468,750
	I&C CONTROL VALVES	1	LOT				17.50	2500	100 000		43,750	143,750
	TOTAL A/C 5821							20000	375,000		350,000	725,000
	TOTAL	5820							9,003,050		1,050,000	10,053,000

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Gibbs & Hill, Inc.
ENGINEERS. DESIGNERS. CONSTRUCTORS
NEW YORK

JOB NO. 11-2772-001 DESCR. 100 MW SOLAR PLANT

CLIENT MMSHPP LOCATION BARSTOW, CALIF

ESTIMATE

EST. BY AJC PAGE NO. 10
CHKD. BY SHEET NO. OF
DATE 8-13-79 APPROVED BY

ITEM OR ACCT. NO.	DESCRIPTION	QUANTITY	UNIT	COST PER UNIT: MAT'L. $	COST PER UNIT: SUBC. $	COST PER UNIT: LABOR MH'S	COST PER UNIT: LABOR $/HR	TOTAL MH'S	COST: MATERIALS EXPENSES	COST: SUB-CONTRACTS	COST: LABOR	COST: TOTAL
5830	Feed Heating & Condensing											
	System											
	Condenser - One Pass 45000 SF											
	with 3/4" dia. 18 BWG Wall											
	Muntz Metal Tube Sheets &	1	EA	390000				6000	390000			
	Admiralty Tubes											
	Condenser $300000											
	Tubes $2x45000SF 90000											
J-103	Quote: Marley $390000											
	40' x 240'											
	Condensate Makeup											
	Pumps	2	EA	7000		150		300	14000			
	L.P. Feedwater Heaters											
	#1 160 SF	1		21000				75	21000			
	#2 3400	1		85000				200	85000			
	#3 3000	1		75000				150	75000			
	H.P. Ditto											
	#5 850	1		27000				100	27000			
	#6 2550	1		81000				200	81000			
	#7 6200			190000				350	190000			
	In-House Data							7375	883000			

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JOB NO. 11-2772-001 DESCR. 100 MW SOLAR PLANT

Gibbs & Hill, Inc.
ENGINEERS, DESIGNERS, CONSTRUCTORS
NEW YORK

EST. BY [illegible] PAGE NO. 11
CHKD. BY SHEET NO. OF
CLIENT MMSHPP LOCATION BARSTOW, CALIF

ESTIMATE

DATE 5-23-79 APPROVED BY
Rev. 8-30-79

ACCT. NO. OR ITEM NO.	DESCRIPTION	QUANTITY	UNIT	COST PER UNIT MAT'L $	COST PER UNIT SUBC. $	LABOR MHRS	LABOR $/HR	TOTAL MHRS	COST MATERIALS EXPENSES	COST SUB-CONTRACTS	COST LABOR	COST TOTAL
~~030~~	Deacrator 100 psig Design	1	EA	90000				650	90000			
5830	In-House Data											
	Boiler Feed Pumps											
	1100 GPM 1800 HP Motor	3	EA	200000		525		1575	600000			
	In-House Data											
	Condensate Pumps											
	740 GPM 125 HP Motor	3	EA	15000		200		600	45000			
	In-House Data											
	Condenser Vacuum Pump	2	EA	90000		350		700	180000			
	600 ACFM w/30 HP Motor											
	In-House Data											
								3525	915000			
	Total from Previous Sheet							7375	883000			
							17.50	10900	1798000		191000	1989000
	Piping, Fittings, Valves,											
	Supports & Insulation	1	Lot				17.50	17770	364000		311000	675000
	TOTAL							28670	2162000		502000	2664000

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Gibbs & Hill, Inc.
ENGINEERS, DESIGNERS, CONSTRUCTORS
NEW YORK

JOB NO. 11-2772-001 DESCR. 100 MW SOLAR PLANT

CLIENT MMSHPP LOCATION BARSTOW, CALIF

ESTIMATE

EST. BY AJC PAGE NO. 12
CHKD. BY SHEET NO. OF
DATE 5-23-79 APPROVED BY

ITEM OR ACCT. NO.	DESCRIPTION	QUANTITY	UNIT	COST PER UNIT MAT'L. $	SUBC. $	LABOR MH'S	LABOR $/HR	TOTAL MH'S	COST MATERIALS EXPENSES	SUB-CONTRACTS	LABOR	TOTAL
5840	Water Treatment Incl.	1	LOT				17.50	10000	350000		175000	525,000
	Piping											
	In-House Data											
	CONDENSATE SURGE & STORAGE	1	LOT				17.50	4285	150,000		75,000	225,000
	SYSTEM											
	TOTAL A/C 5840							14285	500,000		250,000	750,000

J-105

F-825, 2-79

Gibbs & Hill, Inc.
ENGINEERS, DESIGNERS, CONSTRUCTORS
NEW YORK

JOB NO. 11-2772-001 DESCR. 100 MW SOLAR PLANT

CLIENT MMSHPP LOCATION BARSTOW, CALIF

EST. BY NJC PAGE NO. 13
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DATE 5-23-79 APPROVED BY
REV. 8.30.79

ESTIMATE

ITEM OR ACCT. NO.	DESCRIPTION	QUANTITY	UNIT	COST PER UNIT: MAT'L. $	COST PER UNIT: SUBC. $	LABOR: MH'S	LABOR: $/HR	TOTAL MH'S	COST: MATERIALS EXPENSES	COST: SUB-CONTRACTS	COST: LABOR	COST: TOTAL
5850	Cooling Tower System											
	Cooling Tower-Mech. Draft											
	Wood Construction 5 cells											
	Each at 40' x 40' x 30'H,	1	EA		900000					900000		
	73,000 GPM 160 BHP/Cell											
	Quote Marley F&E $900,000											
	Concrete Basin Incl. Earth											
J-106	Work Floor 40 x 200 = 8000											
	Walls 2(40 x 200)8= 3840											
	11840											
	x 1.5 = 17760/27 = 657	660	CY	120		12		7920	79200			
	Circulating Water Pumps											
	37000 GPM, each, vert											
	w/1200 HP Motors	2	EA	80000		400		800	160000			
	In-House Data											
	Service Water Heat Exchangers	1	LOT					300	34000			
	Intake Screens System Incl Crane	1	LOT	150000		1000		1000	150000			
	In-House Data											
	CARRIED FORWARD						17.50	10020	423200	900000	175350	1498550

Gibbs & Hill, Inc.
ENGINEERS, DESIGNERS, CONSTRUCTORS
NEW YORK

B NO. 11-2772-001 DESCR. 100 MW SOLAR PLANT

EST. BY AJC PAGE NO. 14

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IENT MMSHPP LOCATION BARSTOW, CA.

ESTIMATE

DATE 8-23-79
Rev. 8-30-79

TEM OR CT. NO.	DESCRIPTION	QUANTITY	UNIT	COST PER UNIT MAT'L. $	COST PER UNIT SUBC. $	LABOR MH'S	LABOR $/HR	TOTAL MH'S	COST MATERIALS & EXPENSES	COST SUB-CONTRACTS	COST LABOR	COST TOTAL
5850	BROUGHT FORWARD							10020	423200	900000	175350	1498550
(CONT)												
	CIRCULATING WATER PIPE											
	54" Dia. 200' RUN INCL.											
	VALVES, EXPANSION JOINTS	400	LF				17.50	2700	45000		47250	92250
	AND EARTH WORK											
	PIPING, VALVES, FITTINGS											
	& SUPPORTS	1	LOT					7430	120000		130000	250000
									(200)		(600)	(800)
J-107	TOTAL A/C 5850							20150	588000	900000	352000	1840000

325.3-75

JOB NO. 11-2772-001 DESCR. 100 MW SOLAR PLANT

Gibbs & Hill, Inc.
ENGINEERS, DESIGNERS, CONSTRUCTORS
NEW YORK

EST. BY ADC PAGE NO. 15
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CLIENT MMSHPP LOCATION BARSTOW, CALIF

ESTIMATE

ITEM OR ACCT. NO.	DESCRIPTION	QUANTITY	UNIT	COST PER UNIT		LABOR		TOTAL MH'S	COST			
				MAT'L. $	SUBC. $	MH'S	$/HR		MATERIALS EXPENSES	SUB-CONTRACTS	LABOR	TOTAL
	Electrical											
	Summary By Accounts											
5861	Switchgear							3300	634000			
								2660	83000			
	A/C 5861						16.55	5960	717000		99000	816000
5862	Station Service Equipment						16.55	2680	330000		44000	374000
5863	Protective Equipment						16.55	5380	281000		89000	370000
5864	Power Wiring, Electrical Structures & Wiring Container						16.55	36000	550000		596000	1146000

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F-825, 2-79

Gibbs & Hill, Inc.
ENGINEERS, DESIGNERS, CONSTRUCTORS
NEW YORK

JOB NO. 11-2772-001 DESCR. 100 MW SOLAR PLANT

CLIENT MMSHPP LOCATION BARSTOW, CALIF

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ESTIMATE

ITEM OR ACCT. NO.	DESCRIPTION	QUANTITY	UNIT	COST PER UNIT: MAT'L. $	COST PER UNIT: SUBC. $	COST PER UNIT: LABOR M.H'S	COST PER UNIT: LABOR $/HR	TOTAL MH'S	COST: MATERIALS EXPENSES	COST: SUB-CONTRACTS	COST: LABOR	COST: TOTAL
	Electrical											
	Generator Step Up Power Transformer 3 PH 125 MVA	1	EA	450000		1500		1500	450000			
	Unit Auxiliary Transformers 3 PH	1	EA	52000		500		500	52000			
	Unit Auxiliary Transformer 3 PH	1	EA	52000		500		500	52000			
	General Auxiliary Transformer 3 PH	1	EA	80000		800		800	80000			
	Total - Above A/C 5861							3300	634000			

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Gibbs & Hill, Inc.
ENGINEERS, DESIGNERS, CONSTRUCTORS
NEW YORK

JOB NO. 11-2772-001 DESCR. 100 MW SOLAR PLANT

CLIENT MMSHPP LOCATION BARSTOW, CALIF

EST. BY AIC PAGE NO. 17

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DATE 9-13-79 APPROVED BY

ESTIMATE

ITEM OR ACCT. NO.	DESCRIPTION	QUANTITY	UNIT	COST PER UNIT MAT'L. $	COST PER UNIT SUBC. $	COST PER UNIT LABOR MH'S	COST PER UNIT LABOR $/HR	TOTAL MH'S	COST MATERIALS EXPENSES	COST SUB-CONTRACTS	COST LABOR	COST TOTAL
	Electrical											
5861	Isolated Phase Bus											
	KV 110 KV BIL 4500A	300	FT	220		7		2100	66000			
5861	w/supports (from Gen to											
	100 MVA) Transformer											
	100' x 3 = 300'											
5861	Ditto 1200A (From 100 MVA	80	FT	220		7		560	17600			
	Trans. to Aux. Transf T1A & T1B	ADJUST							(600)			
	A/C 5861							2660	83000			
5863	Generator Neutral Grounding Equipment	2	EA	6600		400		800	13200			
5863	Generator Potential Trans.	2	EA	17000		500		1000	34000			
5863	Surge Protection Equipment	2	EA	8900				INCL.	17800			
5863	Grounding Resistor	2	EA	3000		40		80	6000			
5863	Oil Circuit Breaker KV											
	1200A __ KVA	7	EA	30000		500		3500	210000			
	A/C 5863							5380	281000			

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Gibbs & Hill, Inc.
ENGINEERS. DESIGNERS. CONSTRUCTORS
NEW YORK

JOB NO. 11-2772-001 DESCR. 100 MW SOLAR PLANT

CLIENT MMSHPP LOCATION BARSTOW, CALIF

EST. BY P.C. PAGE NO. 18
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DATE 8-23-79 APPROVED BY

ESTIMATE

ITEM OR ACCT. NO.	DESCRIPTION	QUANTITY	UNIT	COST PER UNIT MAT'L. $	SUBC. $	LABOR MH'S	LABOR $/HR	TOTAL MH'S	COST MATERIALS & EXPENSES	SUB-CONTRACTS	LABOR	TOTAL
	Electrical											
5862	4.16 KV Switchgear-Indoor											
	Feeder Circuit Breakers	3	EA	18000		100		300	54000			
	480V Load Center	3	(Incl the Following):									
	Incoming Line Section	3	EA	1200		25		75	3600			
	1000 KVA Transformer											
	4160 - 480 V 3 PH	3	EA	14000		200		600	42000			
	Main Feeder Breaker-1600A	3	EA	11000		50		150	33000			
	Tie Breaker	3	EA	11000		50		150	33000			
	Feeder Breaker	15	EA	5000		50		750	75000			
	480V Motor Control Center	3	EA	14000		135		405	52000			
		ADJUST							400			
	D.C. Equipment											
	Battery Charger, D.C. Panel											
	Board	1	EA					250	38000			
	A/C 5862							2680	331000			
	Power, Cont. Cable, Trays,											
5864	Conduit, Underground Duct,	1	LOT					30000	450000			
	Cathodic Protection & Grounding											
	Precipitator - Pwr & Control	L.S.	-					6000	100000			
	A/C 5864							36000	550000			

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Gibbs & Hill, Inc.
ENGINEERS, DESIGNERS, CONSTRUCTORS
NEW YORK

JOB NO. 11-2772-001 DESCR. 100 MW SOLAR PLANT

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CLIENT MMSHPP LOCATION BARSTOW, CALIF

ESTIMATE

DATE 9-13-79 APPROVED BY ______

ITEM OR ACCT. NO.	DESCRIPTION	QUANTITY	UNIT	COST PER UNIT MAT'L. $	COST PER UNIT SUBC. $	LABOR MH'S	LABOR $/HR	TOTAL MH'S	COST MATERIALS EXPENSES	COST SUB-CONTRACTS	COST LABOR	COST TOTAL
5870	Air Quality Control											
	Electrostatic Precipitator											
	180,000 CFM 99.5% EFF											
	43'-4" LG x 29'-10"W x 54'-7"H	1	EA	550000	600000				550000	600000		
	Empty 440,000#											
	Belco Quote $ 550,000											
	S/C Labor $ 600,000											
	Foundation for Above	150	CY	100		13	17.50	1950	15000		34000	
									565000	600000	34000	1199000

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F-825 7-70

CONSTRUCTION COSTS

CLIENT
LOCATION
PROJECT

BY ______ CHKD. ______ APVD. ______

NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5890	OIL FIELD SALT HEATER SUMMARY												
	5891 OIL FIELD SALT HEATER									1,700,000	531,542	1,587,200	3,890,670
	5892 AIR PREHEATER AND FD FANS									170,000	108,000	513,300	791,300
	5893 FOUNDATIONS									76,000		32,000	108,000
	5894 INSTRUMENTATION AND CONTROL									25,000	68,415	407,400	500,815
	5895 DESIGN AND ENGINEERING									541,000			541,000
	TOTAL 5890									2,512,000	779,885*	2,539,900	5,831,785

* INCL. MARKUP

DATE ______ REVISION NO. ______ REVISION DATE ______ PAGE NO. ______ OF ______
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CONSTRUCTION COSTS

CLIENT ______
LOCATION ______
PROJECT ______

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5891	Oil Fired Salt Heater												
	Material from B/U sheets											1,587,200	
	Shop Fabrication									663,000			
	Field Erection									1,037,000			
	Transportation										72,000		
	Total Direct Cost									1,700,000	72,000	1,587,200	3,359,200
	Markup:												531,470
													3,890,670
	All costs per Foster Wheeler												

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5891 TUBING MATERIAL COSTS ($1000)

ITEM	MAT'L	WEIGHT M KG	(TONS)	COSTS ($1000)
ECONOMIZER	106C	5.6	(6.2)	11.8
HRA WALLS	106C	36.3	(40.0)	64.6
FURNACE				
FLOOR	106C	5.5	(6.1)	11.1
REAR WALL	T 12	10.4	(11.5)	27.9
SIDE AND FRONT WALLS AND ROOF	T 12	27.7	(30.5)	60.9
PRIMARY BUNDLE	T 12	31.8	(35.0)	67.7
SECONDARY BUNDLE	347	31.8	(35.0)	257.4
DIVISION WALL	347	4.8	(5.3)	45.0
PENDENTS	347	21.8	(24.0)	202.5
TOTAL				748.9

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5891 MATERIAL COSTS ($1000)

CODE NO. 5891 SALT HEATER

TUBING(1)	835.4
PIPING(1)	218.0
PLATFORMS AND STRUCTURALS	96.7
SOOT BLOWERS	91.0
DRAINS, VENTS AND VALVES	87.0
BURNERS	69.0
REFRACTORY, INSULATION, AND SHEATHING	67.0
HEAT TRACING	50.0
HANGERS, BUCK-STAYS, ETC.	46.0
MISCELLANEOUS	27.1
	1587.2

(1)INCLUDES $86.5 AND $21.9 FOR FINS, LUGS, WELD WIRE, ETC.

CONSTRUCTION COSTS

CLIENT ______________________

LOCATION ______________________

PROJECT ______________________

BY ________ CHKD. ________ APVD. ________

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS			COST/UNIT			COSTS (________)			
				PER UNIT	TOTAL	RATE	LABOR	SUB CONTR.	MAT'L	LABOR	SUB CONTRACT	MATERIAL	TOTAL
5392	AIR PREHEATER AND FD FANS												
	AIR HEATER											300,000	
	FLUES AND DUCTS											107,100	
	FD FAN AND DRIVE											106,200	
	FIELD ERECTION									170,000			
										170,000		513,300	683,300
	MARKUP (G&A AND FEE)												108,000
													$791,300

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Gibbs & Hill, Inc.
ENGINEERS DESIGNERS, CONSTRUCTORS
NEW YORK

JOB NO. 11-2772-001 DESCR. 100 MW SOLAR PLANT

CLIENT MMSHPP LOCATION BARSTOW, CALIF

EST. BY AIC PAGE NO. 20

CHKD. BY SHEET NO. OF

DATE 2-21-79 APPROVED BY

ESTIMATE

ITEM OR ACCT. NO.	DESCRIPTION	QUANTITY	UNIT	COST PER UNIT MAT'L. $	COST PER UNIT SUBC. $	LABOR MH'S	LABOR $/HR	TOTAL MH'S	COST MATERIALS & EXPENSES	COST SUB-CONTRACTS	COST LABOR	COST TOTAL
5890	Oil Fired Salt Heater System											
5893	Heater System Foundations											
	Concrete Incl. Forms, Rebar & Earthwork											
	30' x 80' x 4'	300	CY	107		14.6	17.50	4370	32000		76000	108000

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F-825 2-79

CONSTRUCTION COSTS

CLIENT ______
LOCATION ______
PROJECT ______

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5894	INSTRUMENTATION AND CONTROL												
	Burner Mgt.											98,000	
	SALT TEMPERATURE											309,400	
	FIELD ERECTION									25,000			
										25,000		407,400	432,400
	MARKUP												68,415
													500,815
5895	DESIGN AND ENGINEERING									541,000			541,000
	SOURCE: FWDC FILES												

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589x APPROXIMATE DISTRIBUTION OF PRODUCTIVE ERECTION MANHOURS

SALT HEATER	
UNIT	31,725
BURNERS AND PIPING	2,750
SOOTBLOWERS	870
STRUCTURAL STEEL AND PLATFORM	2,300
LAGGING AND INSULATION	10,000
TESTING AND INSPECTIONS	2,850
SCAFFOLDING AND CLEANUP	3,100
OPERATING ENGINEER	5,700
SUBTOTAL	59,295
AIR HEATER AND FANS	
AIR HEATER	2,400
FD FAN AND DRIVE	800
FLUES AND DUCTS	1,205
SUBTOTAL	4,705
INSTRUMENTATION AND CONTROLS	
COMBUSTION CONTROLS	500
SALT CONTROLS	500
SUBTOTAL	1,000
TOTAL HOURS	65,000

	MARTIN MARIETTA	BADGER PLANTS	GIBBS & HILL	FOSTER WHEELER	TOTAL
5900 INDIRECTS					
5910 FIELD CONSTRUCTION	$ 1,000,000	$ 2,600,000	$ 4,900,000	$ 1,003,000	$ 9,503,000
5920 ENGINEERING AND MANAGEMENT	400,000	1,000,000	3,426,000	165,000	4,991,000
5930 CONTINGENCY	650,000	3,834,000	1,919,000	364,000	$ 6,767,000
	$ 2,050,000	$ 7,434,000	$ 10,245,000	$ 1,532,000	$ 21,261,000

NOTE: INDIRECT COSTS ESTIMATED BY EACH SUBCONTRACTOR AND PRIME FOR ALL ACCOUNTS FOR WHICH THEY ARE RESPONSIBLE FOR. SEE CONSTRUCTION COST CODES, THIS APPENDIX, FOR RESPONSIBILITIES.

APPENDIX K: 500 MWe - 18 HOUR CAPITAL COST WORKSHEETS

This appendix contains the cost worksheets for the capital cost of the 500 MWe-18 hours of storage Solar Central Receiver Hybrid Power System. All estimates are in 1979 $, Nth plant costs, and use Barstow, CA as the plant site.

500 MWe - 18 HOUR STORAGE

SOLAR CENTRAL RECEIVER HYBRID POWER SYSTEM

CAPITAL COST

5000	Plant Cost			$ 13,592,000
5100	Land, General Site Preparation			
5110	Land		5,818,000	
5120	Yard Work (Balance of plant)		560,000	
5130	Yard Work (Collector fields)		7,214,000	
5200	Administrative Areas			$ 1,823,000
5210	Operations		19,000	
5211	Administration Buildings	In 5810		
5212	Control Building	In 5810		
5213	Communications Equipment	19,000		
5220	Security		776,000	
5230	Storage and Maintenance		1,028,000	
5231	Storage and Maintenance Buildings			
5232	Transportation and Lifting Equipment			
5233	Miscellaneous Equipment			
5300	Collector Subsystem ($\$80/m^2 \cdot R$)			$421,814,000
5310	Reflective Unit			
5320	Drive Unit			
5321	Azimuth or Horizontal Drive			
5322	Elevation or Vertical Drive			
5323	Motors			
5324	Position Indicators or Encoders			
5325	Power Distribution and Emergency Supply			

5330	Control and Instrumentation			
5331	Sensor or Calibration Equipment			
5332	Field Control Electronics			
5333	Control Signal Distribution Equipment			
5340	Foundations and Site Preparation			
5350	Heliostat Support and Protection			
5351	Heliostat Support Structure			
5352	Heliostat Protective Enclosure			
5354	Lightning Protection			
5360	Field Assembly and Checkout			
5370	Design and Engineering			
5400	Receiver Subsystem			145,719,000
5410	Receiver Unit		42,711,000	
5411	Absorber Unit	34,682,000		
5412	Support Structure			
5413	Receiver Circulation Equipment	6,711,880		
5414	Instrumentation and Control	1,317,175		
5420	Riser, Downcomer and Horizontal Piping		56,920,000	
5421	Vertical Piping	6,920,000		
5422	Variable Horizontal	50,000,000		
5430	Working Media Cost		9,018,000	
5431	Working Media Cost	6,940,000		
5432	Working Media Processing Equipment	2,078,000		
5440	Tower		11,795,000	

5450	Tower Foundation		11,243,000	
5460	Salt/Steam Generator and Related Piping		12,832,000	
5461	Salt/Steam Generator	4,768,000		
5462	Salt/Steam Circulation Equipment	3,486,000		
5463	Steam/Water Circulation Equipment	4,133,000		
5464	Foundations	453,000		
5470	Design and Engineering		1,200,000	
5500	Master Control Subsystem			1,438,000
5510	Hardware		688,000	
5520	Hardware Design and Engineering		-0-	
5530	Software Design, Development, and Tests		750,000	
5600	Non-Solar Energy Subsystem			3,409,000
5610	Fuel Oil Supply System		1,288,000	
5611	Fuel Oil Storage	807,00C		
5612	Fuel Oil Preparation/Feed	481,00C		
5620	Salt Pipes and Pumps		1,921,000	
5650	Foundations		200,000	
5700	Energy Storage Subsystem			77,340,000
5710	Media Containment Equipment		20,950,000	
5720	Media Circulation Equipment		5,263,000	
5750	Foundations		3,639,000	
5760	Media		46,239,000	
5770	Design and Engineering		1,250,000	

5800	Electric Power Generation Subsystem			86,907,000
5810	Turbine Building		4,121,000	
5820	Steam Turbine Generator		36,431,000	
5830	Feed Heating and Condensing System		9,644,000	
5840	Water Treatment and Condensate Makeup System		2,715,000	
5850	Cooling Tower System		4,820,000	
5860	Electric Plant Equipment		9,796,000	
5861	Switchgear	2,953,000		
5862	Station Service Equipment	1,354,000		
5863	Protective Equipment	1,340,000		
5864	Power Wiring, Electrical Structures, and Wiring Containers	4,149,000		
5870	Air Quality Control		4,340,000	
5890	Oil Fired Salt Heater System		16,040,000	
5891	Oil Fired Salt Heater			
5892	Air Preheater and Forced Draft Fans			
5893	Heater System Foundations			
5894	Instrumentation and Control			
5895	Design and Engineering			
5900	Indirect Costs		82,557,000	
5910	Indirect Field Construction Costs			
5920	Engineering & Management			
5930	Contingency			
	TOTAL		$834,600,000	

CONSTRUCTION COSTS

CLIENT

LOCATION Barstow

PROJECT 500 MWe - 12 hour Nth plant

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS (1979 $) LABOR	COSTS (1979 $) SUB CONTRACT	COSTS (1979 $) MATERIAL	COSTS (1979 $) TOTAL
5000	PLANT COST SUMMARY												
	5100 LAND, GENERAL SITE PREPARATION												13,592,000
	5200 ADMINISTRATIVE AREAS												1,823,000
	5300 COLLECTOR ($80/m².R)												421,814,000
	5400 RECEIVER SUBSYSTEM												145,719,000
	5500 MASTER CONTROL SUBSYSTEM												1,438,000
	5600 NON-SOLAR ENERGY SUPPLY												3,409,000
	5700 THERMAL STORAGE SUBSYSTEM												77,340,000
	5800 ELECTRIC POWER GENERATION SUBSYSTEM												86,907,000
	5900 INDIRECTS												82,557,000
	TOTAL PLANT COST												$ 834,599,000

DATE ______ REVISION NO. ______ REVISION DATE ______ PAGE NO. ______ OF ______

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CONSTRUCTION COSTS

CLIENT ______
LOCATION Barstow
PROJECT 500 MWe - 18 hr SCRHPS

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5100	Land, General Site Preparation												
5110	Land	8620	AC						675			5,818,500	5,818,500
5120	Yard work (Balance of plant)												
	Roads 20'W x 9000'	20000	SY					4			80,000		80,000
	Fire loop	5000	LF	.7	3500	17.50	12.25		20	61,250		100,000	161,250
	Rail	5000	LF					63.80			319,000		319,000
										61,250	399,000	100,000	560,250
5130	Yard work (collector fields)												
	5 x 100 MWe										7,213,445		7,213,445
	TOTAL 5100									61,250	7,612,445	5,918,500	13,592,195

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CONSTRUCTION COSTS

CLIENT ____________________

LOCATION Barstow

PROJECT 500 MWe - 18 hr Scripps

BY ________ CHKD. ________ APVD. ________

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5200	Administrative Areas												
5210	Operations												
	Same as 100 MWe	1	Lot					19,000			19,000		19,000
5220	Security												
	Balance-of-Plant												
	Same as 100 MWe									50,000	23,000	33,000	106,000
	Collector Fields												
	Fencing:	67,000	LF					10			670,000		670,000
										50,000	693,000	33,000	776,000
5230	Storage and Maintenance												
	Same as 100 MWe									58,000	245,000	725,000	1,028,000
	Total A/C 5200									108,000	957,000	758,000	1,823,000

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CONSTRUCTION COSTS

CLIENT ______

LOCATION Barstow

PROJECT 500 MWe - 18 hr. SCRUPS

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS			COST/UNIT			COSTS ( )			
				PER UNIT	TOTAL	RATE	LABOR	SUB CONTR.	MAT'L.	LABOR	SUB CONTRACT	MATERIAL	TOTAL
5300	Collector												
	11,944 heliostats/module × 49.05 =												
	585,853 m^2/module × 10 mod	5.858×10^6	m^2					72.00			421,814,160		421,814,160
	(Decrease in number of heliostats due to increased turbine eff.)												

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CONSTRUCTION COSTS

CLIENT ______

LOCATION Barstow

PROJECT 500 MWe - 18 hr SCRAPS

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5400	RECEIVER												
5410	RECEIVER UNIT												
	5411, 5412 ABSORBER UNIT SUPPORT STRUCTURE (SEE 100 MWe BACKUP)	10	EA				1,199,302	110,000	2,158,899	11,993,020	1,100,000	21,588,990	34,682,010
	5413 RECEIVER CIRCULATION EQUIP 5 x 100 MWe												6,711,880
	5414 INSTRUMENTATION AND CONTROL 5 x 100 MWe												1,317,175
	TOTAL 5410												42,711,065

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CONSTRUCTION COSTS

CLIENT ____________
LOCATION ____________
PROJECT 500-MWe 18 hr

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS ( ) SUB CONTRACT	COSTS ( ) MATERIAL	COSTS ( ) TOTAL
5420	Riser, Downcomer & Horizontal piping												
	5421 Riser and Downcomer												
	5 x 100 MWe									2,666,190	466,200	3,787,690	6,920,080
	5422 Horizontal piping	1	LOT										50,000,000
	(From modularizing studies)												
	10 module config.												
	TOTAL A/C 5420												56,920,000
5430	Working Media Cost												
	5431 Media	62.3×10^6	lb						.1114				6,940,000
	5432 Processing equipment												
	six-tenths power rule												
	2.62 x 793,264												2,078,000
	TOTAL A/C 5430												9,018,000

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CONSTRUCTION COSTS

CLIENT ______
LOCATION ______
PROJECT ______

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS ( ) SUB CONTRACT	COSTS ( ) MATERIAL	COSTS ( ) TOTAL
5440	TOWER (COST PER UNIT = 100 MWe)	10	EA					1,179,500			11,795,000		11,795,000
5450	TOWER FOUNDATION (COST PER UNIT - 100 MWe)	10	EA					1,123,400			11,234,000		11,243,000
5460	SALT/STEAM GENERATION AND PIPING												
	5461 SALT/STEAM GENERATOR SIX-TENTHS POWER RULE $\left(\frac{1270\ MW_t}{263\ MW_t}\right)^{.6} \times 1,850,570$												4,759,081
	5462 SALT/STEAM CIRCULATION EQUIPMENT $\left(\frac{1270\ MW_t}{263\ MW_t}\right)^{.6} \times 1,355,235$												3,485,935
	5463 STEAM/WATER CIRCULATION $\left(\frac{1270\ MW_t}{263\ MW_t}\right)^{.6} \times 1,607,000$												4,133,530
	5462 FOUNDATIONS 3 x 100 MWe												453,000
	TOTAL A/C 5460												12,832,346

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CONSTRUCTION COSTS

CLIENT
LOCATION Barstow
PROJECT 500 MW. - 18 hr

BY CHKD. APVD.

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5470	Design and Engineering												
	5410 - Receiver -0-												
	5420 - Piping $500,000												
	5430 - Media -0-												
	5440, 5450 - Tower $600,000												
	5460 - Hx $100,000												1,200,000
	Total A/c 5400												145,719,000

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CONSTRUCTION COSTS

CLIENT ______

LOCATION Barstow

PROJECT 500 MWe - 18 hr. SCRUBS 1st plant

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5500	Master Control System												
	5510 Hardware (Does not include HAC)												
	Assume 2 x 100 MWe											688,350	688,350
	5520 Hardware Design												-0-
	5530 Software Allow:										750,000		750,000
	Total A/C 5500										750,000	688,350	1,438,350

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CONSTRUCTION COSTS

CLIENT
LOCATION Barstow
PROJECT 500-MWe 19 hr scrubs

BY CHKD. APVD.

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5600	NON-SOLAR ENERGY												
5610	FUEL OIL SUPPLY												
	5611 STORAGE												
	FUEL OIL STORAGE $\left(\frac{750{,}000\text{ gal}}{625{,}000\text{ gal}}\right)^{.7} = 1.136 \times 125{,}000 = 142{,}000$	5	EA					142,000			710,000		710,000
	DAY TANK $\left(\frac{200{,}000\text{ gal}}{100{,}000\text{ gal}}\right)^{.7} \times 60{,}000 = 97{,}470$	1	EA					97,470			97,470		97,470
	TOTAL A/C 5611										807,470		807,470
	5612 PREPERATION/FEED												
	PUMP HOUSE	1000	SF					50			50,000		50,000
	PUMPS, HX, ETC 2.62 x 100 MWe										430,780		430,780
	TOTAL A/C 5612										480,780		480,780
	TOTAL A/C 5610										1,288,250		1,288,250

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CONSTRUCTION COSTS

CLIENT

LOCATION

PROJECT

BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5620	SALT PIPES AND PUMPS												
	SIX-TENTHS POWER RULE												
	2.62 × 100 MWe												1,921,000
5650	FOUNDATIONS												
	SIX-TENTHS POWER RULE												
	2.62 × 100 MWe												200,000
	TOTAL A/C 5600												3,409,000

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CONSTRUCTION COSTS

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PROJECT ______
BY ______ CHKD. ______ APVD. ______

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5700	ENERGY STORAGE SUBSYSTEM												
5710	MEDIA CONTAINMENT EQUIPMENT												
	$\left(\frac{21{,}263\ MWH_t}{4445\ MWH_t}\right)^{.8} \times \$5{,}489{,}506 =$										20,950,000		20,950,000
5720	MEDIA CIRCULATION EQUIPMENT												
	$\left(\frac{21{,}263\ MWH_t}{4445\ MWH_t}\right)^{.60} \times 2{,}057{,}608 =$										5,262,740		5,262,740
5750	FOUNDATIONS												
	$\left(\frac{21{,}263\ MWH_t}{4445\ MWH_t}\right)^{.8} \times \$1{,}040{,}247 =$										3,638,680		3,638,680
5760	MEDIA												
	415,000,000 lb x $.1114/lb =										46,239,000		46,239,000
5770	DESIGN AND ENGINEERING												
	SIMILAR TO 100 MWe, 1st PLANT									1,250,000			1,250,000
	TOTAL 5700												77,340,000

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CONSTRUCTION COSTS

CLIENT ______________________

LOCATION ______________________

PROJECT ______________________ BY ________ CHKD. ________ APVD. ________

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS			COST/UNIT			COSTS ( )			
				PER UNIT	TOTAL	RATE	LABOR	SUB CONTR.	MAT'L.	LABOR	SUB CONTRACT	MATERIAL	TOTAL
5800	Electric Power Generation Subsystem												
5810	Turbine Building												
	Six-tenths power rule × 100 MWe												4,121,000
5820	Turbine Generator (incl. I&C)												
	$\left(\frac{500\ MW_e}{100\ MW_e}\right)^{.8} \times 10,053,000$												36,431,000
5830	Feedheating and condensing system												
	$\left(\frac{500\ MW_e}{100\ MW_e}\right)^{.8} \times 2,664,000$												9,643,680
5840	Water treatment and makeup												
	$\left(\frac{500\ MW_e}{100\ MW_e}\right)^{.8} \times 750,000$												2,715,000
5850	Cooling tower system												
	$\left(\frac{500\ MW_e}{100\ MW_e}\right)^{.6} \times 1,840,000$												4,820,000

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CONSTRUCTION COSTS

CLIENT ______________________

LOCATION ______________________

PROJECT ______________________ BY ________ CHKD. ________ APVD. ________

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS			COST/UNIT			COSTS ( )			
				PER UNIT	TOTAL	RATE	LABOR	SUB CONTR.	MAT'L.	LABOR	SUB CONTRACT	MATERIAL	TOTAL
5860	Electric Plant Equipment												
	5861 Switchgear												
	3.62 × 816,000 =												2,953,000
	5862 Station Service Equip												
	3.62 × 374,000 =												1,354,000
	5863 Protective Equipment												
	3.62 × 370,000 =												1,340,000
	5864 Power Wiring, Etc												
	3.62 × 1,146,000												4,149,000
	Total A/C 5860												9,796,000
5870	Air Quality Control												
	Assume eight-tenths power rule												
	$\left(\frac{250\text{ MWe}}{50\text{ MWe}}\right)^{.8} \times 1,199,000$												4,340,000

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CONSTRUCTION COSTS

CLIENT ______________________
LOCATION ______________________
PROJECT ______________________

BY ________ CHKD. ________ APVD. ________

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5890	OIL-FIRED SALT HEATER SYSTEM												
	ESTIMATE FROM FOSTER WHEELER FOR 250 MW_e SALT HEATER, INCL. FD FANS, AIR HEATER, INST AND CONTROL, AND DESIGN (5891, 5892, 5894, 5895)												15,500,000
	Top-supported unit.												
	5893 FOUNDATIONS												
	ASSUME 5 x 50 MW_e COST												540,000
	TOTAL A/C 5890												16,040,000
	TOTAL A/C 5800												86,907,000

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CONSTRUCTION COSTS

CLIENT
LOCATION
PROJECT 500 MWe -18 hr

BY ____ CHKD. ____ APVD. ____

A/C NO.	ITEM & DESCRIPTION	QUAN.	UNIT	MANHOURS PER UNIT	MANHOURS TOTAL	MANHOURS RATE	COST/UNIT LABOR	COST/UNIT SUB CONTR.	COST/UNIT MAT'L.	COSTS ( ) LABOR	COSTS SUB CONTRACT	COSTS MATERIAL	COSTS TOTAL
5900	INDIRECTS												
	USE SAME PERCENTAGE OF PLANT COST NOT INCLUDING COLLECTOR SUBSYSTEM AS 100 MWe ESTIMATE.												
	.25 x $330,228,000 =												82,557,000

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