SAN/0499-50
MDC G8502

10 MWe Solar Thermal Central Receiver Pilot Plant Solar Facilities Design Integration

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PSS FINAL DESIGN CALCULATIONS BOOK 26 OF 26--MDAC GENERAL ANALYSIS AND BACKGROUND DATA (RADL ITEM 7-8)

September 1980

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PREPARED FOR THE
U.S. DEPARTMENT OF ENERGY
SOLAR ENERGY
UNDER CONTRACT DE-AC-03-79SF10499

PREFACE

This document is provided by McDonnell Douglas Astronautics Company (MDAC) in accordance with Department of Energy Contract Number DE-AC03-79SF10499, Reports and Deliverables List (RADL Item 7-8).

The Plant Support Subsystem Final Design Calculations (RADL Item 7-8) are arranged in a twenty-six book volume as shown on the master Table of Contents.

Book 26 of this document is provided as a supplement to the Stearn-Roger calculations. These calculations prepared by MDAC include general design analysis and background data utilized to arrive at the plant design.

Questions concerning this report should be directed to R.J. Perkins at (714) 896-3073.

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BOOK 4 - RECEIVER TOWER STRUCTURAL, CONSTRUCTION PACKAGE 5A (RADL ITEM 7-21)

Note: This document includes design calculation for the reciever tower steel (Construction Package 5A) which was previously submitted by MDAC letter A3-228-EP-RJP-46, dated 16 January 1980, and therefore, is not included in this submittal. Please transfer your copy to your RADL ITEM 7-8 file, marking it as BOOK 4 of 25.

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AUXILIARY STEAM NETWORK SIZING REQUIREMENTS

OBJECTIVE

DEFINE AUXILIARY STEAM NETWORK PIPING AND CONTROL VALVE REQUIREMENTS. CONSIDERATION SHALL BE GIVEN TO FEEDWATER HEATER BLANKETING, DEAERATOR PEGGING, TURBINE SEALS, AND MISC PIPING/EQUIPMENT HEATING AND CONDITIONING. DEFINE DESUPERHEATER REQUIREMENTS.

DATA SOURCE:

HEAT AND MASS BALANCE ANALYSIS
RADL 2-15 DEC 1979

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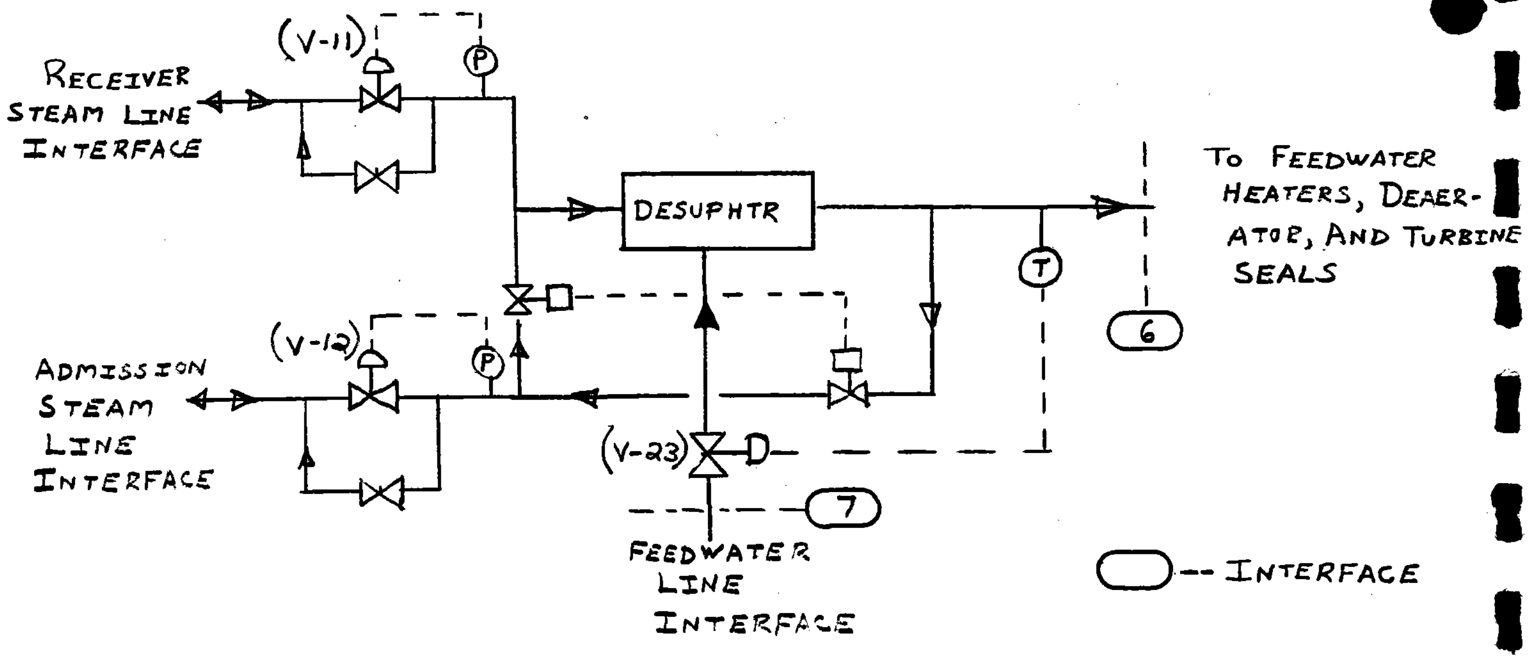
AUXILIARY STEAM NETWORK



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AUXILIARY STEAM SIZING ANALYSIS

I. CROSS TIE TO MAIN STEAM LINE

SUPPLY TO	REFERENCE CASE
1. DEAERATOR (PEG TO 20psia)	RECEIVER STAND ALONE
2. No. 4 HEATER	RECEIVER STAND ALONE
3. TURBINE SEAL	GE INPUT (MAY NOT PASS THROUGH AUX NETWORK)

1. DEAERATOR PEGGING

ADJUST DATA IN RECEIVER STAND ALONE TO ACCEPT 345 °F, 75 psia STEAM $^{h=1202.6\ BTU/LB}$ (UP FROM 75 psia SAT STEAM IN RECEIVER STAND ALONE)

FROM RUN → 5334 LB/HR

$h_{IN} = 1181.9\ BTU/LB$
$h_{OUT} = 196\ BTU/LB$

$$\dot{m} = \dot{m}_{RUN}\left(\frac{\Delta h_{RUN}}{\Delta h_{ACTUAL}}\right)$$

$$= 5334\left(\frac{1181.9 - 196}{1202.6 - 196}\right) =$$ [redacted]

2. No 4 HEATER

MAKE SAME ADJUSTMENT AS ABOVE

FROM RUN → 5757 LB/HR

$h_{IN} = 1181.9\ BTU/LB$
$h_{OUT} = 98.9\ BTU/LB$

$$\dot{m} = \dot{m}_{RUN}\left(\frac{\Delta h_{RUN}}{\Delta h_{ACTUAL}}\right)$$

$$= 5757\left(\frac{1181.9 - 98.9}{1202.6 - 98.9}\right) =$$ [redacted]

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3. TURBINE SEALS

- GE CURRENT PLAN IS TO DRAW TURBINE SEAL STEAM FROM THROTTLE STEAM AND ADMISSION STEAM LINES
- THERE MAY BE SOME INTEREST IN DRAWING STEAM THROUGH AUX NETWORK FOR THE TURBINE
- LOW TEMP CONDENSER MAY RESULT IN ADDED AUX STEAM CAPABILITY
- MAY NEED TO PEG DEAERATOR AT P > 20 psia

ALLOCATE AN EXTRA 1300 LB/HR CAPABILITY TO AUX STEAM SYSTEM (PER CONVERSATION WITH PETE DOERSAM)

TOTAL STEAM DUTY

- DEAERATOR PEGGING = 5224 LB/HR @ 345°F 75psia
- No. 4 HTR STEAM = 5649 LB/HR @ 345°F 75psia
- TURBINE SEALS + CONTINGENCY = 1300 LB/HR @ 345°F 75psia

TOTAL [redacted] — [redacted]

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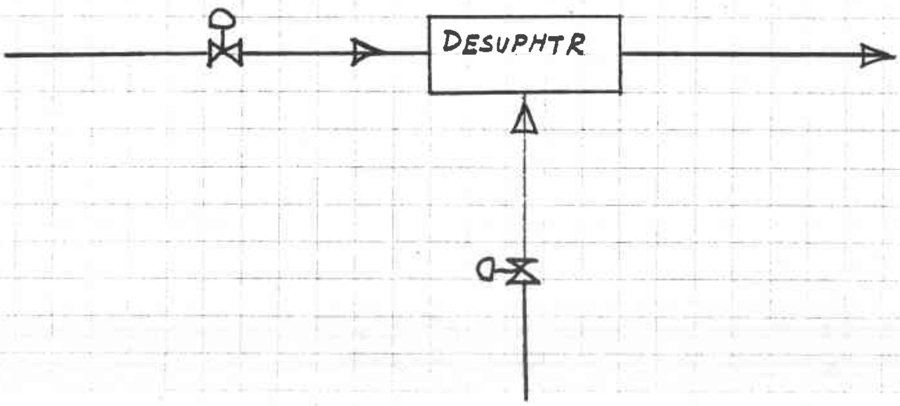

12173 LB/HR
1202.6 BTU/LB
75 PSIA
345 °F

1. RATED RECEIVER STEAM, 121 °F (88.9 BTU/LB) SPRAY WATER
950°F 1461 BTU/LB

$$\dot{m}_s + \dot{m}_c = \dot{m}_{TOT} = 12173 \text{ LB/HR}$$

$$h_s \dot{m}_s + h_c \dot{m}_c = h_T \dot{m}_T$$

$$h_s \dot{m}_s + h_c(\dot{m}_{TOT} - \dot{m}_s) = h_T \dot{m}_{TOT}$$

$$\dot{m}_s (h_s - h_c) = \dot{m}_{TOT}(h_T - h_c)$$

$$\dot{m}_s = \dot{m}_{TOT}\left(\frac{h_T - h_c}{h_s - h_c}\right) = 12173\left[\frac{1202.6 - 88.9}{1461 - 88.9}\right]$$

$$\boxed{\begin{aligned} \dot{m}_s &= 9880.5 \text{ LB/HR} \\ \dot{m}_c &= 2292 \text{ LB/HR} \end{aligned}}$$

2. DERATED RECEIVER STEAM, 121 °F (88.9 BTU/LB) SPRAY WATER
(650°F 1243.4 BTU/LB)

$$\dot{m}_s = 12173\left[\frac{1202.6 - 88.9}{1243.4 - 88.9}\right]$$

$$\boxed{\begin{aligned} \dot{m}_s &= 11742.8 \text{ LB/HR} \\ \dot{m}_c &= 430 \text{ LB/HR} \end{aligned}}$$

CORRECTION

SINCE RECEIVER STAND ALONE AT DERATED STEAM INVOLVES A HIGHER FLOW CAPABILITY (130,000 LB/HR) VS THE 112,625 MAX FOR RATED STEAM, MORE WATER MUST BE HEATED BY THE RATIO OF $\frac{130000}{112.625}$ (ESTIMATED)

$\dot{m}_s = 13554$ LB/HR

$\dot{m}_c = 496$ LB/HR

$\dot{m}_T = 14050$ LB/HR $\Longrightarrow$ 1300 LB/HR TURBINE + CONTINGENCY
6126 LB/HR DEAERATOR
[illegible]

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II CROSS TIE TO ADMISSION STEAM LINE

SUPPLY TO	REFERENCE CASE
1. DEAERATOR (PEG TO 20psia)	6-2$^{\text{R-1}}$, OR LOW FLOW MODES 4 *
2. No 4 HEATER	" , "
3 TURBINE SEAL	GE INPUT (MAY NOT PASS THROUGH AUX NETWORK,

1. DEAERATOR PEGGING $p = 20$ psia

ADJUST DATA IN MODE 6-2 FOR 345°F, 65 psia STEAM ($h = 1204.6$ BTU/LB) $h_{OUT} =$

FROM MODE 6-2

$$\dot{m}_{RUN} = \dot{m}_{TO\ DESUP} + \dot{m}_{COND} = 2530.3 + 140.7 = 2671 \text{ LB/HR}$$

$$h_{RUN} = \frac{\dot{m}_{TO\ DESUP}\, h_{TO\ DESUP} + \dot{m}_{COND}\, h_{COND}}{\dot{m}_{RUN}}$$

$$= \frac{(2530.3)(1263.1) + (140.7)(77.1)}{2671} = 1200.6 \text{ BTU/LB}$$

$$\dot{m} = \dot{m}_{RUN} \left(\frac{\Delta h_{RUN}}{\Delta h_{ACTUAL}} \right)$$

$$= 2671 \left(\frac{1200.6 - 196.0}{1204.6 - 196.0} \right) = 2660 \text{ LB/HR ADJUSTED}$$

2. No. 4 HEATER

(NO AUX STEAM DEMAND)

* LOW MODE 4 OR 7 TURBINE FLOWS NO LONGER SIGNIFICANT IF NOT PEGGING THE DEAERATOR AT 248°F SAT.

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3. TURBINE SEALS

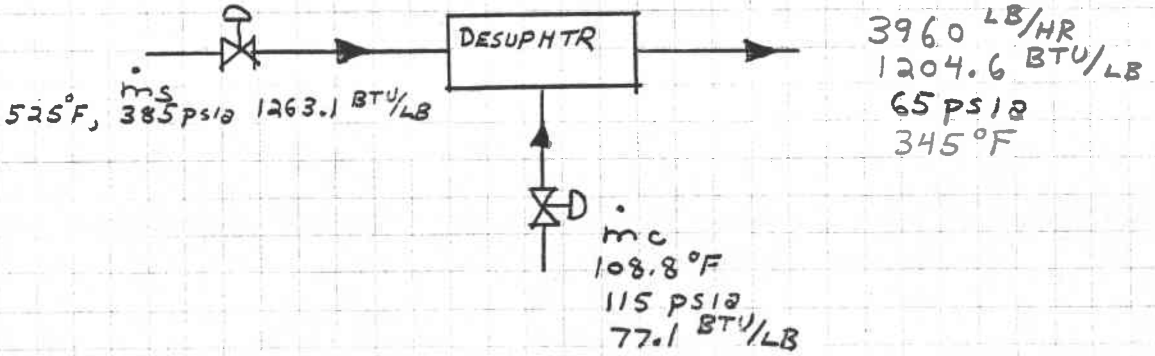
- GE PLANS TO USE ADMISSION STEAM LINE DIRECTLY BUT MAY UTILIZE AUX TIE IN
- ADD CONTINGENCY FOR COLD CONDENSER, LOWER TURBINE LOAD, AND POSSIBLE NEED TO PEG DEAERATOR AT >29ps

CONTINGENCY = 1300 LB/HR

TOTAL STEAM DUTY

- DEAERATOR 2660 LB/HR @ 345°F 65psia ($1204.6 \frac{BTU}{LB}$)
- No 4 HTR 0
- TURBINE SEALS + CONTINGENCY 1300 LB/HR @ 345°F 65psia ($1204.6 \frac{BTU}{LB}$)

TOTAL [redacted] — [redacted]



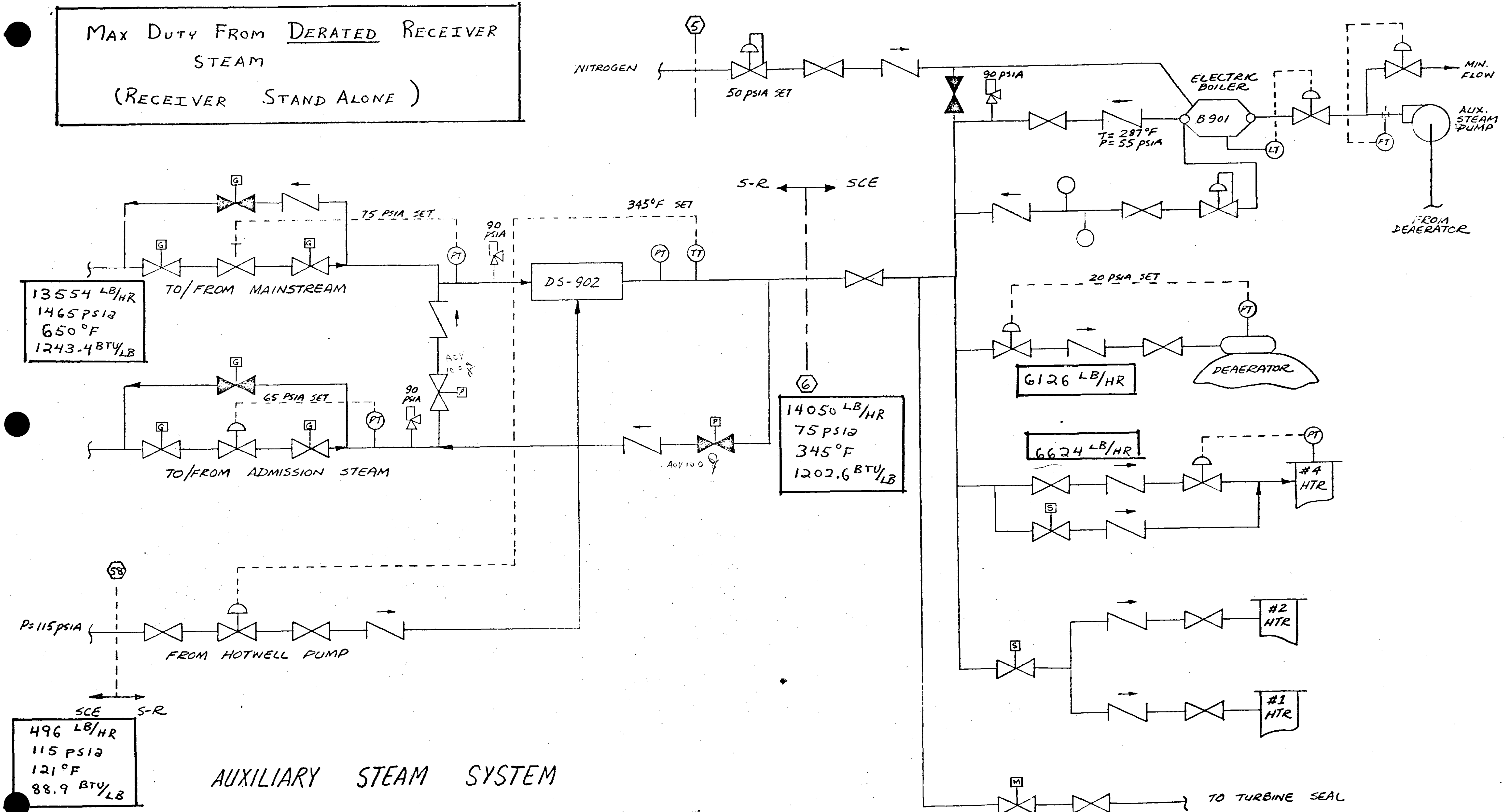
$$\dot m_s = \dot m_{TOT}\left[\frac{h_T - h_c}{h_s - h_c}\right]$$

$$= 3960\ LB/HR\left[\frac{1204.6 - 77.1}{1263.1 - 77.1}\right]$$

[redacted]

[redacted]

MAX DUTY FROM DERATED RECEIVER STEAM
(RECEIVER STAND ALONE)



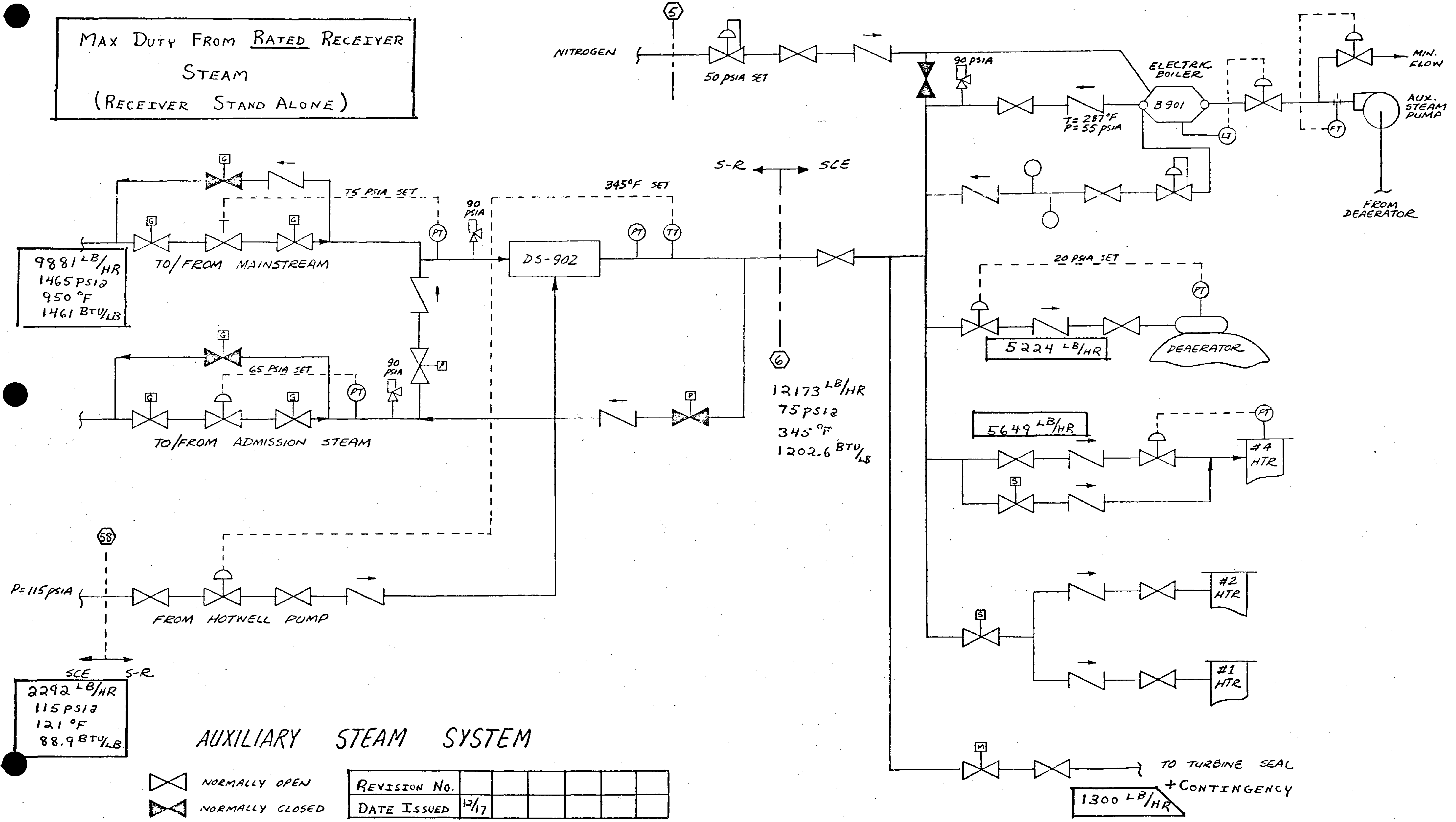
AUXILIARY STEAM SYSTEM

⋈ NORMALLY OPEN

⧓ NORMALLY CLOSED

REVISION No						
DATE ISSUED	12/17					

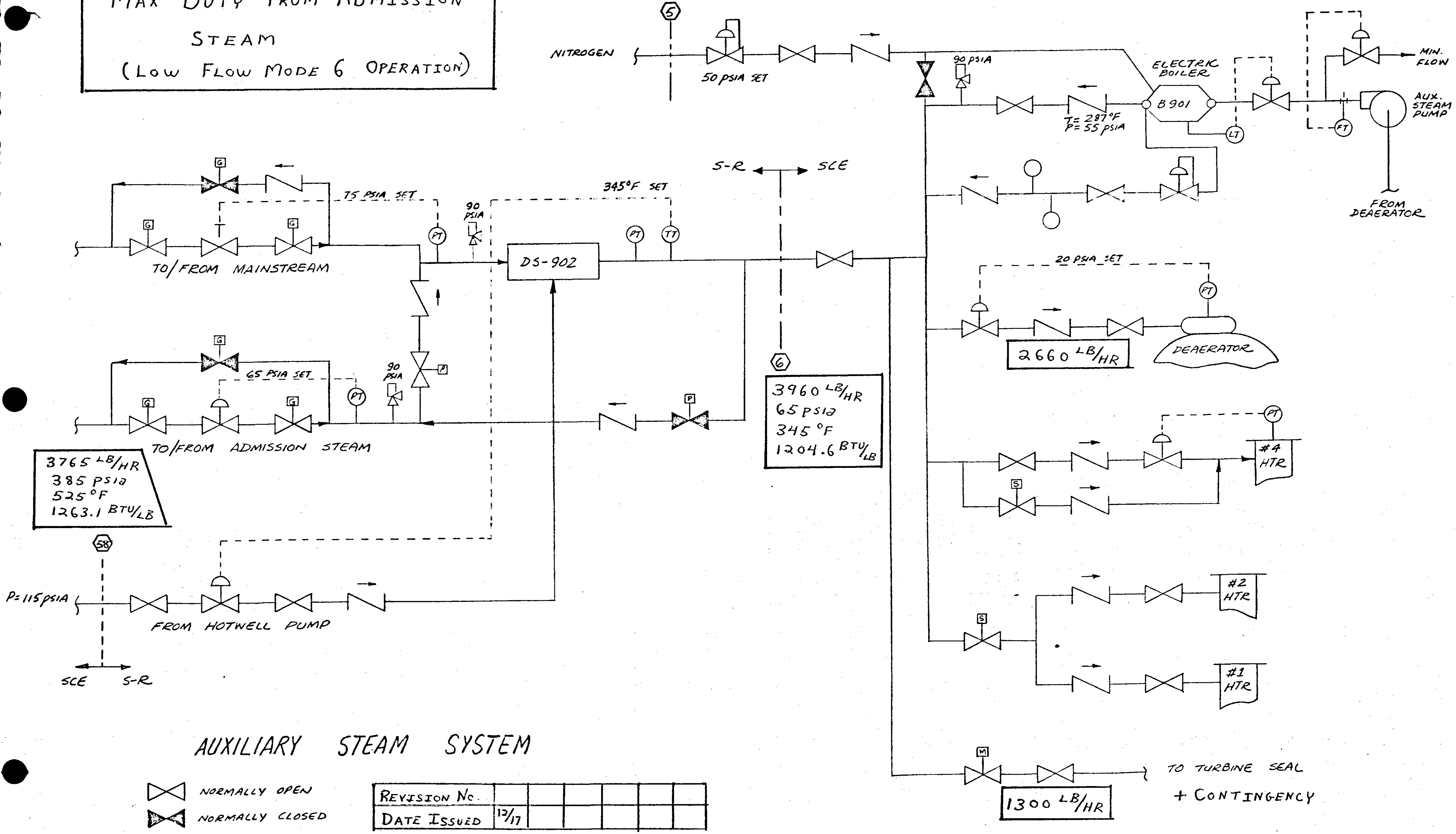
MAX DUTY FROM RATED RECEIVER STEAM (RECEIVER STAND ALONE)



AUXILIARY STEAM SYSTEM

REVISION NO.						
DATE ISSUED	12/17					

MAX DUTY FROM ADMISSION STEAM
(LOW FLOW MODE 6 OPERATION)



AUXILIARY STEAM SYSTEM

⋈ NORMALLY OPEN
⧓ NORMALLY CLOSED

REVISION No.						
DATE ISSUED	12/17					

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CONDENSER DUMP NETWORK

OBJECTIVE

- DEFINE CONDENSER DUMP NETWORK REQUIREMENTS INCLUDING
  - THE STEAM DUMP DRAG VALVE
  - DESUPERHEATER
  - SPRAY WATER VALVE
  - DUMP LINE SIZE
  - RECEIVER FLASH TANK STEAM VALVE

DATA SOURCE:

HEAT AND MASS BALANCE ANALYSIS
RADL 2-15 DEC 1979

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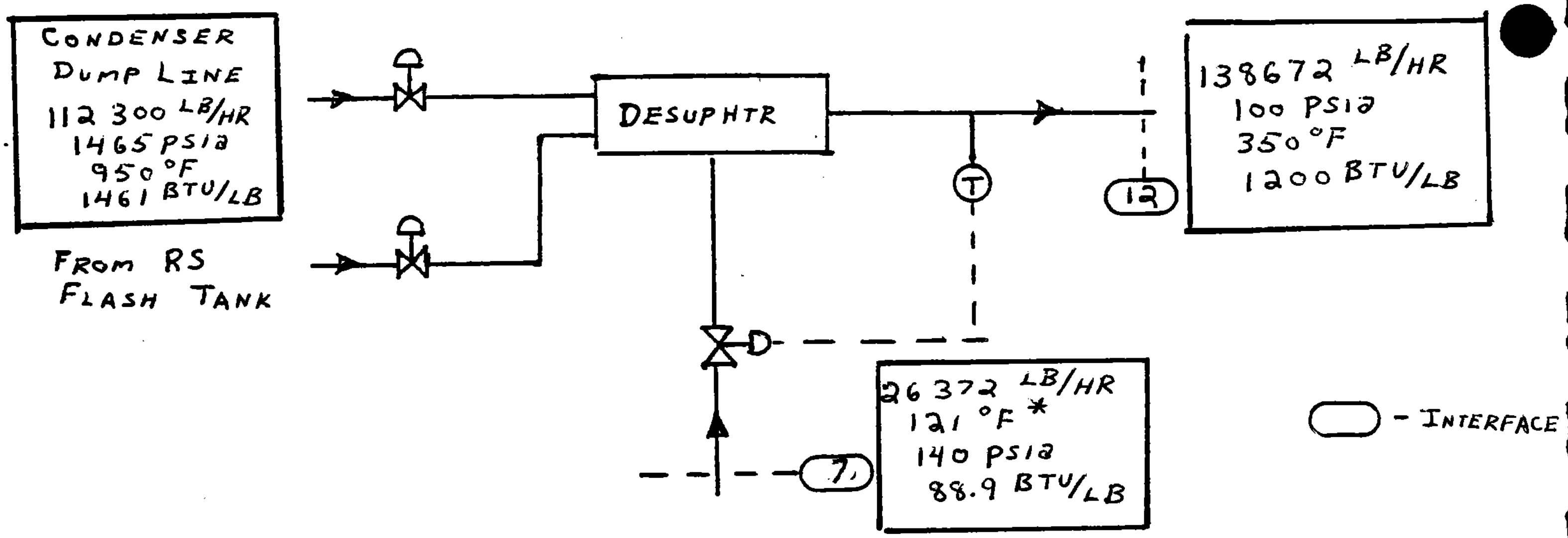
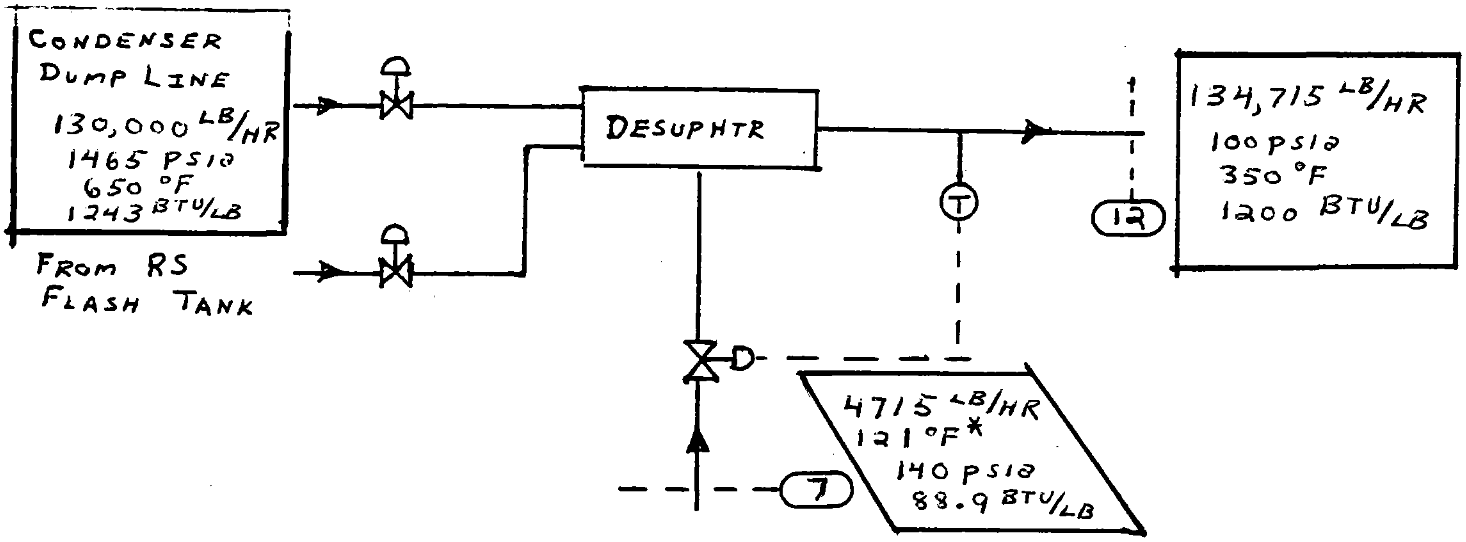
CONDENSER DUMP NETWORK



- TURBINE TRIP — MAX FLOW RATED RECEIVER STEAM



- THERMAL STORAGE CHARGE TRIP

MAX FLOW DESIGN CASES

* ASSUMES 3½"Hg CONDENSER PRESSURE DURING THIS OPERATION

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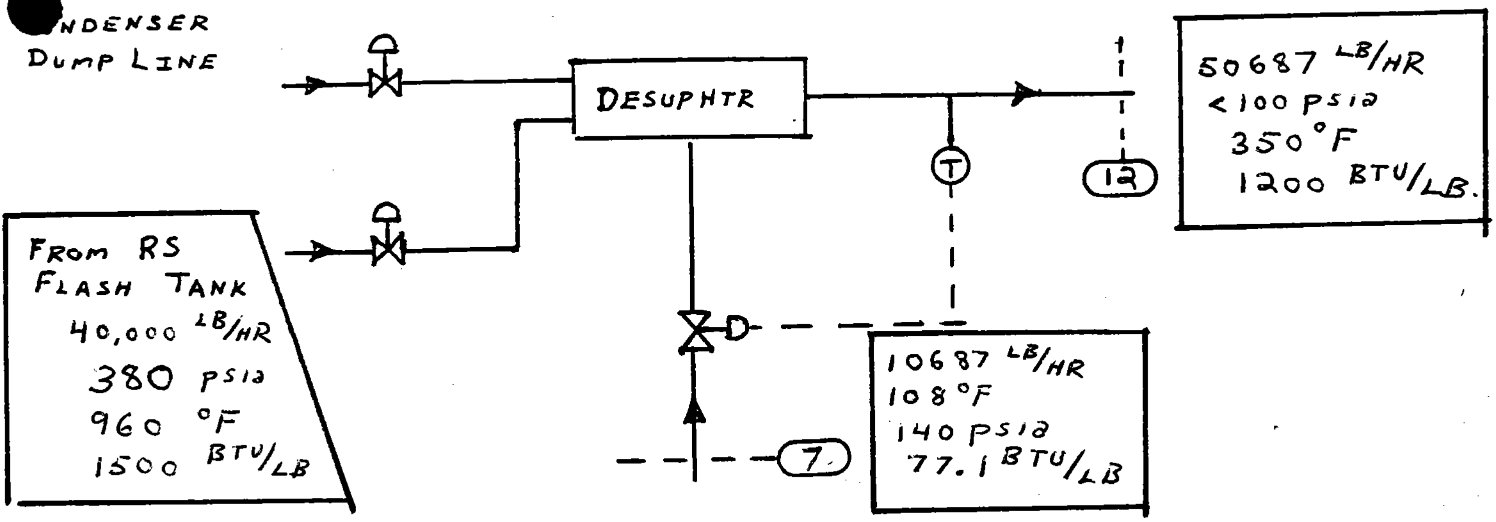
CONDENSER DUMP NETWORK



- MAX DUTY FROM RECEIVER FLASH TANK

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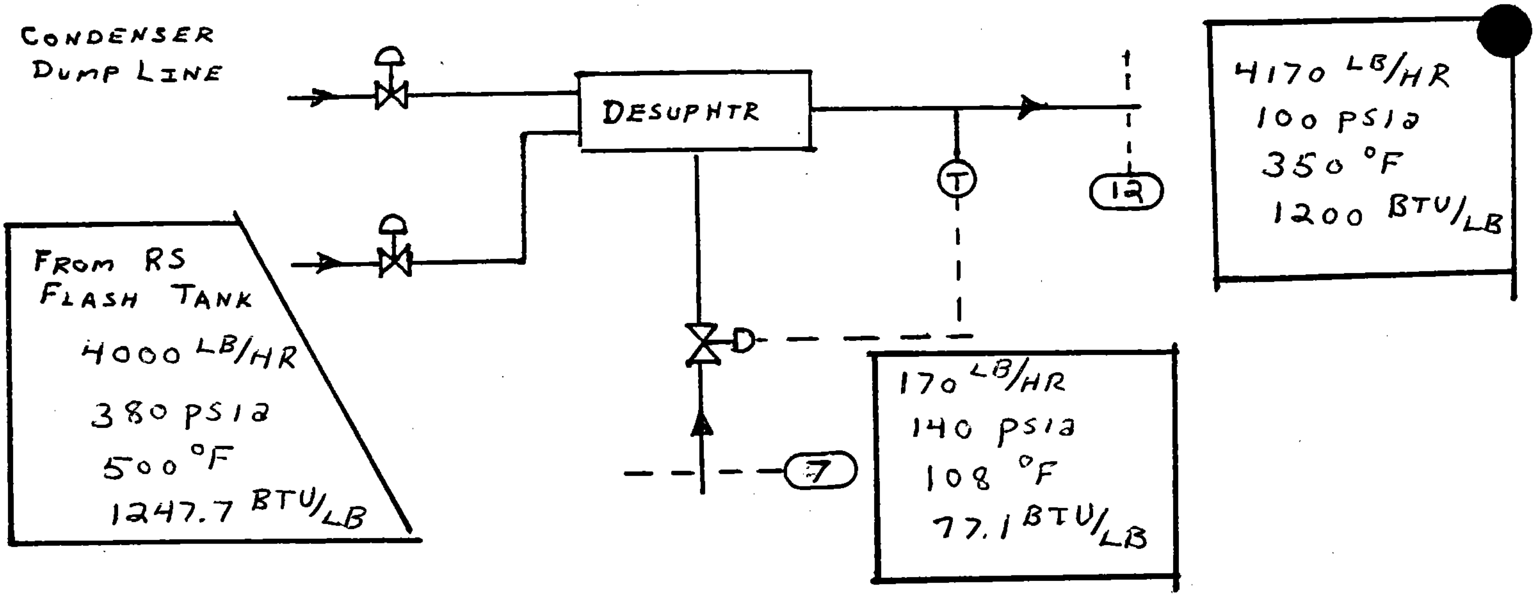
CONDENSER DUMP NETWORK



MINIMUM CONDENSER DUMP NETWORK DUTY

- THIS SET OF CONDITIONS REPRESENT A <u>TYPICAL</u> "MINIMUM DUTY" SITUATION FOR THE CONDENSER DUMP NETWORK. CARE MUST BE EXERCISED TO ENSURE THAT THE DESUPERHEATER AND CONDENSATE SPRAY WATER CONTROL VALVE HAVE SUFFICIENT TURNDOWN CAPABILITY TO ACCOMODATE THIS TYPICAL "MINIMUM DUTY". NOTE: WITH THE EXCEPTION OF PERIODS WHEN THE PLANT IS IN A TURBINE TRIP, THERMAL STORAGE CHARGE LOOP TRIP, OR RECEIVER STAND ALONE MODE, THE NORMAL DUTY FOR THE CONDENSER DUMP NETWORK WILL BE OVER THE RANGE OF LOW TO MODERATE (< ½ MAX) FLOW.

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THERMAL STORAGE FLASH TANK CIRCUIT

OBJECTIVE:

DEFINE BASIC CONTROL VALVE AND LINE SIZING REQUIREMENTS FOR THE FLASH TANK OUTLET STEAM AND CONDENSATE CIRCUITS

- CONDENSATE LEVEL CONTROL VALVES

LV-74 B	TO NO 2 HTR
LV-74D-1 LV-74D-2	TO CONDENSER

- STEAM PRESSURE CONTROL VALVES

PV-636	FLASH TANK OUTLET
PV-640	TO CONDENSER

DATA SOURCE:

HEAT AND MASS BALANCE ANALYSIS
RADL 2-15 DEC 1979

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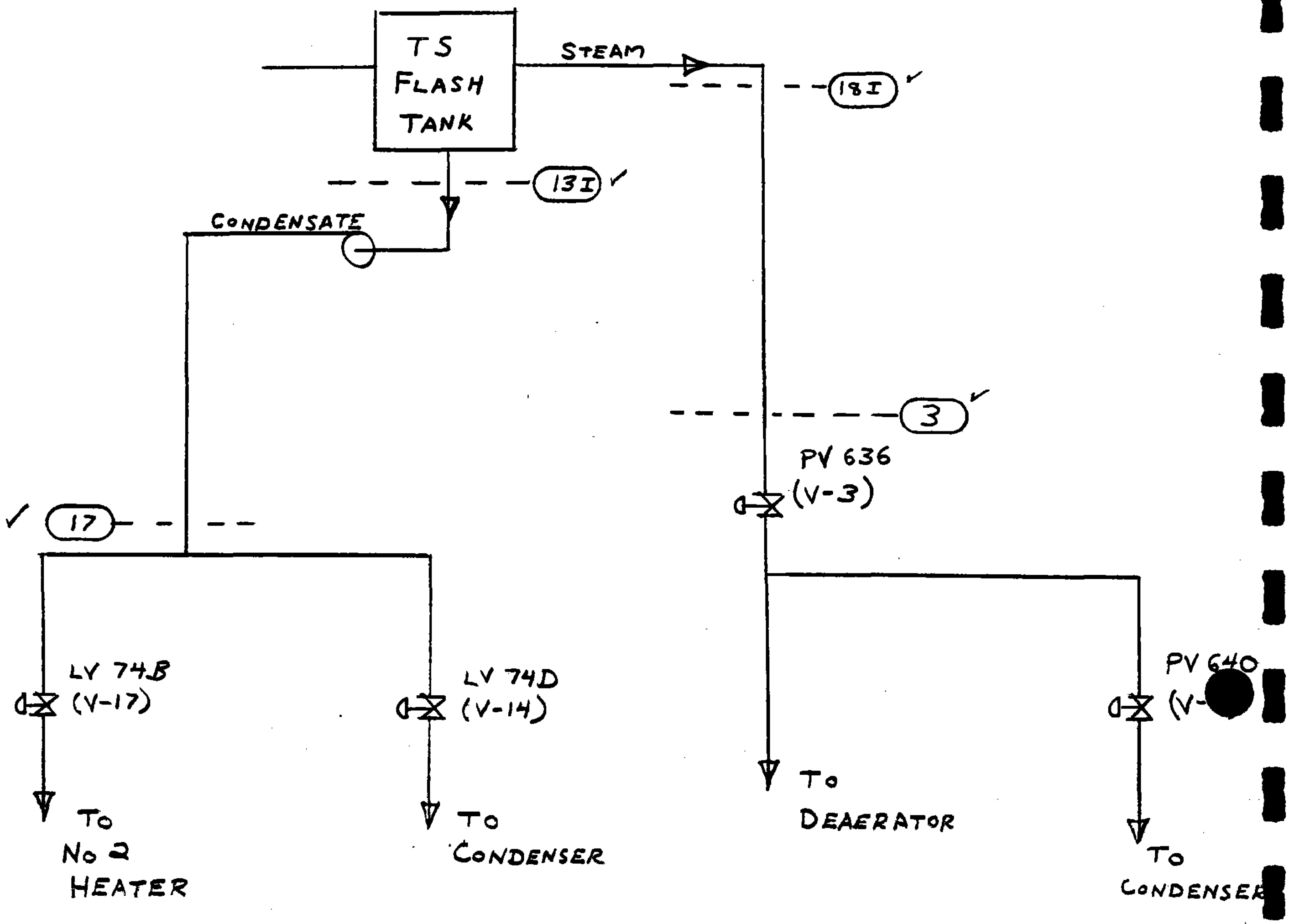
FIGURE 2

THERMAL STORAGE FLASH TANK CIRCUIT



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THERMAL STORAGE FLASH TANK CIRCUIT

1. CONDENSATE CIRCUIT

	OPERATING		DESIGN	
	MAX	MIN		
(13I)	117 500	5720	117500	LB/HR
	135	135	165	PSIG
	358	358	360	°F
(17)	117500	5720	117500	
	150	150	180	
	358	358	360	

LV 74B (V-17)

SOURCE

- MAX FLOW = 117 500 LB/HR — MODE 5-1
- MIN FLOW = 5876 LB/HR — MIN WATER FLOWE DURING CHARGE

LV 74D (V-14)

- MAX FLOW = 117500 LB/HR
- MIN FLOW =

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2. VAPOR CIRCUIT

(18I) TOTAL (MAX) VAPOR = 7IA + 11I + 14I + 12I

7IA — 6060 LB/HR, 460°F, 150 psia, 1252.9 BTU/LB

11I+14I — 130,000 LB/HR, 435°F, 1355 psia 413.3 BTU/LB

12I — 11000 LB/HR, 480°F, 150 psia 1263.6 BTU/LB

$$\bar{h} = \frac{\dot{m}_1 h_1 + \dot{m}_2 h_2 + \dot{m}_3 h_3}{\dot{m}_1 + \dot{m}_2 + \dot{m}_3}$$

$$= \frac{(6060)(1252.9) + (130000)(413.3) + (11000)(1263.6)}{6060 + 130000 + 11000}$$

$$\bar{h} = 511.5 \ \text{BTU/LB}$$

@ 150 psia

$h_f = 330.5$, $h_g = 1194.1$, $h_{fg} = 863.6$ BTU/LB

$\chi = .20959$

$\dot{m}_{STEAM} = 30822$ LB/HR

$\dot{m}_{WATER} = 116{,}238$ LB/HR

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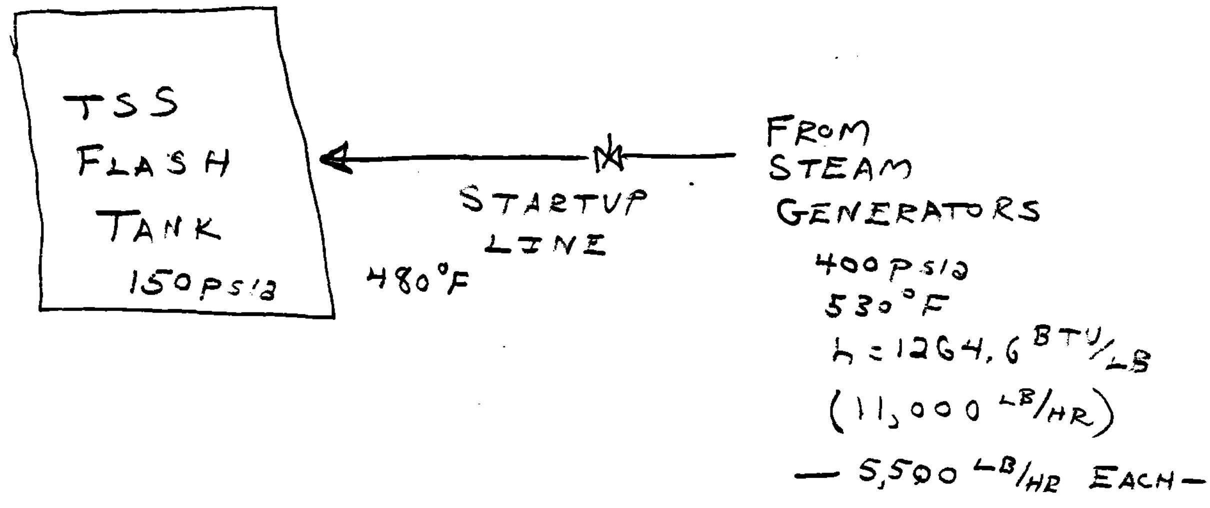

TSS
FLASH
TANK
150 psia
480°F
STARTUP
LINE
FROM
STEAM
GENERATORS
400 psia
530°F
h = 1264.6 BTU/LB
(11,000 LB/HR)
— 5,500 LB/HR EACH —

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RECEIVER FLASH TANK CIRCUIT

OBJECTIVE:

DEFINE BASIC CONTROL VALVE AND LINE SIZING REQUIREMENTS FOR THE FLASH TANK OUTLET STEAM AND CONDENSATE CIRCUITS

- CONDENSATE LEVEL CONTROL VALVES

LV-74 A	TO NO 2 HTR
LV-74 C	TO CONDENSER

- STEAM PRESSURE CONTROL VALVES

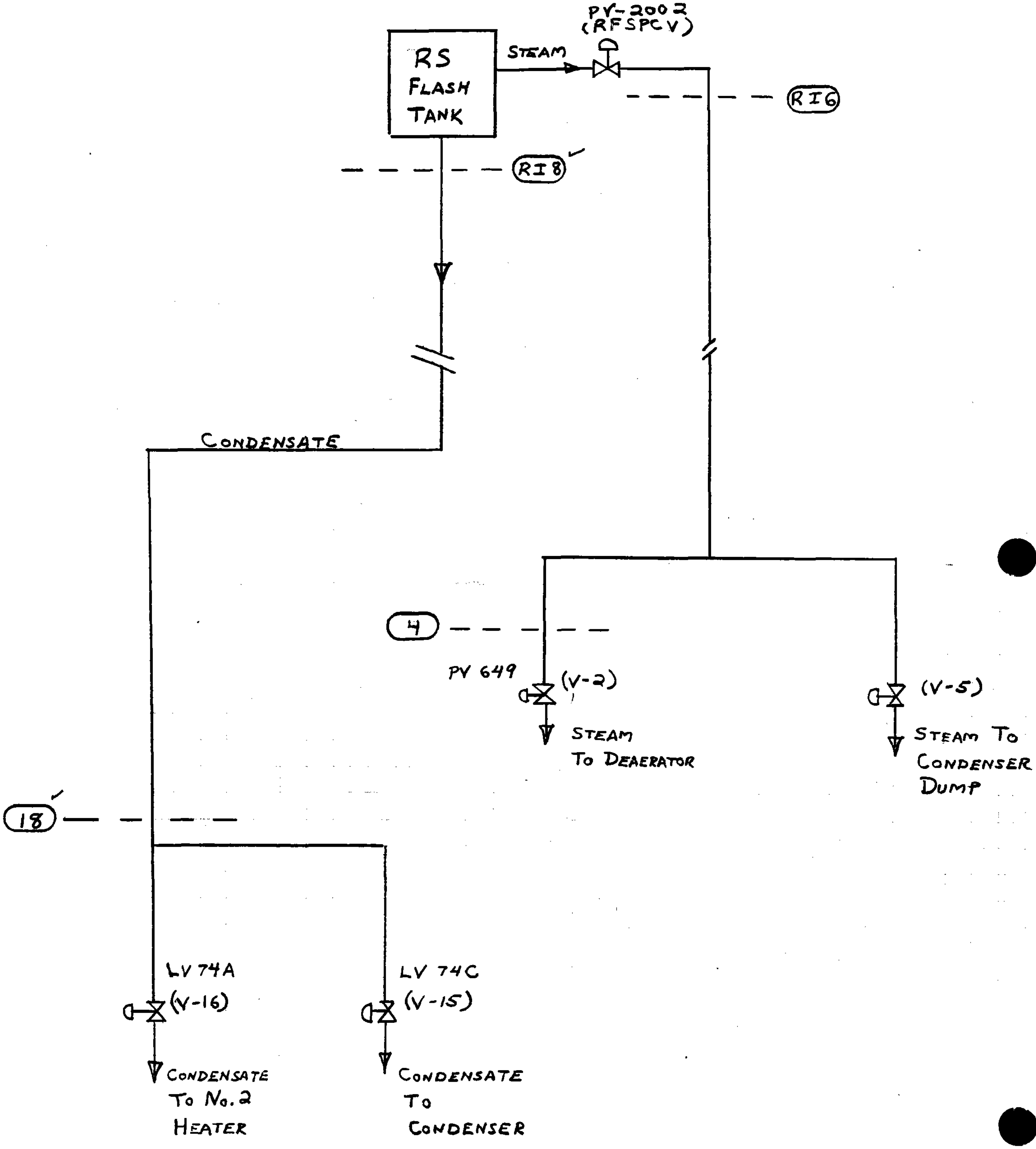
PV-2002	FLASH TANK OUTLET
PV-649	TO DEAERATOR
PV-XXX (V-5)	TO STEAM DUMP

DATA SOURCE:

HEAT AND MASS BALANCE ANALYSIS
RADL 2-15 DEC 1979

FIGURE 1

RECEIVER FLASH TANK CIRCUIT



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RECEIVER FLASH TANK CIRCUIT

1. CONDENSATE LEG

	OPERATING		DESIGN	
	MAX	MIN		
(R18)	40,000	4000	40000	LB/HR
	485	385	585	PSIG
	467	200 ?	486	°F
(18)	40,000	4000	40000	
	485 + gravity head	385 + gravity head	585 + gravity head	
	467	200	486	

LV 74A (V-16)

- MAX FLOW = 23811 LB/HR
- MIN FLOW = 4000 LB/HR

SOURCE
REC START #918

MIN FLASH TANK FLOW
~ 6:1 TURN DOWN

LV 74C (V-15)

• MAX FLOW = 40,000 LB/HR	FLASH TANK LIMIT
• MIN FLOW = 4000 LB/HR	FLASH TANK LIMIT

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2. VAPOR LEG

	OPERATING MAX	OPERATING MIN	DESIGN	
RI6	40000	4000	40000	LB/HR
	470* (15psi ΔP ACROSS VALVE PV2002)	365	585	PSIG
	960	439 SAT AT 380psig	960 (SHORT DURATION LINE OPERATION — DON'T COMPOUND DESIGN CONSERVATISM BY GOING TO 1010°F)	°F
4	6285	800	6285	LB/HR
	365	365	585	PSIG
	660 (TEMP OVERRIDE)	439	660	°F

PV 649

- MAX FLOW = 6285 LB/HR (REC STARTUP – 40,000 LB/HR STEAM)
- MIN FLOW = 800 LB/HR (DESIRABLE LOWER LIMIT – ARBITRARY)
- TEMP 660°F (CONTROLLED BY TEMP OVERRIDE TO PROTECT DA)

V-5

- ACCOMODATE FULL VAPOR LEG FLOW – 40,000 LB/HR
- MIN VALUE 4000 LB/HR (MIN FLASH TANK)

(1) 6285 LB/HR ~~+25% ADDITIONAL FLOW TO AID DEAERATION DURING~~ (REC STARTUP) ~~MODE 6 OPERATION~~

(2) MIN TO DISPLACE AUX STEAM AS SOON AS POSSIBLE

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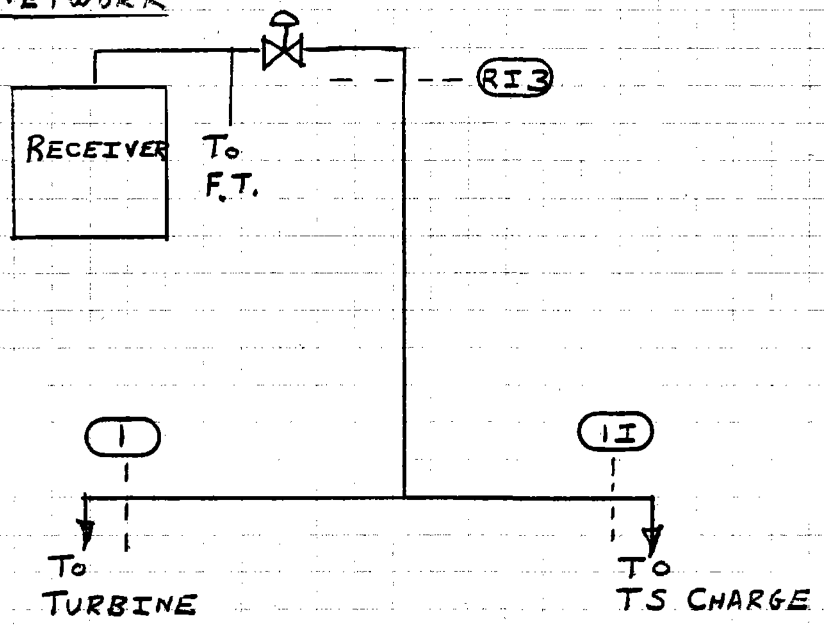
MAIN STEAM NETWORK



	OPERATING MAX	OPERATING MIN	DESIGN	
RI3	135141	31716	135141	LB/HR
	1565	1455	1775	PSIG
	960	960	1010	°F
I	112300	30000	120000	
	1450	1450	1775	
	950	950	1010	
II	105,000 } 130000	5250	130000	
	1450 } 1450	1450	1775	
	950 } 650	950	1010	

ORKSHEET

VALVE (V1) SIZING DATA

9/27/79
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P_{TANK}	$\dot{m}$	P_{REF}	T_{ET}	h_{ET}	$1/\rho_{OUT}$	P_{OUT}	T_{SUP}		C_V	LINE VELO.
500	40,000	382	467	1204	1.133 410psia	445	0		83.5	
	20,000	↓	↓	↓	1.191 390psia	398	↓		31.5	
	4,000				1.222 380psia	382			5.9	
	500				1.222 380psia	382			0.74	
500	40000	382	960	1496	1.909 @420psia	488	493		235	
	20000	↓	↓	↓	2.083 @395	411	↓		45	
	4,000				2.166 @380	383			7.8	
	500				2.166 @380	382			0.99	
500	40000	382	750	1385	1.674 410psia	475	283		146	
	20000	↓	↓	↓	1.763 390psia	406	↓		39	
	4000				1.811 380psia	383			7.1	
	500				1.811 380psia	382			.88	

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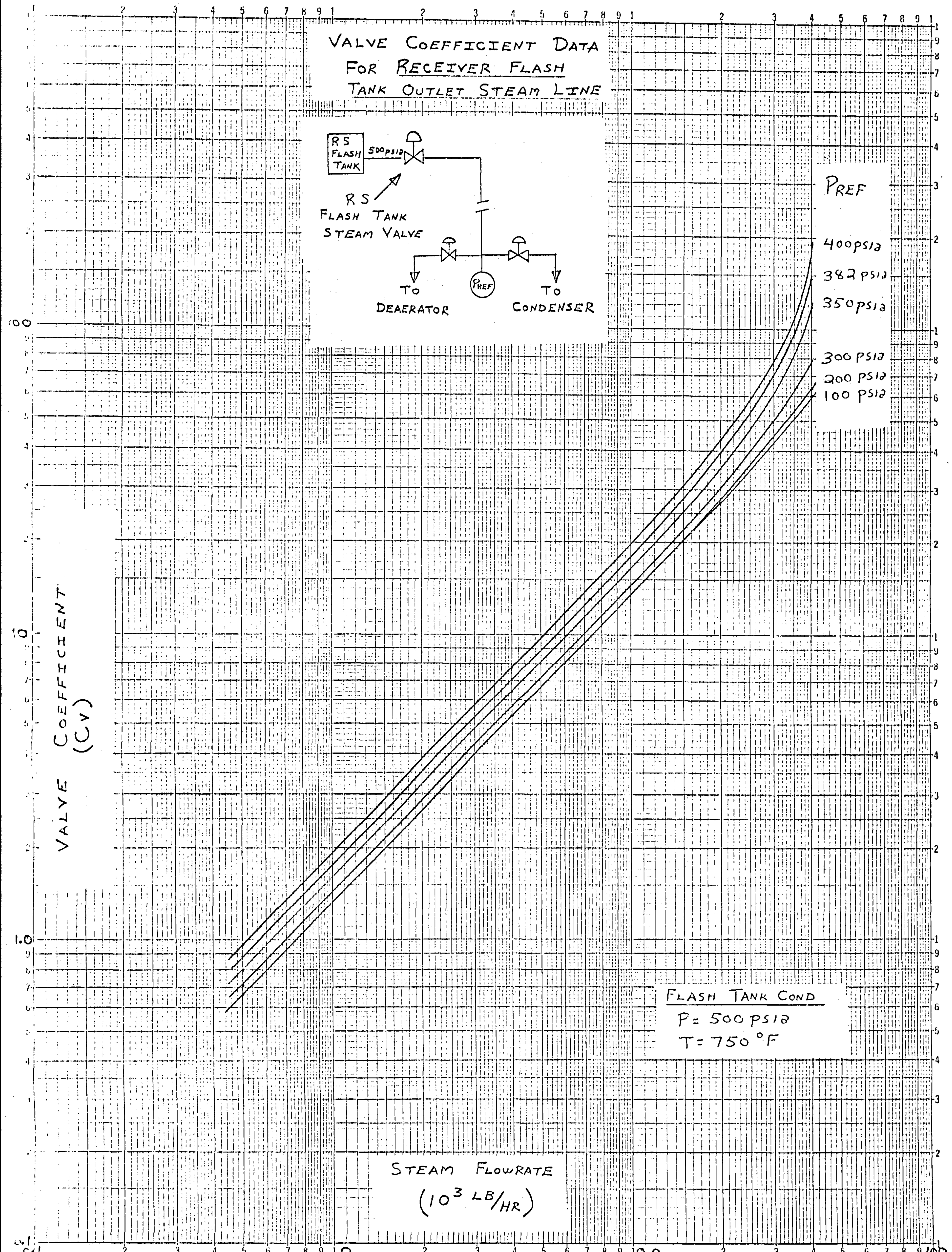

VALVE COEFFICIENT DATA FOR RECEIVER FLASH TANK OUTLET STEAM LINE

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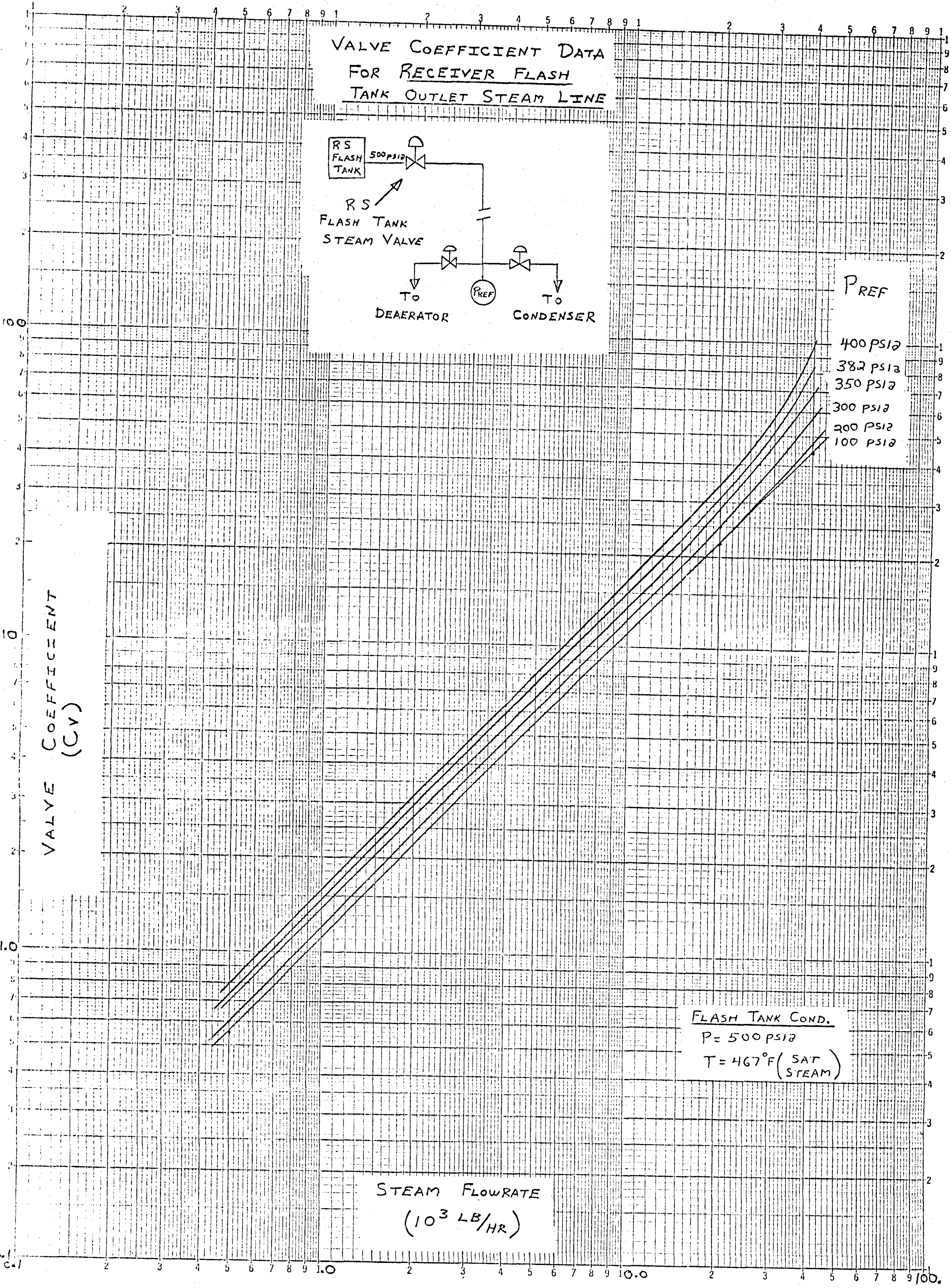
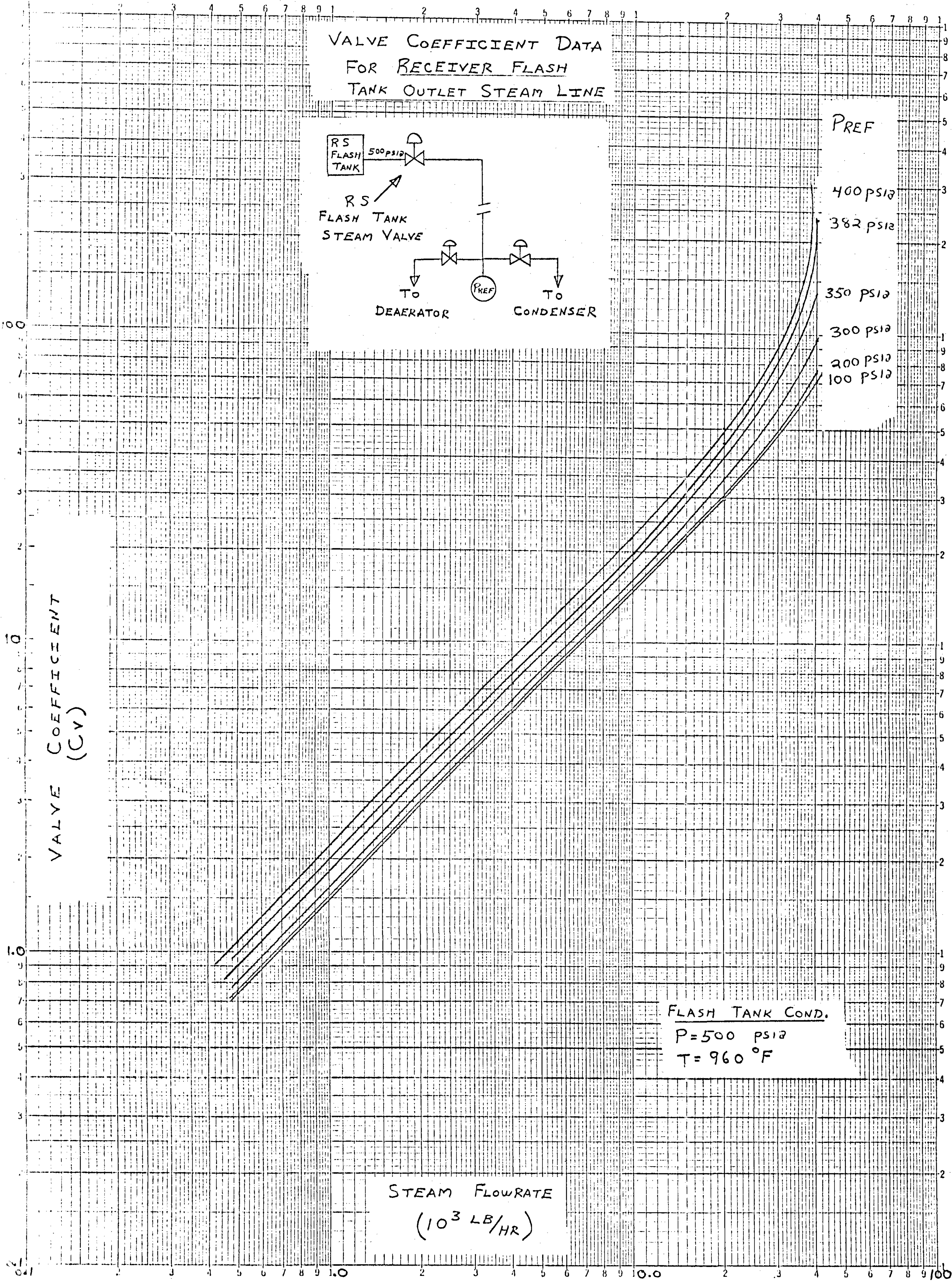

VALVE COEFFICIENT DATA
FOR RECEIVER FLASH
TANK OUTLET STEAM LINE
RS FLASH TANK
500 psia
RS FLASH TANK STEAM VALVE
PREF
TO DEAERATOR
TO CONDENSER
PREF
400 psia
382 psia
350 psia
300 psia
200 psia
100 psia
VALVE COEFFICIENT (Cv)
100
10
1.0
0.1
1.0
10.0
100.
STEAM FLOWRATE (10³ LB/HR)
FLASH TANK COND.
P = 500 psia
T = 467°F (SAT STEAM)

VALVE COEFFICIENT DATA FOR RECEIVER FLASH TANK OUTLET STEAM LINE



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A3-255-EP-RES-641
July 23, 1979

MEMORANDUM

Subject: CONDENSER DUTY - NORMAL AND CONDENSER DUMP OPERATION

To: J. E. Raetz, A3-228; R. G. Riedesel, A3-202

From: R. E. Snyder, A3-255

Copies to: K. R. Knox, R. J. Perkins, E. J. Riel, E. J. Tomei

The purpose of this memo is to:

- Document the condenser duty during normal operation for the worst case operating modes.
- Present the results of an analysis showing the condenser duty during condenser dumps with the corresponding condenser pressure and temperature with no relief/valve flow for the worst case operating modes.
- Present the resulting receiver relief valve flow required to meet the maximum allowable condenser pressure of 5 in. Hg for the critical modes analyzed.

In general, turbine manufactures prescribe a maximum limit on turbine backpressure (condenser pressure) of 5 in. Hg. The curve shown in Figure 2 summarizes the effect of condenser heat load on the condenser pressure. As the load increases so does the pressure. Both the maximum and design pressure and heat load are noted on the curve. This analysis uses the 5 in. Hg limitation and when this limit is exceeded any additional flow (or load) is vented overboard through the receiver relief valves. As soon as the back pressure requirements of the actual turbine to be purchased is known any changes will be incorporated in this study.

All data used in this analysis was obtained from the following report titled, 10 MWE Solar Thermal Central Receiver Pilot Plant Solar Facilities Design Integration Heat and Mass Balance Design Data, MDC G7842 dated April 1979. Run numbers referenced in this memo are identified in the above document. Operating modes are identified in Figure 1.

Condenser duty was analysed for worst case normal and condenser dump operation as follows:

- Mode 1 maximum flow case (Run 104-1) as a baseline. (TABLE I). Condenser pressure during normal operation was below design (2.5 in. Hg) and was below the maximum allowable during condenser dump.
- Mode 2 was not presented as condenser duty would be less than Mode 1 for normal operation and the same for condenser dump.

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- Mode 3 (Run 304-5) was analysed to ensure that in its worst case limit it approached Mode 1 operation, (TSS flow goes to zero) see Table II.
- Mode 4 (Run 408-6) approaches the condenser design pressure during normal operation and potentially exceeds the maximum allowable pressure by more than 1 in. Hg (6.18 in. Hg), TABLE III. However, the condenser dump pressure control valve limits the condenser pressure to 5 in. Hg so that the upstream pressure will rise opening the receiver relief valves. The relief valve flow will be 23689 #/Hr.
- Mode 5 is not critical and was not included.
- Mode 6 is not critical and was not included.
- Mode 7 (Run 701-7) has the highest condenser duty during normal operation and potentially the highest during condenser dump, TABLE IV 40710.7 LB/HR relief valve flow is required to limit the condenser pressure to 5 in. Hg.

Figure 2 is a plot showing condenser pressure as a function of heat load. The control valve on the condenser will limit operation at or below the maximum condenser pressure line. Figure 3 shows receiver relief valve flow versus condenser load. The worst case condenser duty during a condenser dump is shown for the various modes. The Mode 1 and Mode 3 points are identical because in the worst case Mode 3 degrades to a Mode 1 case as the admission flow approaches zero.

For further information contact the undersigned on Extention 3220.

Ray Snyder

Ray Snyder

TABLE I

MODE 1 (RUN 104-1)

	WEIGHTFLOW ($\dot{w}$) LB/HR	ENTHALPY (h) BTU/LB	LOAD (Q) M-BTU/HR	CONDTEMP OF	CONDPRESS IN-HG
NORMAL OPERATION					
THROTTLE STEAM	115000				
ADMISSION STEAM	0				
THERMAL STORAGE CHARGING FLOW	0				
CONDENSER DUTY					
TURBINE	83950.5	1006.1	78.024		
No4 FEED HTR DRN	8102.7	86.9	.083		
LP END PKNGS	650	1444.3	.889		
FROM RESERVOIR	1179.3	1444.3	1.613		
TOTAL			80.609	105.1	2.251
RECEIVER TRIP					
CONDENSER DUTY					
CONDENSER DUMP	115000	1465.4	159.7	124.9	3.938
CONDENSER MAX. ALLOW. RELIEF VALVE FLOW	0				

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TABLE II

MODE 3 (RUN 304-5)

	WEIGHTFLOW ($\dot{w}$) LB/HR	ENTHALPY (h) BTU/LB	LOAD (Q) M-BTU/HR	CONDTEMP OF	CONDPRESS IN-HG
NORMAL OPERATION					
THROTTLE STEAM	90000				
ADMISSION STEAM	25000				
TS CHARGING FLOW	0				
CONDENSER DUTY					
TURBINE	86950.3	998.6	80.136		
No4 FEEDHTR DRN	8599.8	86.9	.087		
LP END PKNGS	650	1434.8	.883		
FROM RESERVOIR	1208.3	1434.8	.1641		
TOTAL			82.747	105.6	2.286
RECEIVER TRIP					
CONDENSER DUTY					
CONDENSER DUMP	90000	1465.4	124.983		
TURBINE	23801	1024.4	22.556		
No4 FEEDHTR DRN	896.7	86.8	.009		
LP END PKNGS	650	1263.2	.771		
TOTAL			148.319	122.0	3.643
CONDENSER MAX. ALLOW			195.211	133.7	5
RELIEF VALVE FLOW	0				

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TABLE III

MODE 4 (RUN 408-6)

	WEIGHTFLOW ($\dot{w}$) LB/HR	ENTHALPY (h) BTU/LB	COND. LOAD /QCond M-BTU/HR	CONDTEMP OF	COND.PRESS IN-HG
NORMAL OPERATION					
THROTTLE STEAM	0				
ADMISSION STEAM	1086.25				
TS CHARGING FLOW	130000				
CONDENSER DUTY					
TURBINE	70706.4	964.7	62.787		
No4 FEEDHTR DRN	15892.6	86.9	.162		
LP END PKNGS	650	1263.2	.771		
TS CHG DRNS,WATER	117513.6	330.8	29.86		
TOTAL			93.58	108.4	2.474
RECEIVER TRIP					
CONDENSER DUTY					
CONDENSER DUMP	103932	1465.4	144.331		
TURBINE	91960.3	966.1	81.793		
No4 FEEDHTR DRN	9458.9	86.9	.096		
LP END PKNGS	650	1263.2	.771		
FROM RESERVOIR	941.3	1263.2	1.117		
TOTAL (NO RELIEF VALUE FLOW)			228.108	141.9	6.180
CONDENSER MAX ALLOW			195.211	133.7	5.
RELIEF VALUE FLOW	23689		195.211	133.7	5.

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TABLE IV

MODE 7 (RUN 701-7)

	WEIGHTFLOW ($\dot{w}$) LB/HR	ENTHALPY BTU/LB	LOAD (Q) M-BTU/HR	COND TEMP °F	COND PRESS IN-HG
NORMAL OPERATION					
THROTTLE STEAM	30000				
ADMISSION STEAM	85000				
TS CHARGING FLOW	130000				
CONDENSER DUTY					
TURBINE	75831.1	981.2	68.593		
No4 FEED HTR DRN	15568.8	86.9	.158		
LP END PKNGS	650	1425.9	.877		
FROM RESERVOIR	1223.9	1425.9	1.651		
TOTAL			96.039	109.0	2.519
RECEIVER TRIP					
CONDENSER DUTY					
CONDENSER DUMP	133784.3	1465.4	185.786		
TURBINE	72103	971.1	64.489		
No4 FEEDHTR DRN	6036.3	86.9	.062		
LP END PKNGS	650	1263.2	.771		
FROM RESERVOIR	537.6	1263.2	.638		
TOTAL (NO RELIEF VALUE FLOW)			251.746	147.8	7.172
CONDENSER MAX ALLOW			195.211	133.7	5
RELIEF VALVE FLOW	40710.7			133.7	5

STEADY STATE
OPERATING MODES

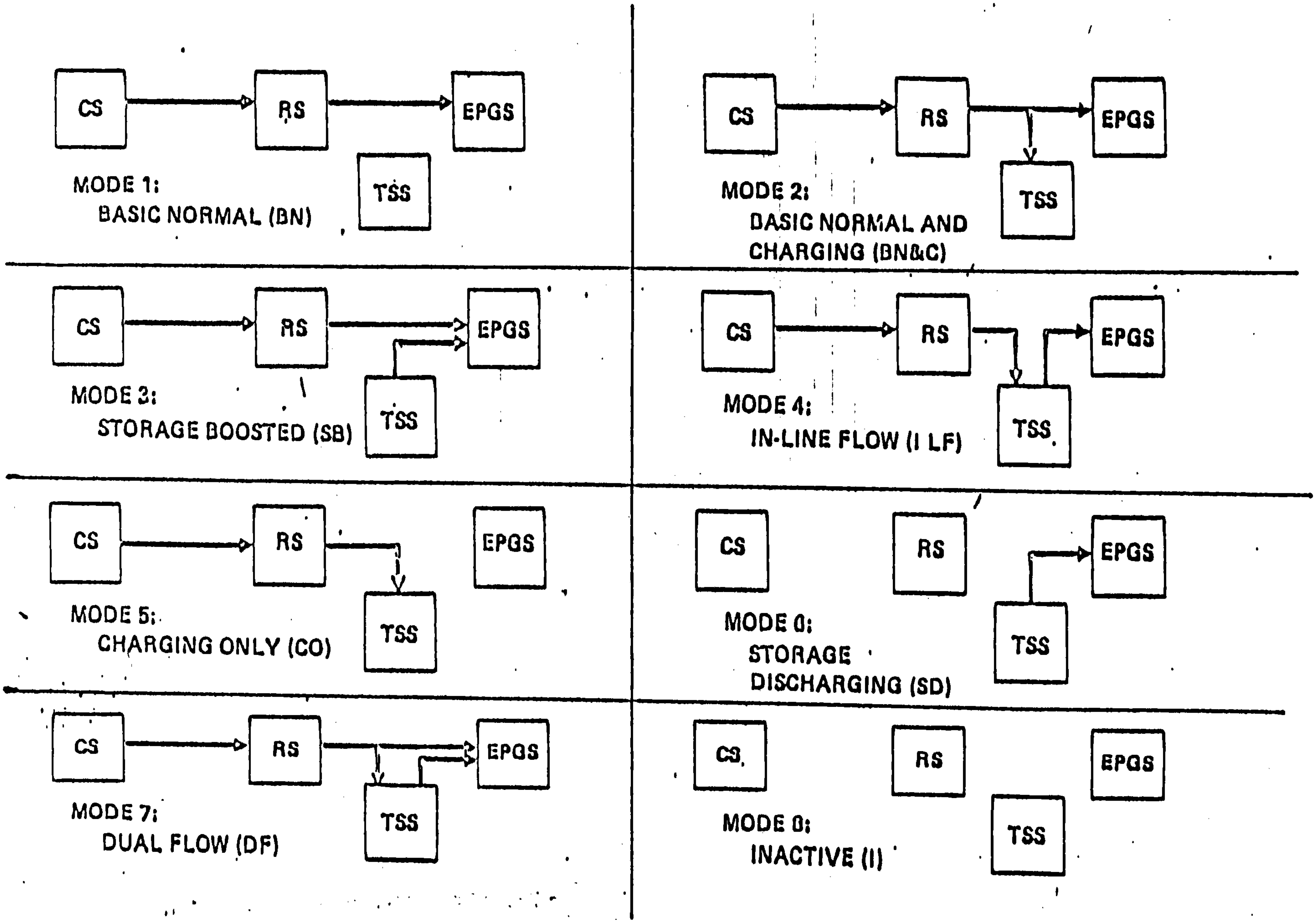

FIGURE 1

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CONDENSER DUMP

RELIEF VALVE FLOW VS CONDENSER LOAD

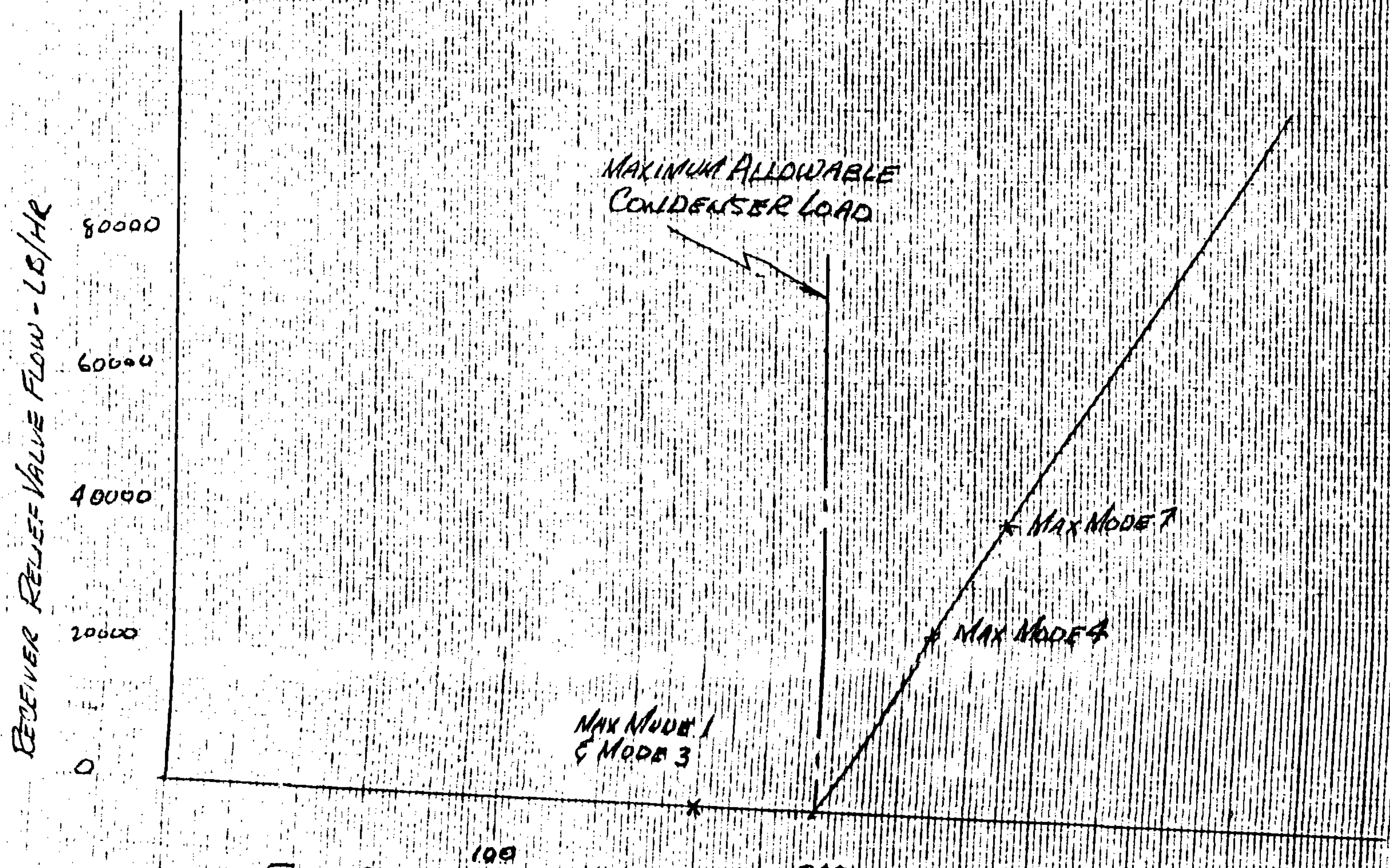

FIGURE 3, CONDENSER LOAD - MILLIONS BTU/HR

CONDENSER DUMP

CONDENSER LOAD LIMITATIONS

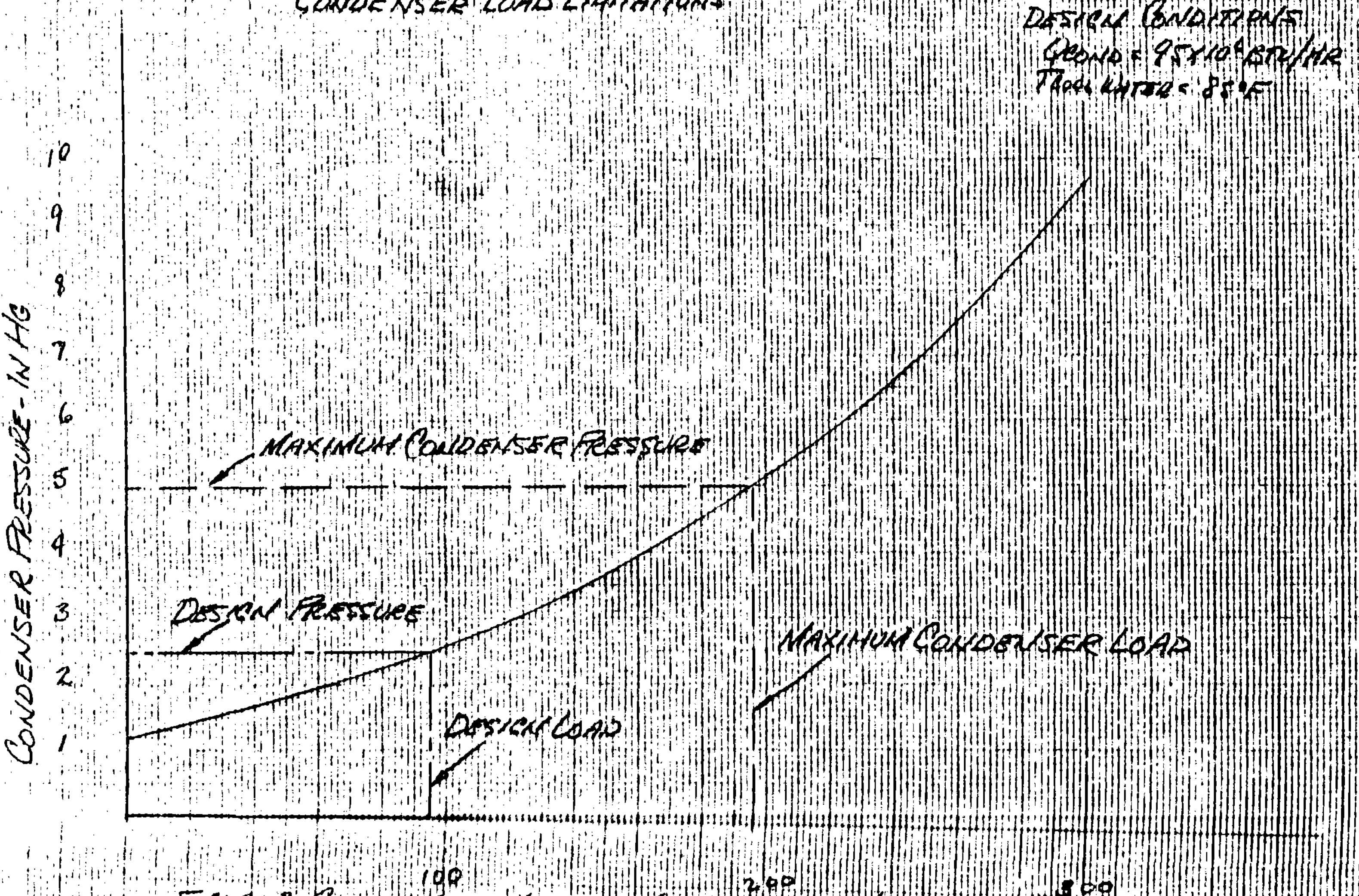

FIGURE 2, CONDENSER LOAD - MILLIONS BTU/HR

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A3-228-JER-EP-465
June 4, 1979

MEMORANDUM

Subject: CONDENSER DUMP PERFORMANCE, OPERATING, AND SIZING REQUIREMENTS

To: R. G. Riedesel

From: J. E. Raetz

Copies to: C. B. Boehmer, P. I. Kawano, K. R. Knox, R. J. Perkins,
E. J. Riel, R. E. Snyder

The purpose of this memorandum is to document the preliminary top level operating and sizing requirements for the condenser dump line and to indicate potential impacts on the condenser. These preliminary requirements shall be used as the basis of the preliminary design analysis and may be revised on the basis of results developed during that analysis.

The principal elements of the condenser dump line which are shown in Figure 1 include a turbine bypass line, pressure control valve, and desuperheating equipment as well as the indicated temperature and pressure sensing equipment. The condenser dump line would connect to the main steam line upstream of the turbine line isolation valve to allow for the dumping of either turbine main steam or thermal storage charging steam flows. The control valve reduces the steam pressure to a condition acceptable to the condenser. The desuperheater is required to reduce the steam to a saturated condition which can then be accomodated by the condenser. Condensate supply to the desuperheater is currently being taken from the outlet of the hotwell pump. This design for the condensate circuitry is tentative pending a more detailed analysis of the entire condenser dump line. If it is found that the local steam pressure at the desuperheater exceeds the condensate pressure available at the outlet of the hotwell pump, an additional higher head pump may be added for desuperheater operation or the required condensate may be supplied from the outlet of the receiver feed pump.

Performance and Operating Requirements

The condenser dump line shall be designed to satisfy the following performance and operating requirements:

1) Control and ramp the receiver steam back pressure* from 380 psia to 1465 psia during receiver startup at a total steam flow rate of 30,000 - 60,000 lb/hr. (steam enthalpy range of 1336 - 1461 BTU/LB). - Max duration 20 min, minimum duration 5 min.

---

* Measured by the condenser dump line pressure sensor

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2) Control and ramp the receiver steam back pressure * downward from 1465 psia to 380 psia during receiver shutdown at a total steam flow rate of 30,0 to 60,000 lb/hr. (steam enthalpy range 1461-1336 BTU/lb) - max duration 20 min, minimum duration 2 min.

3) Maintain receiver back pressure * at 1465 + 200 - 100 psia during a turbine trip at a steam flow rate of 30,000 - 115,000 lb/hr. (nominal steam conditions: 1465 psia, 950°F, 1461 BTU/LB) - max duration 20 min, minimum duration 2 min.

4) Maintain receiver back pressure * at 1465 + 200 - 100 psia during a trip of thermal storage charging equipment for nominal steam conditions of:

- rated steam
  950°F, 1465 psia, 105,000 - 30,000 lb/hr
- derated steam
  650°F, 1465 psia, 130,000 - 30,000 lb/hr
- max duration 20 min, minimum duration 2 min

5) Control receiver back pressure * during stand alone receiver operation with steam conditions of:

- rated steam
  950°F, 1465 psia, 30,000 - ~~115,000~~ TBD* lb/hr
- derated steam
  650°F, 1465 psia, 30,000 - ~~130,000~~ TBD* lb/hr
- max duration 8 hr

Estimated Condenser Impacts

The potential impacts of the first four requirements on condenser duty and condenser pressure have been defined on a preliminary basis to assess the effects of the dump line flow on condenser/turbine design and operation. Figure 2 illustrates the maximum duty and pressure anticipated during conditions defined by Requirements 1 and 2 above for steam flow rates of 30,000 and 60,000 lb/hr. The data contained in the figure assumes that the dump line flows are superimposed on the condenser duty experienced during a maximum flow Mode 6 operation - $83.8X10^6$ BTU/HR - which could be occuring during a receiver startup or shutdown. It is seen that for a 60,000 lb/hr dump flow, a maximum condenser pressure of 4.1 in Hg would exist. The corresponding pressure for a 30,000 lb/hr dump is 3.05 in HG.

Figure 3 illustrates the maximum impact of the trip conditions defined by Requirements 3 and 4 above on the condenser duty and pressure. For these conditions which could be produced during Modes 1, 2, and 5, the condenser pressure would be maintained in the range of 3.5 to 4.0 in Hg. Trip conditions of this type which occured during Mode 4 or 7 operation could result in excessive condenser pressures under the worst case conditions and should be disallowed in the trip logic network. During Mode 4 operation for example where both the TS charge rate and turbine flow (from admission steam) are at their maximum levels, a total heat rejection duty requirement in excess of $230X10^6$ BTU/HR could be realized by a trip of the TS charging flow. This would resu in a condenser pressure in excess of 6 in Hg and may cause other trip actions to be initiated. As a result, during Mode 4 or Mode 7 operation, the use of the condenser dump line should be limited by limitations on the condenser pressure which will be established by condenser and turbine suppliers.

*NOT TO BE SIZING DRIVER FOR THE HEAT REJECTION SYSTEM

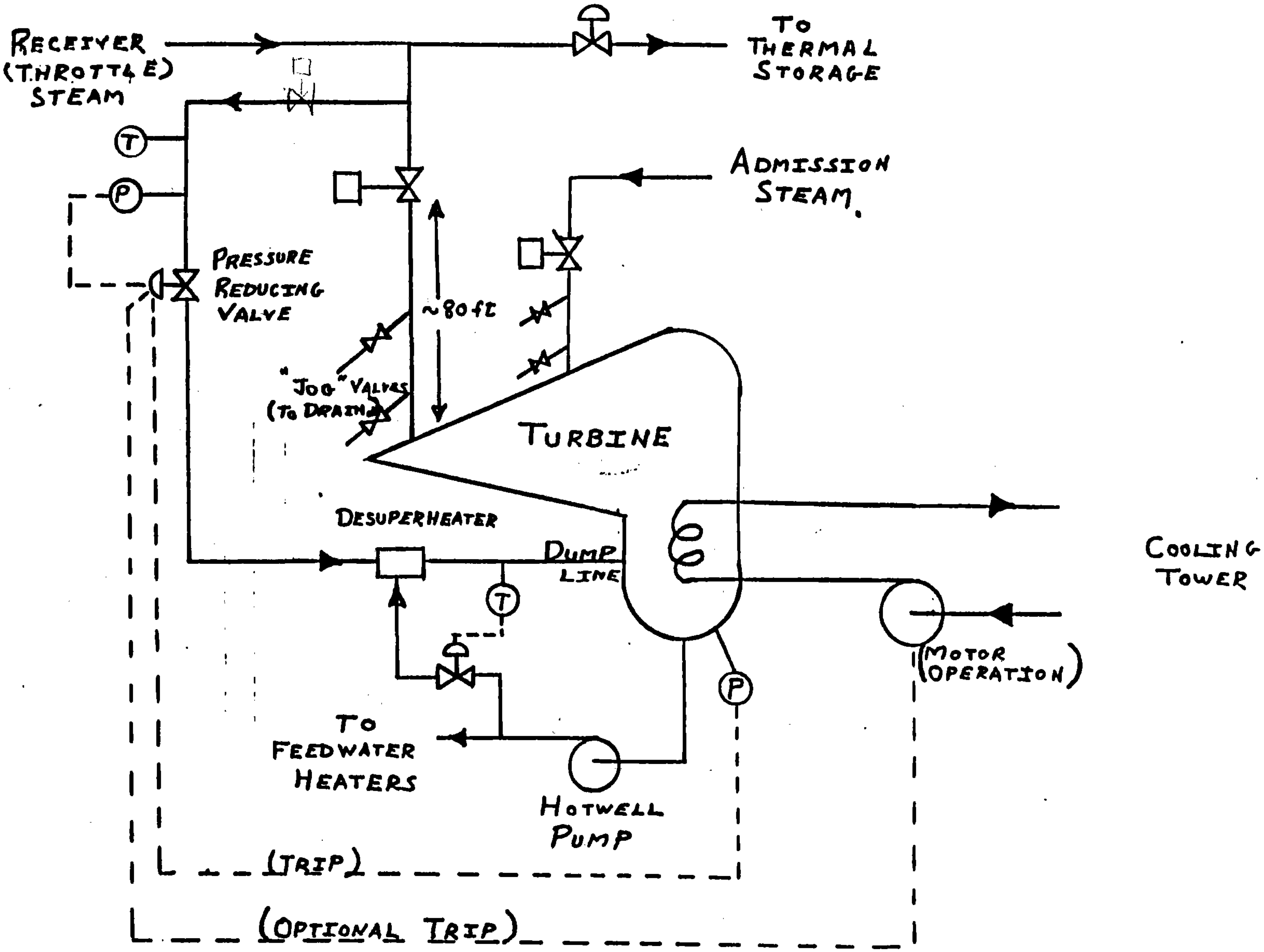

FIG 1 DESIGN OF CONDENSER DUMP CIRCUIT

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FIG 2 IMPACT OF RECEIVER STARTUP/SHUTDOWN LOAD ON CONDENSER DUTY AND PRESSURE

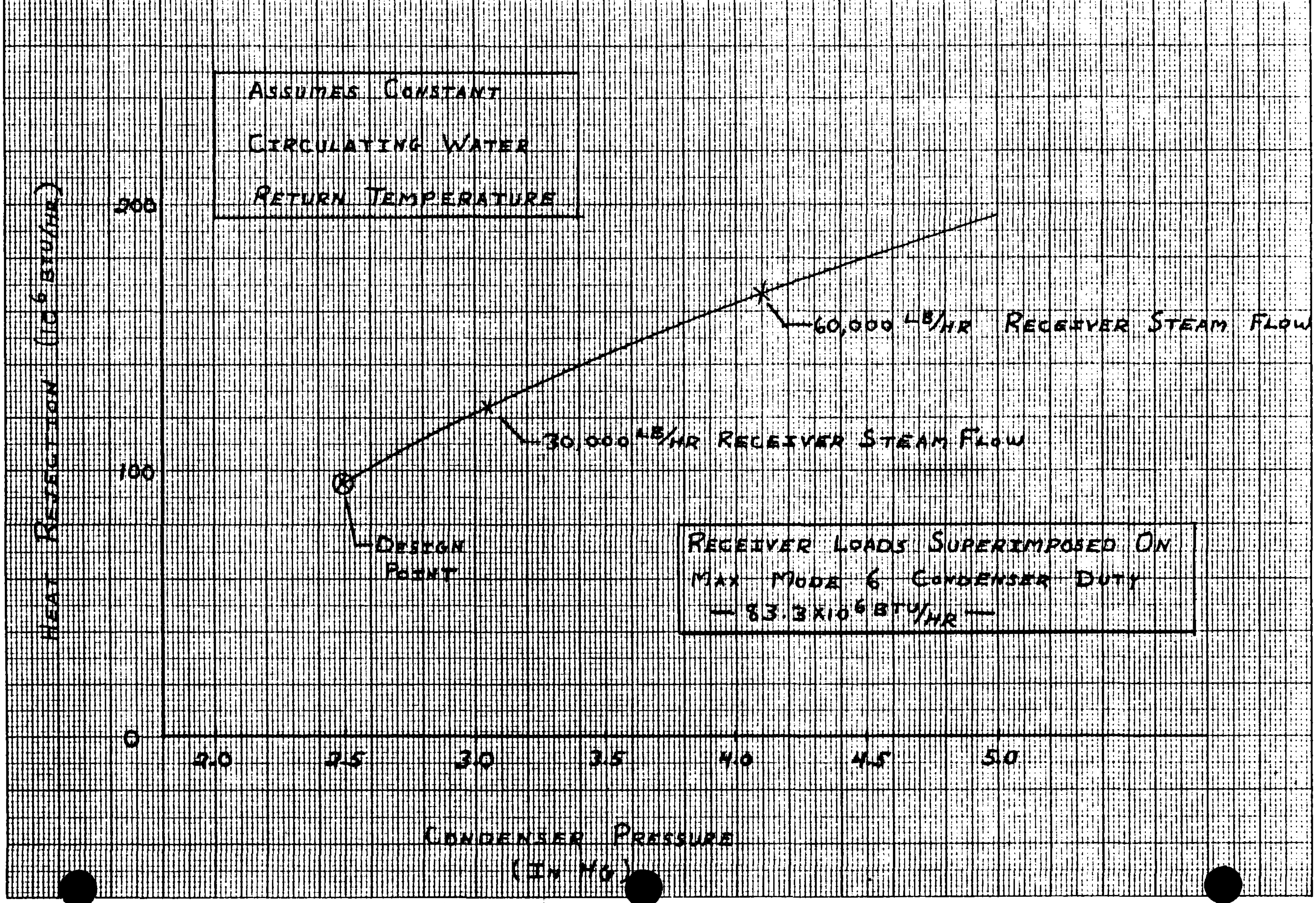
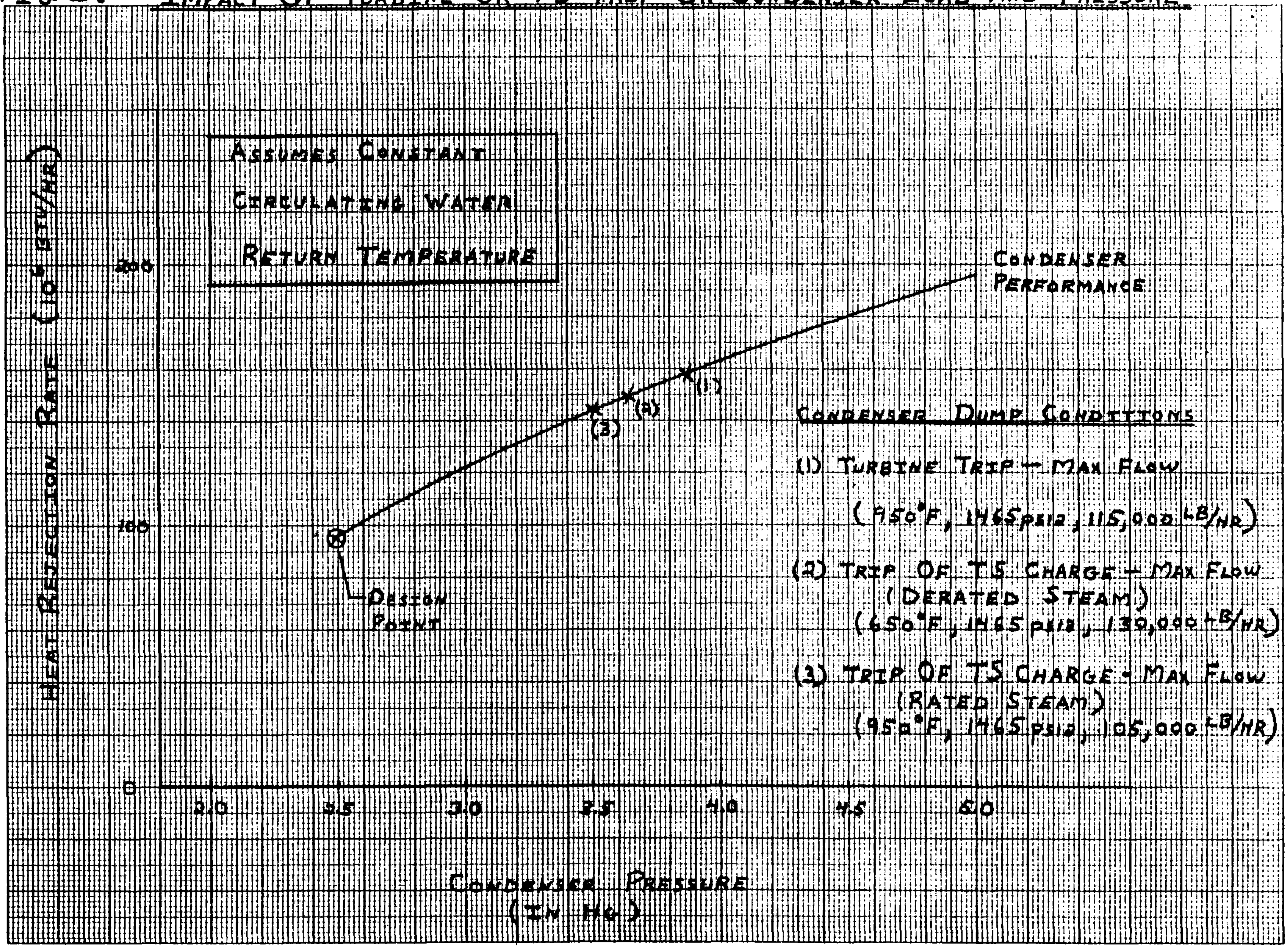


FIG 3. IMPACT OF TURBINE OR TS TRIP ON CONDENSER LOAD AND PRESSURE



CONDENSER DUMP CONDITIONS

(1) TURBINE TRIP – MAX FLOW
(950°F, 1465 psia, 115,000 LB/HR)

(2) TRIP OF TS CHARGE – MAX FLOW
(DERATED STEAM)
(650°F, 1465 psia, 130,000 LB/HR)

(3) TRIP OF TS CHARGE – MAX FLOW
(RATED STEAM)
(950°F, 1465 psia, 105,000 LB/HR)

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The impact on the condenser of using the condenser dump line for extended stand alone receiver operation (Requirement 5 above) was not estimated because extended periods of operation in that manner would cause an increase in the circulating water return temperature which can significantly influence condenser performance.. The temperature rise and the rate at which it occurs depend on the cooling tower capacity and the total volume of water in the circulating water system.

J E Raetz

J. E. Raetz

SFDI CONTROL VALVE REQUIREMENTS

12/16/79
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OBJECTIVE:

DEFINE PRELIMINARY CONTROL DESIGN AND PERFORMANC REQUIREMENTS FOR LONG LEAD SFDI CONTROL VALVES.

NOTE:

THIS PACKAGE NEGLECTS DETAILS OF INLET AND OUTLET PIPING PRESSURE LOSSES PENDING DETAILED DESIGN OF THE RESPECTIVE PIPING NETWORKS. WHEN FINAL DESIGN IS COMPLETED, THE PRESSURE VALUES ON THE RESPECTIVE DATA SHEETS MUST BE REVISED.

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VALVE REVISION CHECK LIST

DISCRIPTION	UPDATED
• V-2 RS FLASH TANK TO DA (STEAM)	✓ ~~PV 649~~ (PV-6473)
• V-3 TS FLASH TANK TO DA (STEAM)	✓ ~~PV636~~ (PV-6474)
• V-4 TS FLASH TANK TO COND (STEAM)	✓ PV640
• V-5 RS FLASH TANK TO COND (STEAM)	✓ PV-1000
• V-8 CONDENSER DUMP (STEAM)	✓ PV-1001
• V-9 CONDENSATE TO DUMP DESUPHTR (COND)	✓ TV-1002
• V-11 MAIN STEAM TO AUX STEAM (STEAM)	✓ PV-1003
• V-12 ADMISSION STEAM TO AUX STEAM (STEAM)	✓ PV-1005
• V-14 TS FLASH TANK TO COND. (COND)	✓ LV 74D
• V-15 RS FLASH TANK TO COND (COND)	✓ LV74C
• V-16 RS FLASH TANK TO #2 HTR (COND)	✓ LV74A
• V-17 TS FLASH TANK TO #2 HTR (COND)	✓ LV74B
• V-23 CONDENSATE TO AUX STEAM DESUP (COND)	✓ TV-1004
• V-24 AUXILIARY STEAM ISOLATION (STEAM)	✓ AOV-1008
• V-25 AUXILIARY STEAM ISOLATION (STEAM)	✓ AOV-1009
• LV-1 TS BLANKETING STEAM INLET WATER LEVEL VALVE	

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CONTROL VALVE DESIGN SHEET

PV-647 B

ISSUED
REVISED

PV 649 RS FLASH TANK TO DEAERATOR

CUSTOMER: ____________________

TAG NO.: ____________________

PROJECT NO.: ____________________

SERVICE: RS FLASH TANK

PROJECT: ____________________

FLUID: STEAM

REV. NO.	1			
DATE	12/15			
BY	JER. (MDAC)			

	FLUID CONDITIONS AT VALVE INLET				VALVE	SYSTEM	APPROX.
	PRESS.	TEMP.	DENSITY	VISC.,		FRICTION LOSS	DESIRED
FLOW [✓ #/HR] GPM, SCFM	PSIA	°F	#/FT^3 OR S.V. [✓ FT^3/#]	c_p or SSU	Δ P PSI	PSI	C_v
XIMUM	6285	380 - SEE NOTE 1	660 SEE NOTE 2	1.6707		SEE NOTE 3		
DESIGN	6285	380 SEE NOTE 1	585	1.53		SEE NOTE 3		
MINIMUM	800	380 SEE NOTE 1	439	1.2222		SEE NOTE 3		

x. Design Temp.: 660 (SEE NOTE 2) °F, Max. Design Press.: 600 PSIA

x. Shut-Off Press.: 360 (SEE NOTE 4) PSI

Valve Service: OPEN/CLOSE ☐ MODULATION ☒

Flashing Expected in Valve? YES ☐ NO ☒

ipe Size and Schedule: ____________________, Pipe Material: ____________________

prox. Valve Body Size: ____________ INCHES

ody Type: ____________________

Valve Characteristic: Linear ☐ Equal Percentage ☐
Quick Opening ☐ Other: MODIFIED PARABOLIC

Tight Shut-Off Required? YES ☐ NO ☐

lowable Leakage: ____________________

Is Handjack or Handwheel Required? YES ☐ NO ☐

ecial Steam Packing Considerations: ____________________

alve Action On Loss of Power: Locks in Pos. ☐ Opens ☐ Closes ☒
Valve Action On Loss of Power air/or sensing fluid Opens ☐ Closes ☒

rm No. :

Date: 12/15/79

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12/14/79
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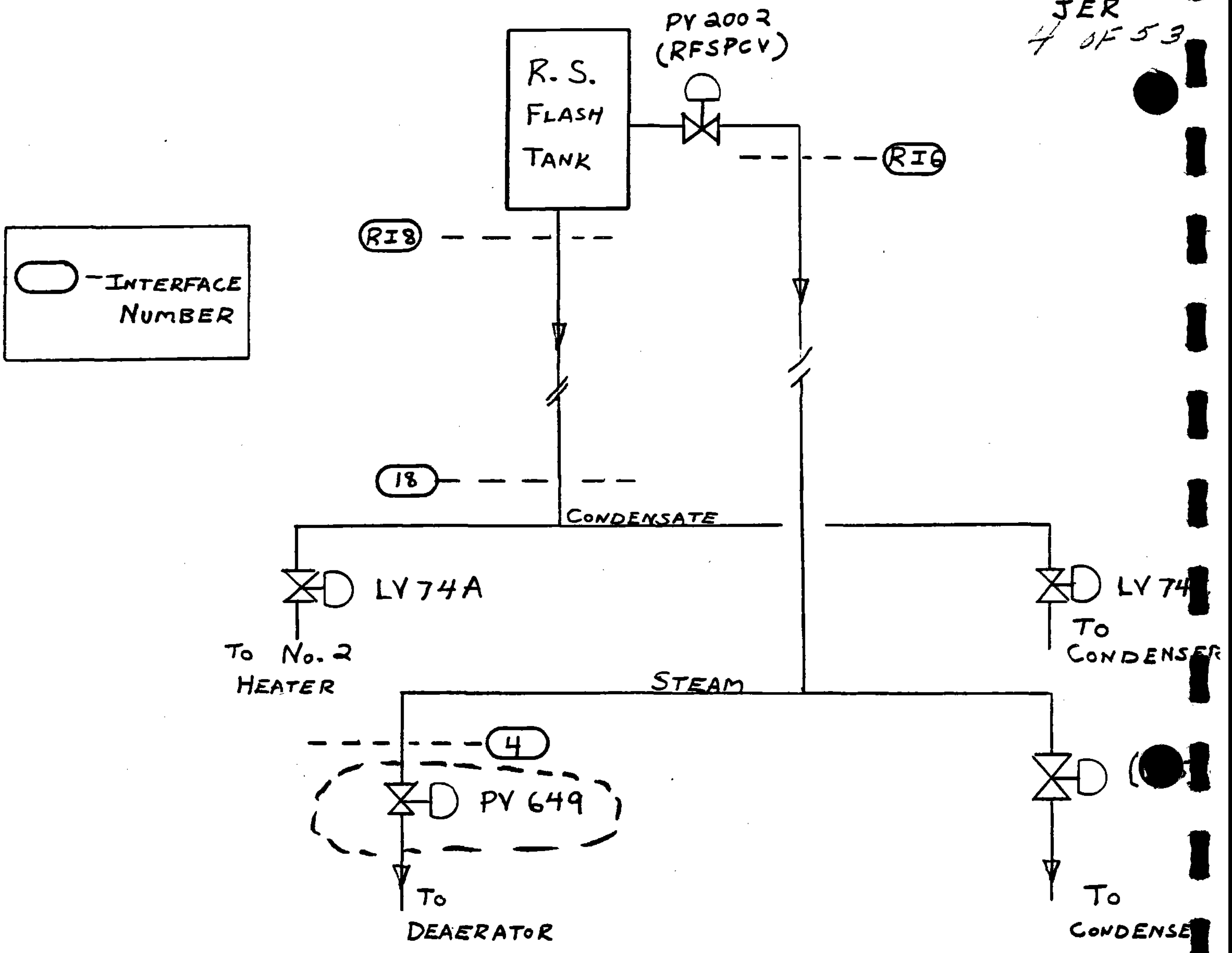

PV 649 NOTES

1. VALVE (V-5) "TO CONDENSER" IS SET TO CONTROL UPSTREAM PRESSURE AT 380psia. IT IS ASSUMED HERE THAT THE SAME PRESSURE WILL EXIST UPSTREAM PV 649.
2. VALVE PV649 SHALL HAVE A STEAM TEMPERATURE OVERRIDE CAPABILITY TO PREVENT FLASH TANK STEAM WITH TEMPERATURES > 660°F FROM ENTERING THE DEAERATOR
3. DOWNSTREAM (DEAERATOR) PRESSURE SHALL BE WITHIN THE RANGE OF 20 - 50 psia.
4. MAX SHUTOFF PRESSURE = 380psia - 20psia = 360 psia

MIN DEAERATOR PRESS

MAX UPSTREAM PRESSURE DURING OPERATION

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VALVE PV 649 (PV-647B)
STEAM DUTY
C_v CHECK

$\dot{m}$	6285 LB/HR	800 LB/HR
P_1	380 psia	380 psia
P_2	50 psia	50 psia
S (DEG SUPHT)	220 °F	220 °F
C_v	10.49	1.335

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CONTROL VALVE DESIGN SHEET

PV 647C

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TAG NO.: PV 636 TS FLASH TANK PRESSURE CONTROL

CUSTOMER: ____

PROJECT NO.: ____

PROJECT: ____

SERVICE: TS FLASH TANK

FLUID: STEAM

REV. NO.	1			
DATE	12/15/79			
BY	JER-(MDAC)			

	FLUID CONDITIONS AT VALVE INLET PRESS. PSIA	TEMP. °F	DENSITY #/FT³ OR S.V. FT³/#	VISC., c_p or SSU	VALVE △ P PSI	SYSTEM FRICTION LOSS PSI	APPROX. DESIRED C_v
FLOW #/HR, GPM, SCFM							
XIMUM 30822	150 SEE NOTE 1	358	3.015		SEE NOTE 2		
ESIGN 12500	150 SEE NOTE 1	358	3.015		SEE NOTE 2		
INIMUM 605	150 SEE NOTE 1	358	3.015		SEE NOTE 2		

ax. Design Temp.: 535 (NOTE 4) °F, Max. Design Press.: 180 PSIA
ax. Shut-Off Press.: 130 (SEE NOTE 3) PSI
alve Service: OPEN/CLOSE ☐ MODULATION ☒

s Flashing Expected in Valve? YES ☐ NO ☒

ipe Size and Schedule: ____ , Pipe Material: ____
pprox. Valve Body Size: ____ INCHES
ody Type: ____

Valve Characteristic: Linear ☐ Equal Percentage ☒
Quick Opening ☐ Other: 50:1 TURNDOWN

s Tight Shut-Off Required? YES ☐ NO ☐
llowable Leakage: ____
s Handjack or Handwheel Required? YES ☐ NO ☐
pecial Steam Packing Considerations: ____

alve Action On Loss of Power: Locks in Pos. ☐ Opens ☐ Closes ☒
alve Action On Loss of Power air/or sensing fluid Opens ☐ Closes ☒

orm No. : Date: 12/15/79

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12/14/79
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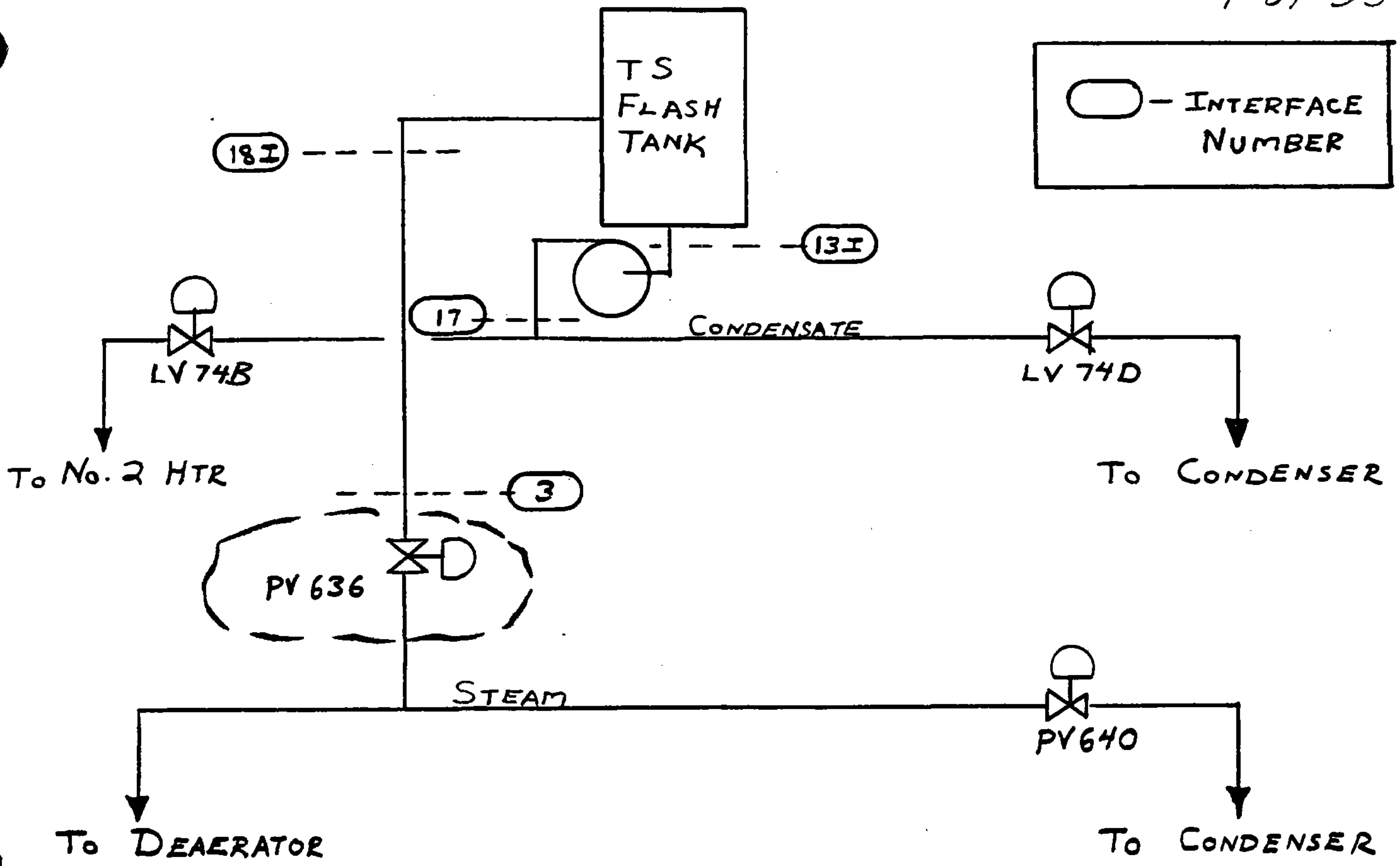

PV 636 NOTES

1. VALVE PV 636 CONTROLS TS FLASH TANK PRESSURE TO 150 psia. THE INLET PRESSURE SPECIFIED FOR THE VALVE (150psia) IGNORES LINE LOSSES BETWEEN THE FLASH TANK AND CONTROL VALVE.

2. VALVE DOWNSTREAM PRESSURE CAN BE ANYWHERE IN THE RANGE OF 20-50psia DEPENDING ON CONDITIONS IN THE DEAERATOR.

3. MAX SHUTOFF PRESSURE = 150psia - 20psia
   MIN DEAERATOR
   FLASH TANK PRESSURE

4. A MAXIMUM VALVE TEMPERATURE CONDITION EXISTS WHEN STEAM GENERATOR STARTUP FLOWS ONLY PASS INTO THE THERMAL STORAGE FLASH TANK (SEE INTERFACES 82I+83I=12I) OR WARMUP BLEEDS FROM 7I AND 8I ENTER THE FLASH TANK THROUGH 7IA (ASSUMING BLEED STEAM ORIGINATES FROM TS — 530°F 400psia NOMINAL).

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CONTROL VALVE DESIGN SHEET

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CUSTOMER: ______

PROJECT NO.: ______

PROJECT: ______

TAG NO.: PV 640 TS FLASH TANK PRESSURE CONTROL To CONDENSER

SERVICE: TS FLASH TANK

FLUID: STEAM

REV. NO.	1			
DATE	12/15/79			
BY	JER. (MDAC)			

	FLUID CONDITIONS AT VALVE INLET				VALVE	SYSTEM FRICTION LOSS	APPROX. DESIRED C_v
	PRESS.	TEMP.	DENSITY $\#/FT^3$ OR S.V. [✓ $FT^3/\#$]	VISC., c_p or SSU	ΔP		
FLOW [✓ #/HR], GPM, SCFM	PSIA	°F			PSI	PSI	
XIMUM 30822	50 SEE NOTE 1	320	9.038		SEE NOTE 2		
DESIGN 12500	50 SEE NOTE 1	320	9.038		SEE NOTE 2		
MINIMUM 605	50 SEE NOTE 1	320	9.038		SEE NOTE 2		

Max. Design Temp.: 520 (SEE NOTE 3) °F, Max. Design Press.: 70 (SEE NOTE 4) PSIA
Max. Shut-Off Press.: 50 PSI
Valve Service: OPEN/CLOSE ☐ MODULATION ☒

Is Flashing Expected in Valve? YES ☐ NO ☒

Pipe Size and Schedule: ______, Pipe Material: ______
Approx. Valve Body Size: ______ INCHES
Body Type: ______

Valve Characteristic: Linear ☐ Equal Percentage ☒
Quick Opening ☐ Other: HIGH TURNDOWN

Is Tight Shut-Off Required? YES ☐ NO ☐
llowable Leakage: ______
Is Handjack or Handwheel Required? YES ☐ NO ☐
Special Steam Packing Considerations: ______

alve Action On Loss of Power: Locks in Pos. ☐ Opens ☐ Closes ☒
Valve Action On Loss of Power air/or sensing fluid Opens ☐ Closes ☒

orm No. : Date: 12/15/79

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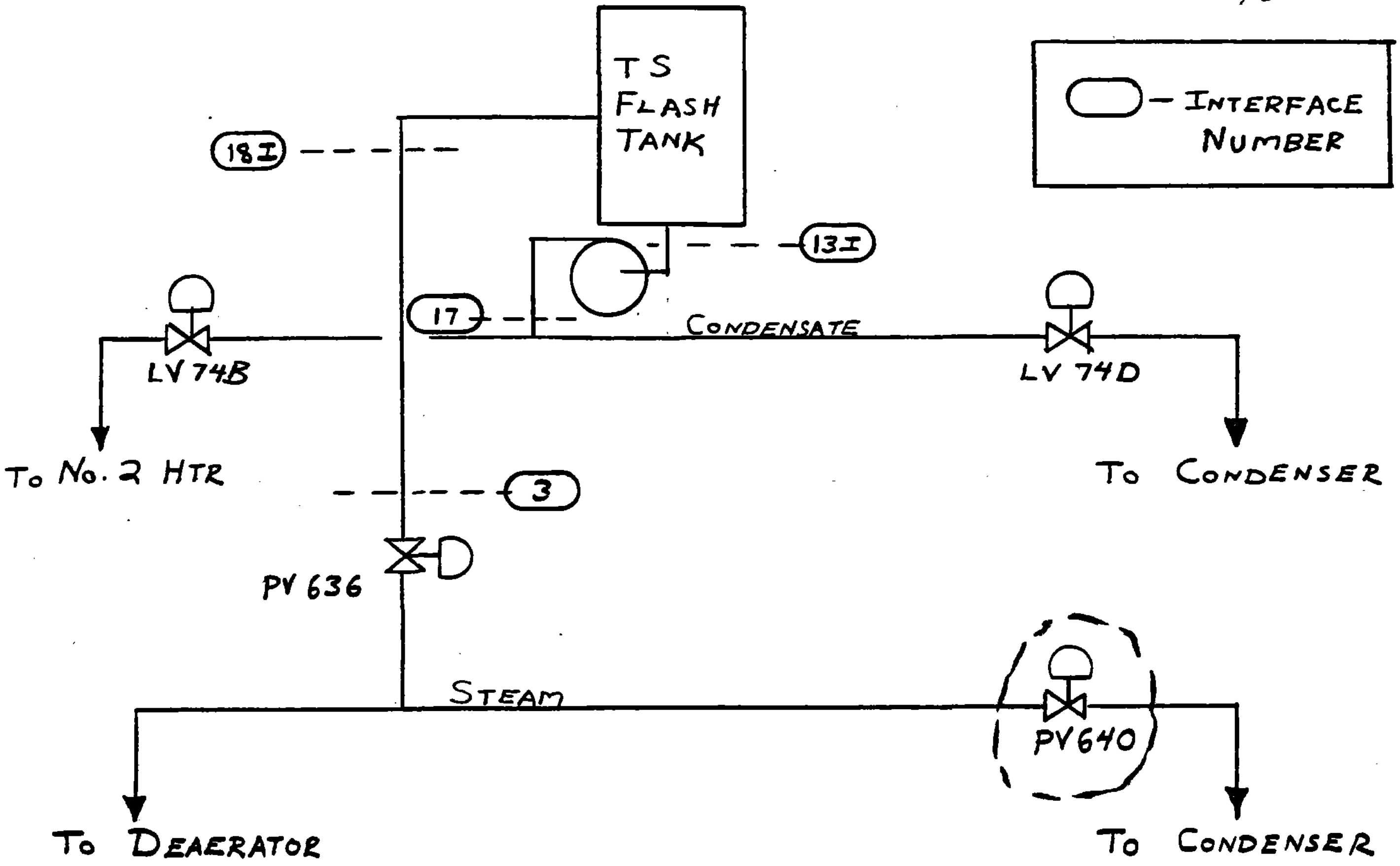

PV 640 NOTES

1. VALVE PV640 CONTROLS UPSTREAM STEAM PRESSURE TO 50 PSIA (MAX DEAERATOR VALUE) OVER ENTIRE FLOW RANGE

2. PRESSURE ON THE DOWNSTREAM SIDE EQUALS CONDENSER PRESSURE + LINE LOSSES. IF A DOWNSTREAM ORIFICE IS USED, A HIGHER VALVE BACK PRESSURE WILL EXIST DURING HIGH FLOW PERIODS.

3. DESIGN TEMP AT INTERFACE 3 AS REDUCED BY THROTTLING PRESSURE TO 70 PSIA (ASSUMED DEAERATOR RELIEF VALVE SET POINT).

4. ASSUMED DEAERATOR RELIEF VALVE SET POINT

IVISION USAGE					
M	P	PP	SH	FI	SP

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CONTROL VALVE DESIGN SHEET PY-1000

ISSUED
REVISED

CUSTOMER: ____________

PROJECT NO.: ____________

PROJECT: ____________

TAG NO.: (V-5) RS FLASH TANK To CONDENSER DUMP DESUPERHEATER

SERVICE: RS FLASH TANK

FLUID: STEAM

REV. NO.	1			
DATE	12/15/79			
BY	JER. (MDAC)			

	FLUID CONDITIONS AT VALVE INLET				VALVE	SYSTEM	APPROX.
	PRESS.	TEMP.	DENSITY	VISC.,		FRICTION	DESIRED
FLOW [✓ #/HR], GPM, SCFM	PSIA	°F	#/FT³ OR S.V. [✓ FT³/#]	c_p or SSU	△ P PSI	LOSS PSI	C_v
XIMUM 40000	380 SEE NOTE 1	960 SEE NOTE 2	1.753		SEE NOTE 4		
ESIGN 40000	380 SEE NOTE 1	585	1.53		SEE NOTE 4		
INIMUM 4000	380 SEE NOTE 1	439	1.222		SEE NOTE 4		

ax. Design Temp.: 960 °F, Max. Design Press.: 600 PSIA
ax. Shut-Off Press.: 380 (SEE NOTE 3) PSI
alve Service: OPEN/CLOSE ☐ MODULATION ☒

s Flashing Expected in Valve? YES ☐ NO ☒

ipe Size and Schedule: ____________ , Pipe Material: ____________
pprox. Valve Body Size: ____________ INCHES
ody Type: ____________

Valve Characteristic: Linear ☐ Equal Percentage ☐
Quick Opening ☐ Other: MODIFIED PARABOLIC

s Tight Shut-Off Required? YES ☐ NO ☐
llowable Leakage: ____________
s Handjack or Handwheel Required? YES ☐ NO ☐
pecial Steam Packing Considerations: ____________

alve Action On Loss of Power: Locks in Pos. ☐ Opens ☐ Closes ☒
alve Action On Loss of Power air/or sensing fluid Opens ☐ Closes ☒

orm No. : Date: 12/15/79

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12/14/79
JER
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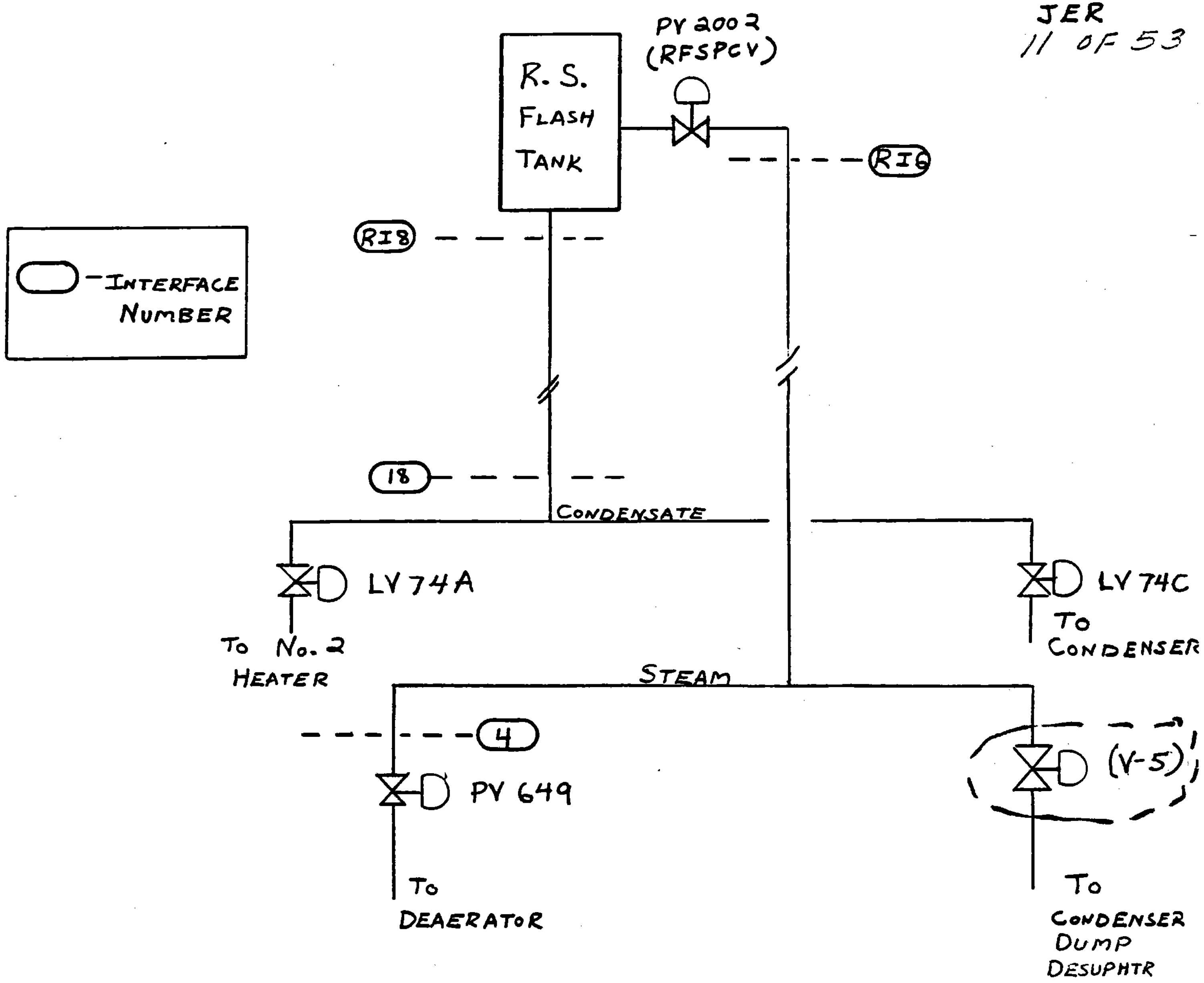

(V-5) NOTES

1. VALVE (V-5) CONTROLS UPSTREAM PRESSURE TO 380 psia OVER ENTIRE FLOW RANGE
2. 960°F IS MAX TEMPERATURE COMING THROUGH INTERFACE RI6
3. MAX SHUTOFF PRESSURE = 380 psia − ~0 psia = 380 psia
   - ~0 psia – CONDENSER PRESSURE -
   - 380 psia – UPSTREAM PRESSURE
4. THE MAXIMUM ΔP ACROSS THE VALVE IS AS PRESENTED IN "NOTE 3" ABOVE. THE USE OF A DOWNSTREAM ORIFICE AND/OR A NONZERO VALUE FOR PRESSURE DROP THROUGH THE CONDENSER DUMP DESUPERHEATER WILL RESULT IN A HIGHER BACK PRESSURE (ESPECIALLY AT HIGH FLOW) WHICH WILL RESULT IN A REDUCED VALVE ΔP.

VALVE PV 1000

STEAM DUTY

C_V CHECK

$\dot{m}$	40,000 LB/HR	4000 LB/HR
P_1	380 psia	380 psia
P_2	5 psia (?) (SMALL)	5 psia (?) (SMALL)
S (DEG SUPHT)	520°F	520°F
C_V	78.89	7.89

IVISION USAGE					
M	P	PP	SH	FI	SP

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Engineering Standard

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ISSUED
REVISED

CONTROL VALVE DESIGN SHEET

CUSTOMER: ____________

TAG NO.: CONDENSER DUMP PRESSURE REDUCING DRAG VALVE

PROJECT NO.: ____________

SERVICE: CONDENSER DUMP

PROJECT: ____________

FLUID: STEAM

PV-1001

REV. NO.	1			
DATE	12/16			
BY	JER-(MDAC)			

	FLUID CONDITIONS AT VALVE INLET				VALVE	SYSTEM	APPROX.
	PRESS.	TEMP.	DENSITY #/FT^3 OR S.V. [✓ FT^3/#]	VISC., c_p or SSU	Δ P	FRICTION LOSS	DESIRED C_v
FLOW [✓ #/HR], GPM, SCFM	PSIA	°F			PSI	PSI	
XIMUM 112,300 / 130 000	1465 / 1465	950 / 650	.534 / .3578		1365 (NOTE 1)		
DESIGN							
MINIMUM 6500	380 / 1465	440 / 950	1.222 / .534		380 (NOTE 2)		

ax. Design Temp.: 1010 (NOTE 3) °F, Max. Design Press.: 1780 (NOTE 3) PSIA

x. Shut-Off Press.: 1465 (NOTE 4) PSI

Valve Service: OPEN/CLOSE ☐ MODULATION ☒

s Flashing Expected in Valve? YES ☐ NO ☒

Pipe Size and Schedule: ____________ , Pipe Material: ____________

pprox. Valve Body Size: ____________ INCHES

ody Type: ____________

Valve Characteristic: Linear ☐ Equal Percentage ☐

Quick Opening ☐ Other: ____________

s Tight Shut-Off Required? YES ☐ NO ☐

llowable Leakage: ____________

Is ndjack or Handwheel Required? YES ☐ NO ☐

ACTUATION TIMES (FULL STROKE) ≃ .2 SEC

Special Steam Packing Considerations: ____________

alve Action On Loss of Power: Locks in Pos. ☐ Opens ☐ Closes ☒

Valve Action On Loss of Power air/or sensing fluid Opens ☐ Closes ☒

rm No. : Date: 12/16/79

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12/16/79

CONDENSER DUMP PRESSURE REDUCING DRAG VALVE 14 OF 50

(DESIGN NOTES)

1. VALVE $\Delta P = 1365$ psi BASED ON 1465 psia UPSTREAM STEAM PRESSURE (PRESSURE CONTROL POINT) — AN ASSUMED 100 psia DOWNSTREAM PRESSURE. THIS VALUE NEGLECTS FLOW LOSSES AS THE STEAM PASSES THROUGH THE DOWNSTREAM DESUPERHEATER.

2. VALVE $\Delta P = 380$ psia BASED ON 380 psia UPSTREAM PRESSURE — CONDENSER PRESSURE (~ 0).

3. BASED ON "DESIGN" INTERFACE CONDITIONS SPECIFIED AT INTERFACES #1 AND #11

4. MAX SHUTOFF PRESSURE (1465 psia) BASED ON A TRIP CONDITION WITH THE DOWNSTREAM PRESSURE AT THE CONDENSER PRESSURE. NOTE THAT A HIGHER SHUTOFF PRESSURE SHOULD POTENTIALLY BE CONSIDERED DUE TO "STEAM HAMMER" EFFECTS THAT COULD OCCUR DURING A TRIP CONDITION.

FOR REFERENCE DESIGN INFORMATION SEE <u>CONDENSER DUMP NETWORK</u> DESIGN DATA P. 1-3

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LAG TIME FOR CONDENSER DUMP VALVE

500 FT 6" DOUBLE EXTRA STRONG
FLOW AREA = .1308 FT^2
} $V = 65.4\ FT^3$
$M = 125.8\ LB$ @ $T=0$

SAFETY VALVES LIFT AT 1780 psia

ASSUME $\overline{P}_{INITIAL}$ = 1500 psia 960°F $v = .520\ ft^3/LB$

ASSUME $\dot{m}_s = 115000\ LB/HR = 31.94\ LB/SEC$

ΔT (Sec)	INCREMENTAL ACCUMULATION (LB)	CUMULATIVE ACCUMULATION (LB)	(v)	PRESSURE AT END OF INTERVAL (PSIa)
.1	1.6	127.4	.513	1516
.2	3.2	130.6	.5007	1550
.3	3.2	133.8	.4888	1585
.4	3.2	136.9	.4777	1624
.5	3.2	140.2	.4664	1658
.6	3.2	143.4	.4560	1692
.7	3.2	146.6	.446	1725
.8	3.2	149.8	.4366	1758

1/12/80
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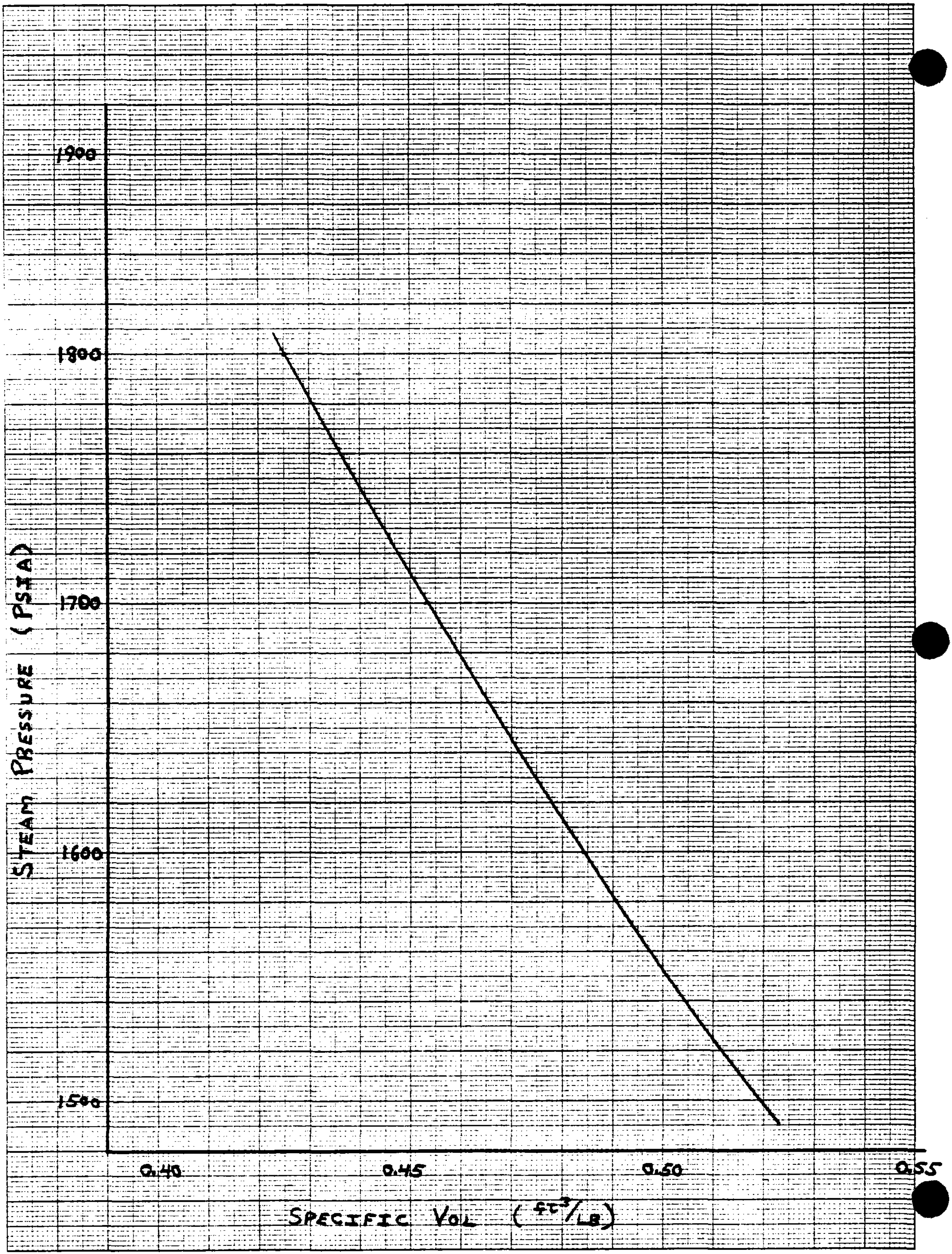

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MEMORANDUM

A3-234-EP-JAG-75
22 January 1980

To: E. J. Riel

Subject: CONDENSER DUMP VALVE ACTUATION REQUIREMENTS

Copies to: R. M. Berry, R. G. Riedesel, J. E. Raetz, G. C. Coleman,
M. L. Joy, A. B. Smee, MDAC; R. Bicknell, Stearns-Rogers; File

This memorandum presents the analysis of the Condenser Dump Valve response requirements. The goal is to determine the necessary valve response to prevent steam header pressure from exceeding 1715 psi which is 50 psi below vent valve actuation pressure.

The Receiver Subsystem Digital Simulation was used in this analysis, and was modified to eliminate unnecessary thermodynamics.

SUMMARY OF RESULTS

The results of the analysis are summarized as a sensitivity plot of Maximum Steam Header Pressure versus Valve Time Constants (Figure I).. The plot shows a vent valve relief limit of 1765 psi with a 50 psi margin as the criteria for valve selection.

Pressure transient histories for a 0.8* second valve, with both proportional and proportion plus integral controllers are shown in Figure II and III respectively.

Based on the results in Figure I, it can be seen that a "faster" valve will minimize the magnitude of the pressure overshoot. Also, a proportional plus integral controller will provide the desireable characteristic of returning the pressure to the setpoint value.

RECOMMENDATIONS

From the sensitivity plot and the pressure transient histories of Figures I through III, it was determined that a 0.8* second valve with proportional

---

* Response time to 90% of valve stroke.

plus integral control will provide acceptable pressure control in the event of a turbine trip.

ANALYSIS AND SUPPORTING DATA

A pictorial description of the system configuration is shown in Figure IV. Flow from 18 boiler panels (WID) enters the steam header and is compared with the downcomer flow (WDD) in a compressibility algorithm which yields specific volume. Pressure in the steam header (P3) is a function of specific volume and enthalpy. Flow in the downcomer is the sum of flow through the Turbine Inlet Valve (WDTV) and flow through the Condenser Dump Valve (WDCDV). Pressure at the condenser dump valve is 87 psi lower than the steam header pressure for approximately rated flow and a 450 ft. Barstow downcomer. For the purpose of this analysis, the turbine inlet valve and the condenser dump valve are considered to be side by side and see the same pressure, PD5.

In the simulation, the turbine inlet valve flow was held constant until 10 seconds and then ramped down to 0.0 lb/sec in 0.1 seconds, simulating a turbine trip. The condenser dump valve actuation was delayed until 0.2 seconds after PD5 reached the setpoint (1565 psi) to simulate worst case digital sampling. A pictorial description of a typical turbine trip scenario is shown in Figure V.

Two condenser dump valve controller configurations were compared. The proportional controller is shown in Figure VI, and the Proportional plus Integral controller is shown in Figure VII. For each controller, four different valves were used with 90% time constants of 0.5, 0.8, 1.0 and 2.0 seconds. Additional runs were made with the proportional plus integral controller and 90% valve time constants of 1.472 and 2.76 seconds. A typical flow history showing the 0.2 second delay is included as Figure VIII.

Additional supporting data in terms of the pressure transient histories for various dump valve actuation times are shown in the attachment.

Please direct any questions or comments to Bob Berry at X3220 or John Gaidelis X3220.

J. A. Gaidelis

J. A. Gaidelis

JAG:lp

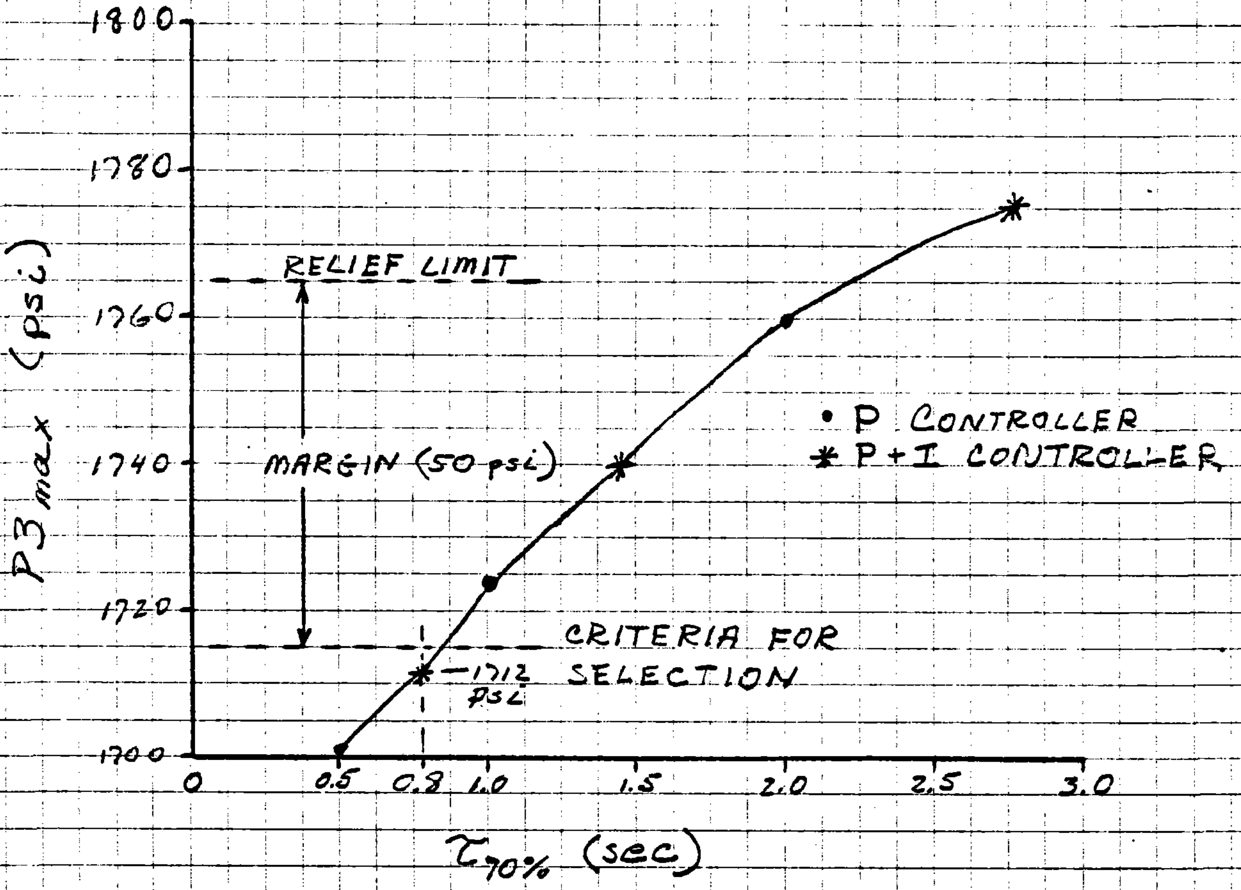

FIGURE I

MAXIMUM STEAM HEADER PRESSURE ($P3_{max}$) VS. VALVE TIME CONSTANT

JAG 01/21/80

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FIGURE II

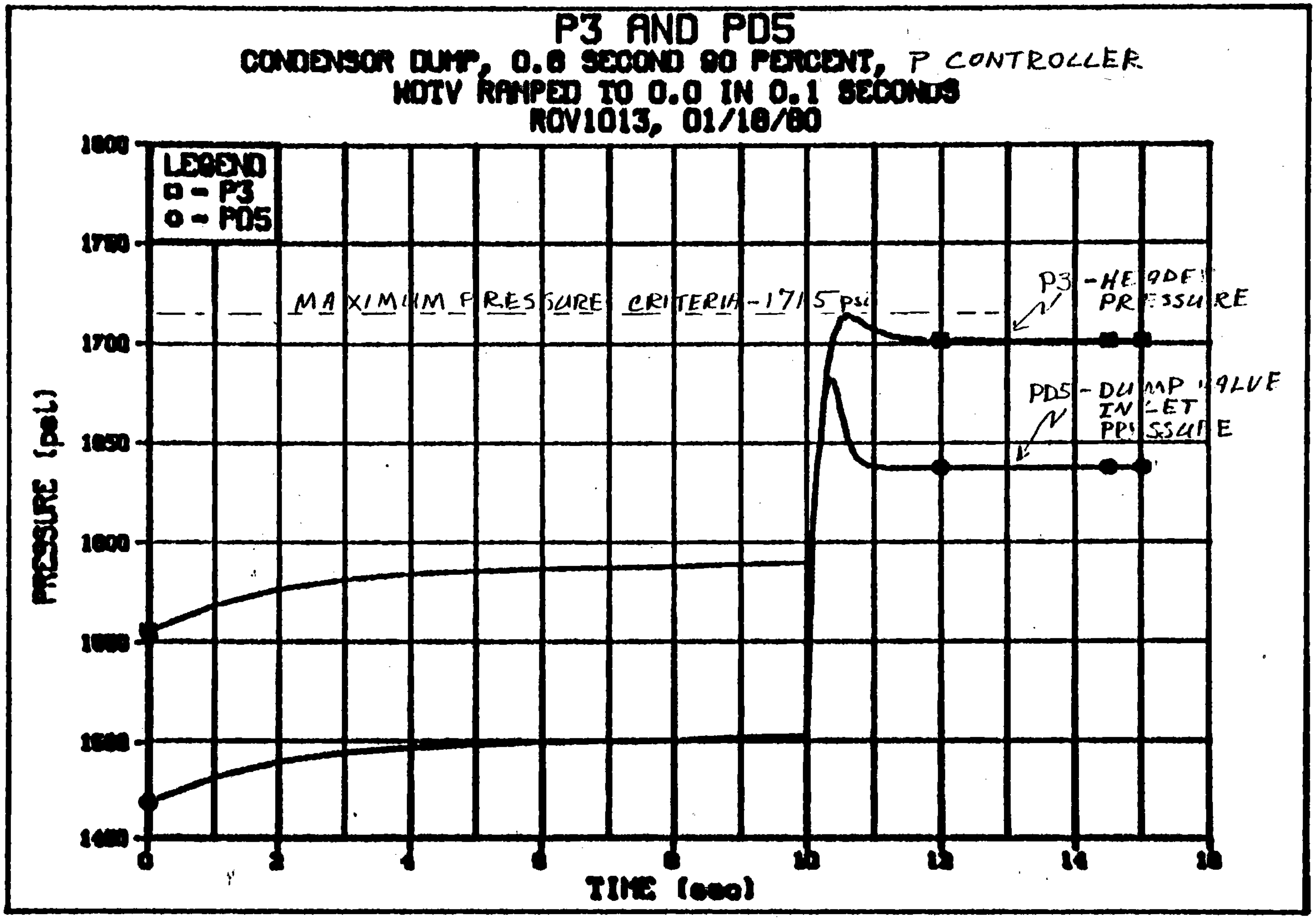
P3 AND PD5
CONDENSOR DUMP, 0.6 SECOND 90 PERCENT, P CONTROLLER
HOTV RAMPED TO 0.0 IN 0.1 SECONDS
ROV1013, 01/18/80

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FIGURE III

P3 AND PD5
CONDENSOR DUMP, 0.8 SECOND 90 PERCENT, P + I CONTROLLER
WDTV RAMPED TO 0.0 LB/SEC IN 0.1 SECONDS
RDV1014, 01/18/80

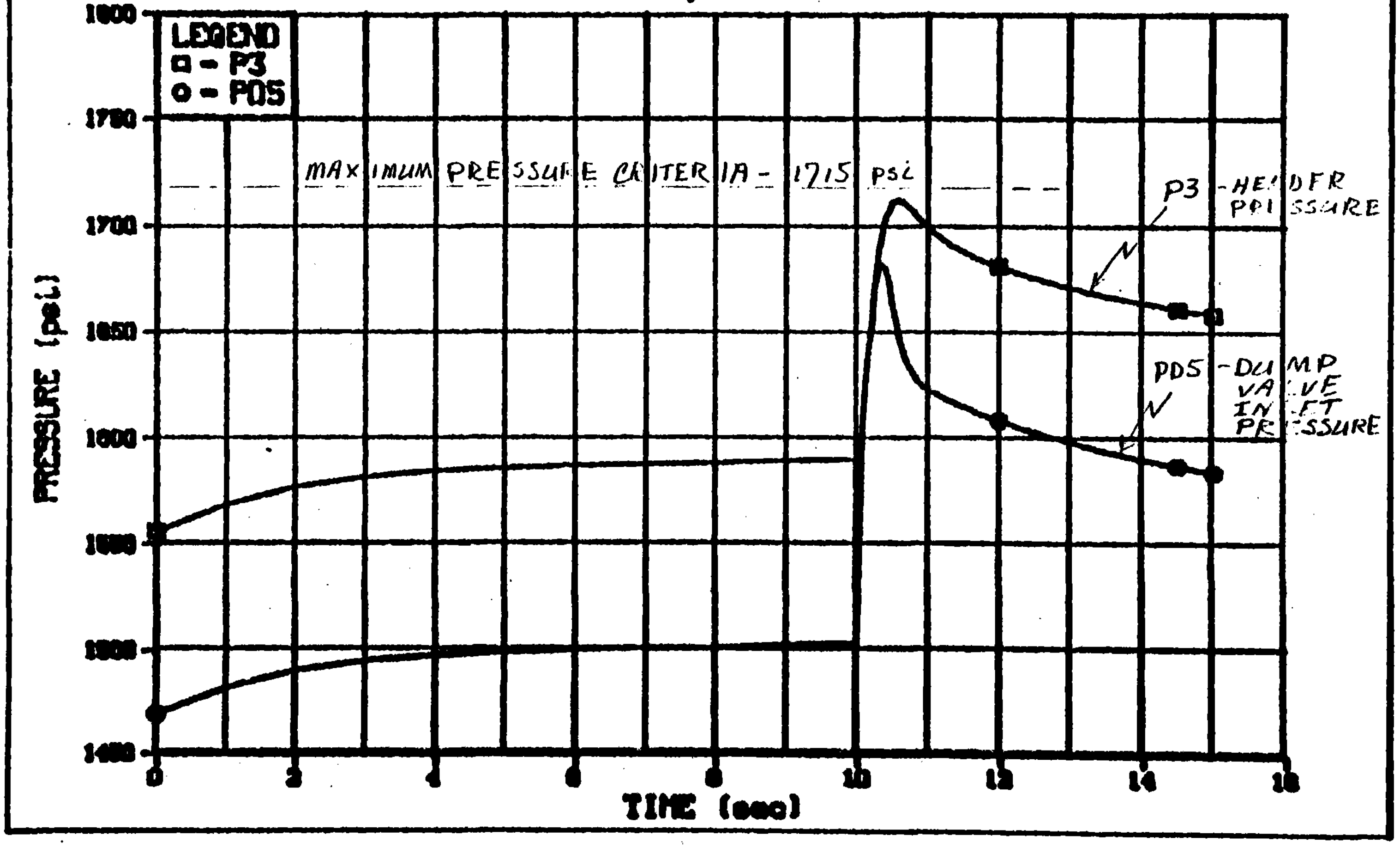
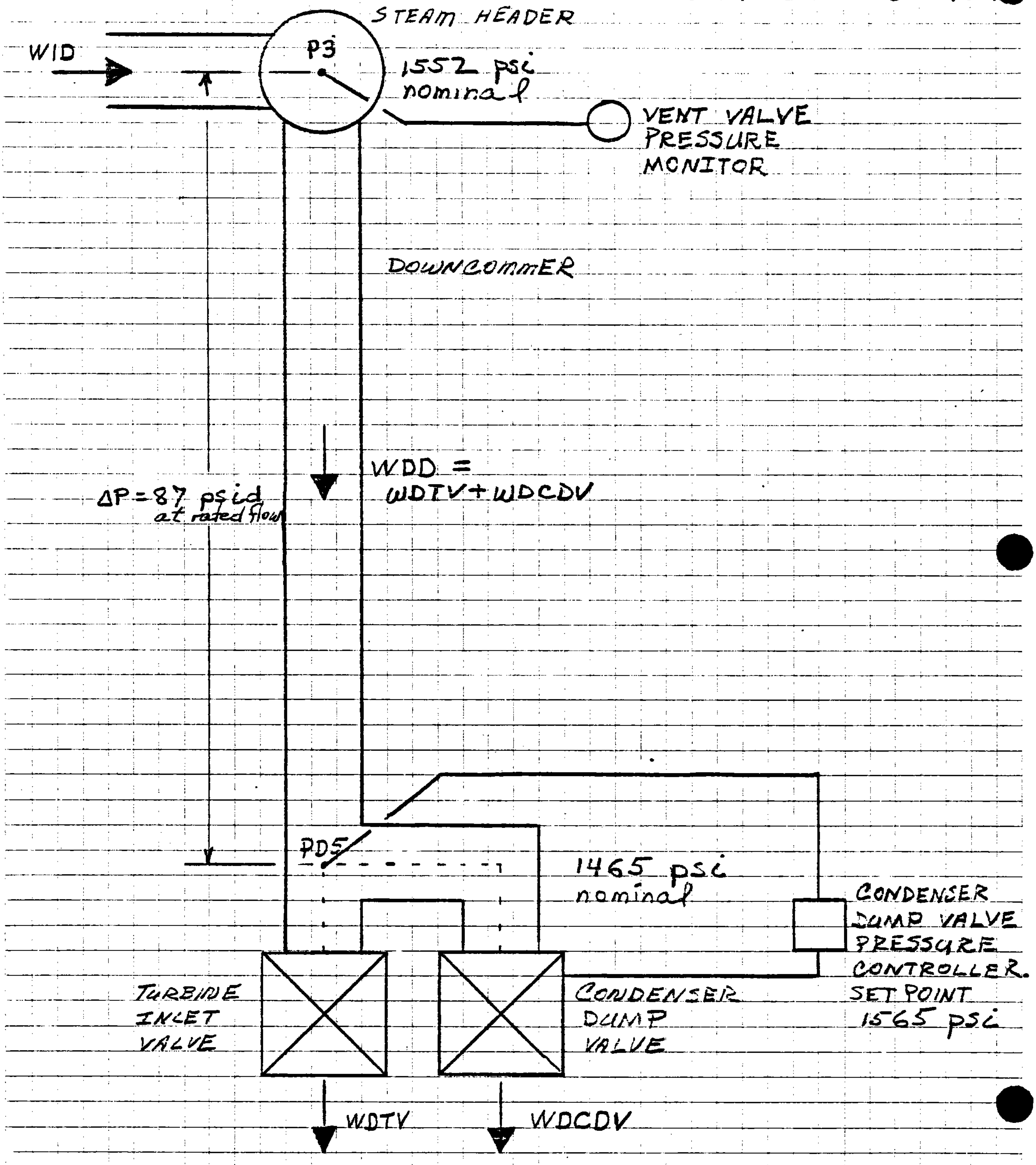


FIGURE IV

TEST SYSTEM CONFIGURATIO



JAG 01/18/80

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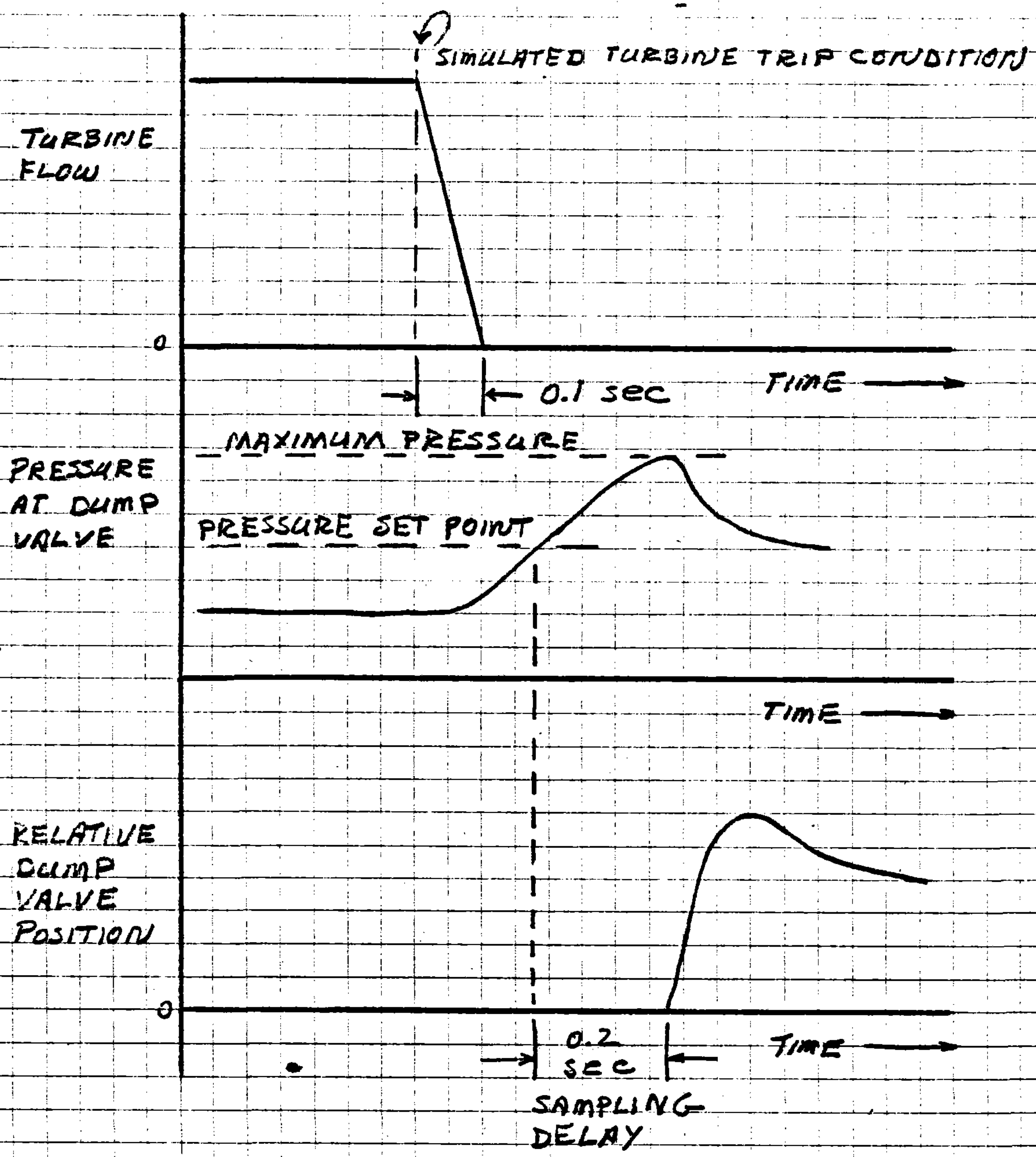

FIGURE V

TYPICAL TURBINE TRIP SCENARIO

FIGURE VI

PROPORTIONAL CONTROLLER WITH 0.8 SECOND - 90% VALVE

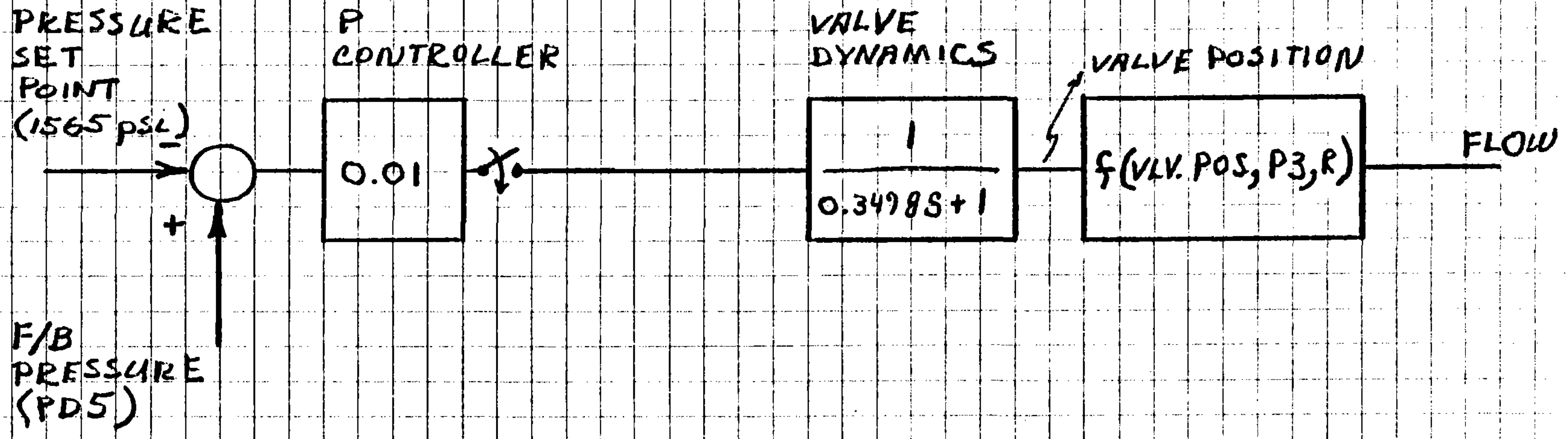

FIGURE VII

PROPORTIONAL +INTEGRAL CONTROLLER WITH 0.8 SECOND - 90% VALVE

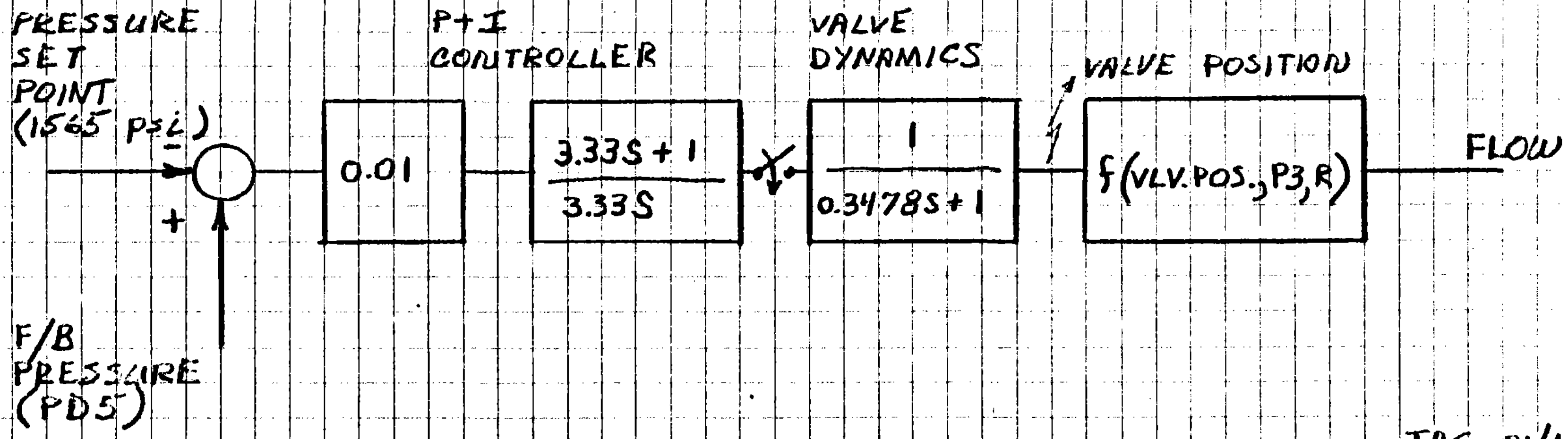

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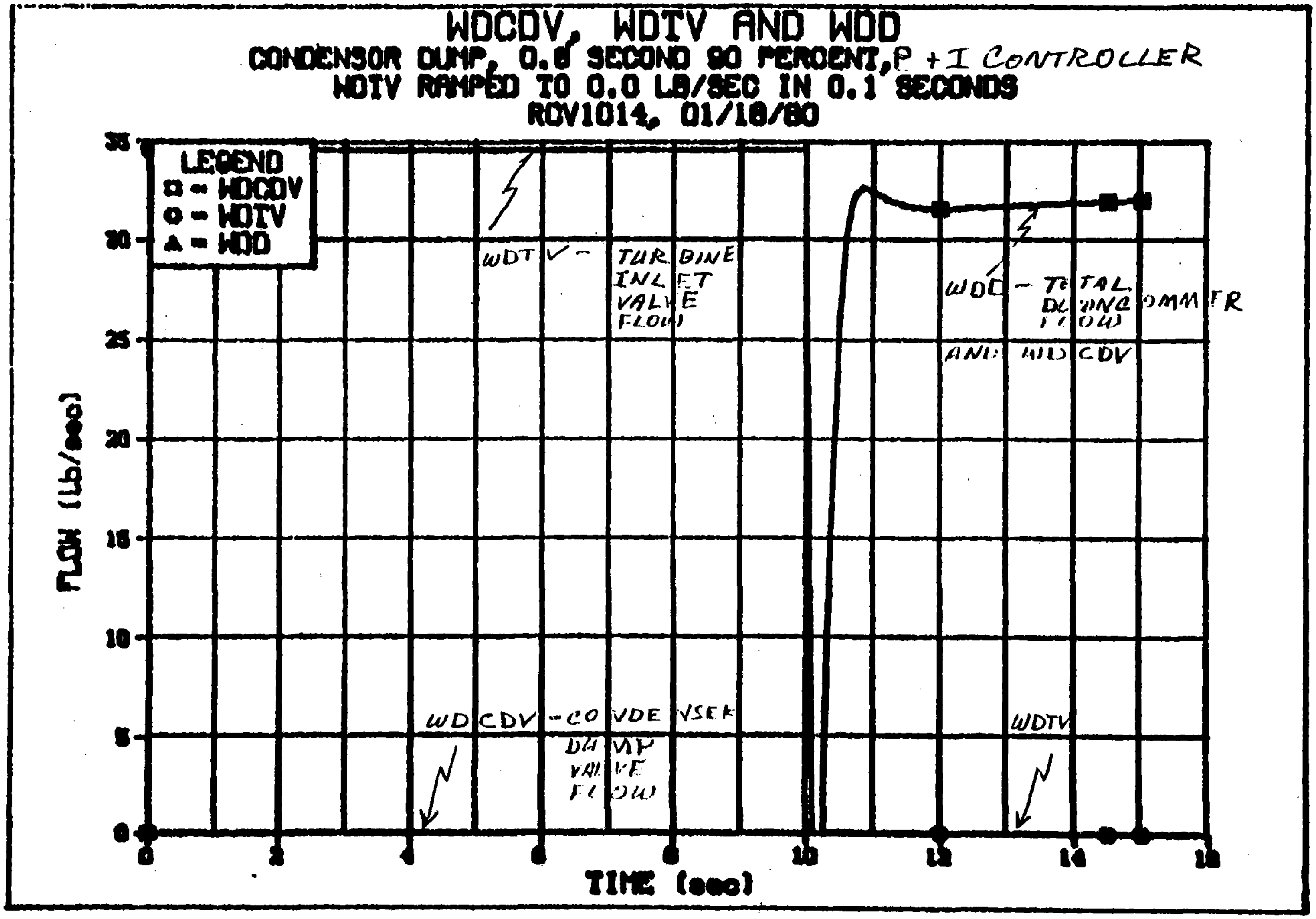
FIGURE VIII


WDCDV, WDTV AND WDD
CONDENSOR DUMP, 0.8 SECOND 90 PERCENT, P + I CONTROLLER
WDTV RAMPED TO 0.0 LB/SEC IN 0.1 SECONDS
RCV1014, 01/18/80

ATTACHMENT

SUPPORTING DATA

FIGURE 1	PRESSURE HISTORY	VALVE ACTUATION TIME	0.5
FIGURE 2	PRESSURE HISTORY	VALVE ACTUATION TIME	1.0
FIGURE 3	PRESSURE HISTORY	VALVE ACTUATION TIME	1.472
FIGURE 4	PRESSURE HISTORY	VALVE ACTUATION TIME	2.0
FIGURE 5	PRESSURE HISTORY	VALVE ACTUATION TIME	2.76

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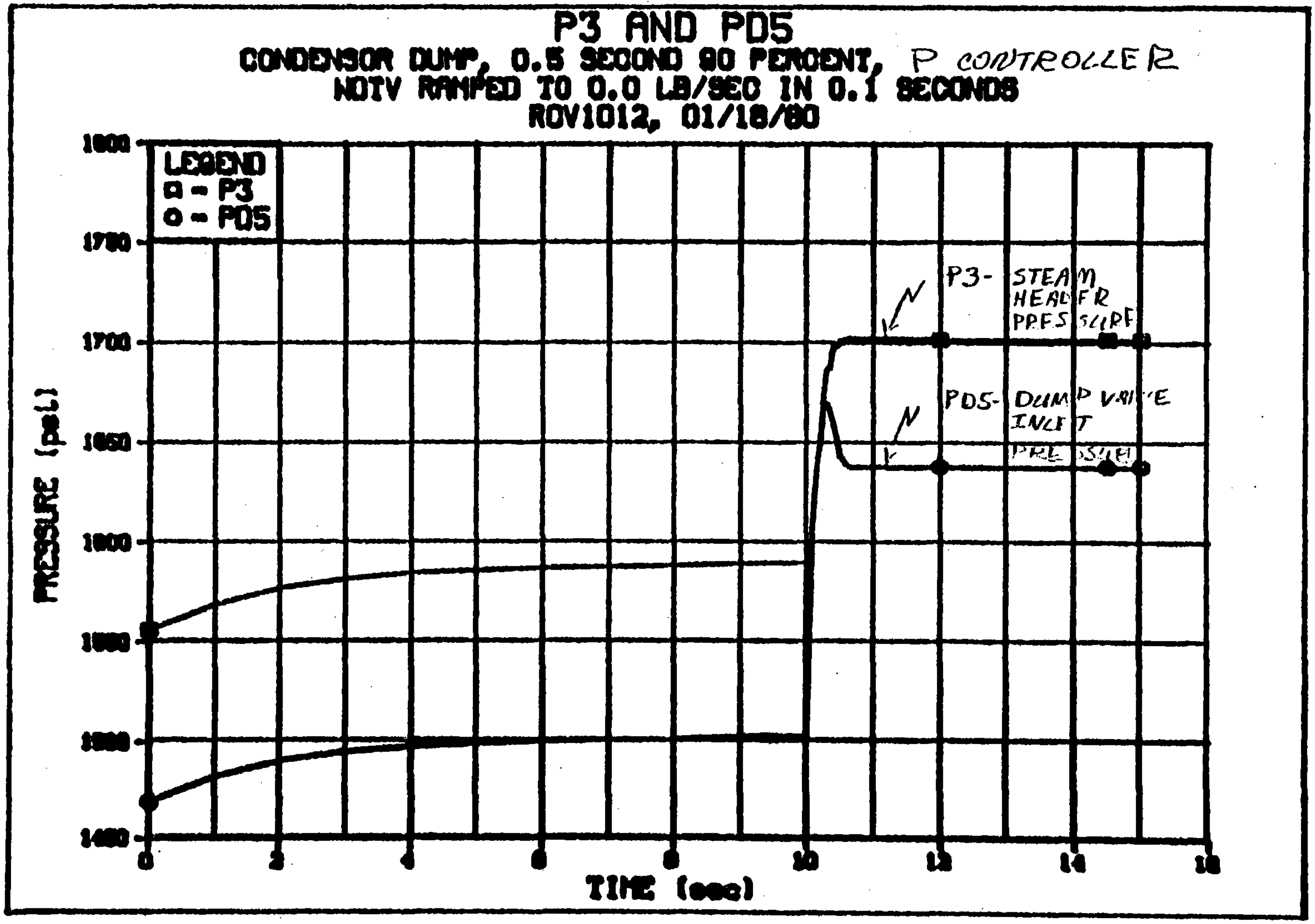
FIGURE 1



P3 AND PD5
CONDENSOR DUMP, 0.5 SECOND 90 PERCENT, P CONTROLLER
NOTV RAMPED TO 0.0 LB/SEC IN 0.1 SECONDS
ROV1012, 01/18/80

FIGURE 2

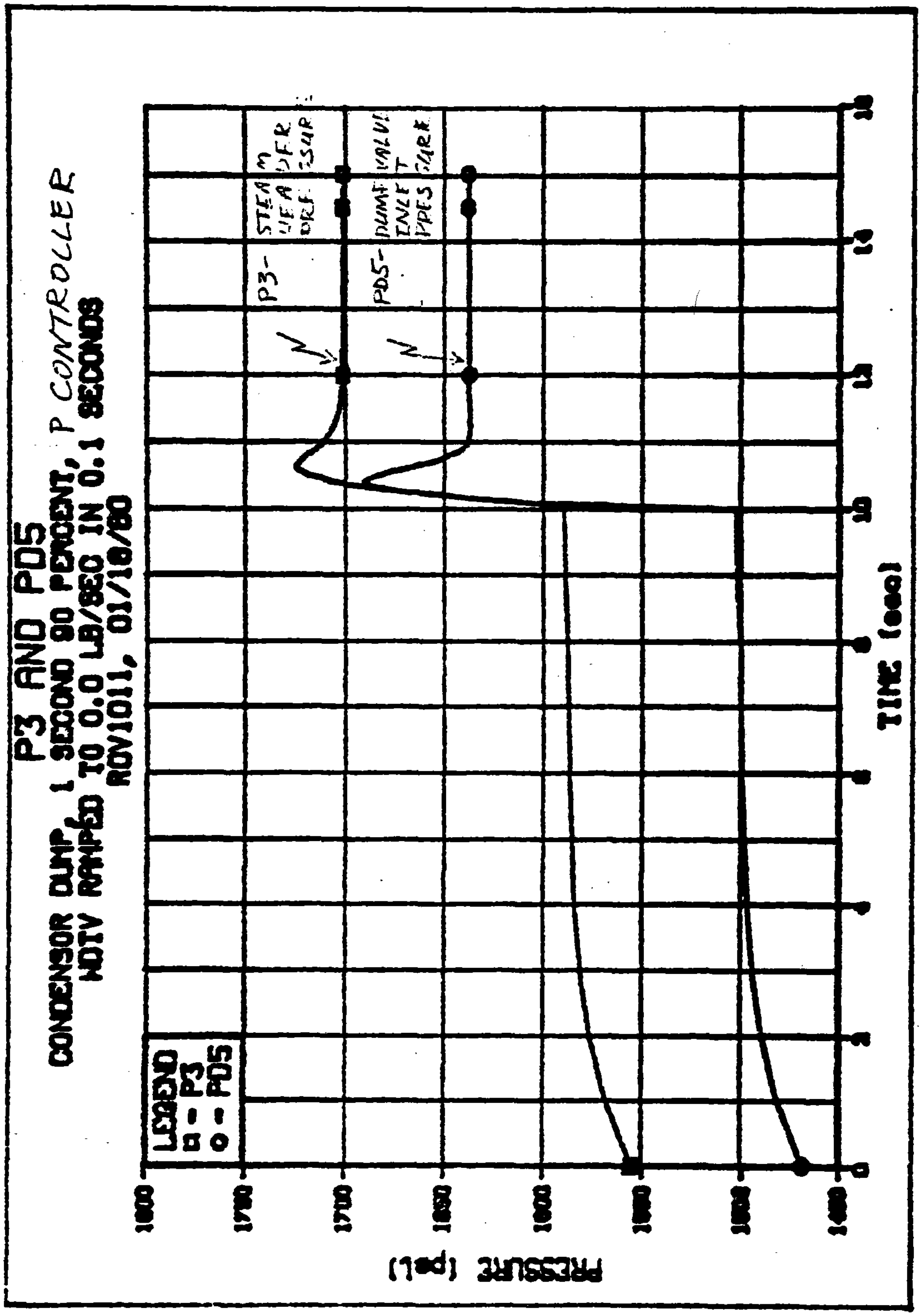

P3 AND PD5
CONDENSOR DUMP, 1 SECOND 90 PERCENT, P CONTROLLER
WDTV RAMPED TO 0.0 LB/SEC IN 0.1 SECONDS
RDV1011, 01/18/80
LEGEND
□ = P3
○ = PD5
P3- STEAM HEADER PRESSURE
PD5- DUMP VALVE INLET PRESSURE
PRESSURE (psi)
1800
1750
1700
1650
1600
1550
1500
1450
1400
TIME (sec)
0
2
4
6
8
10
12
14
16

FIGURE 3

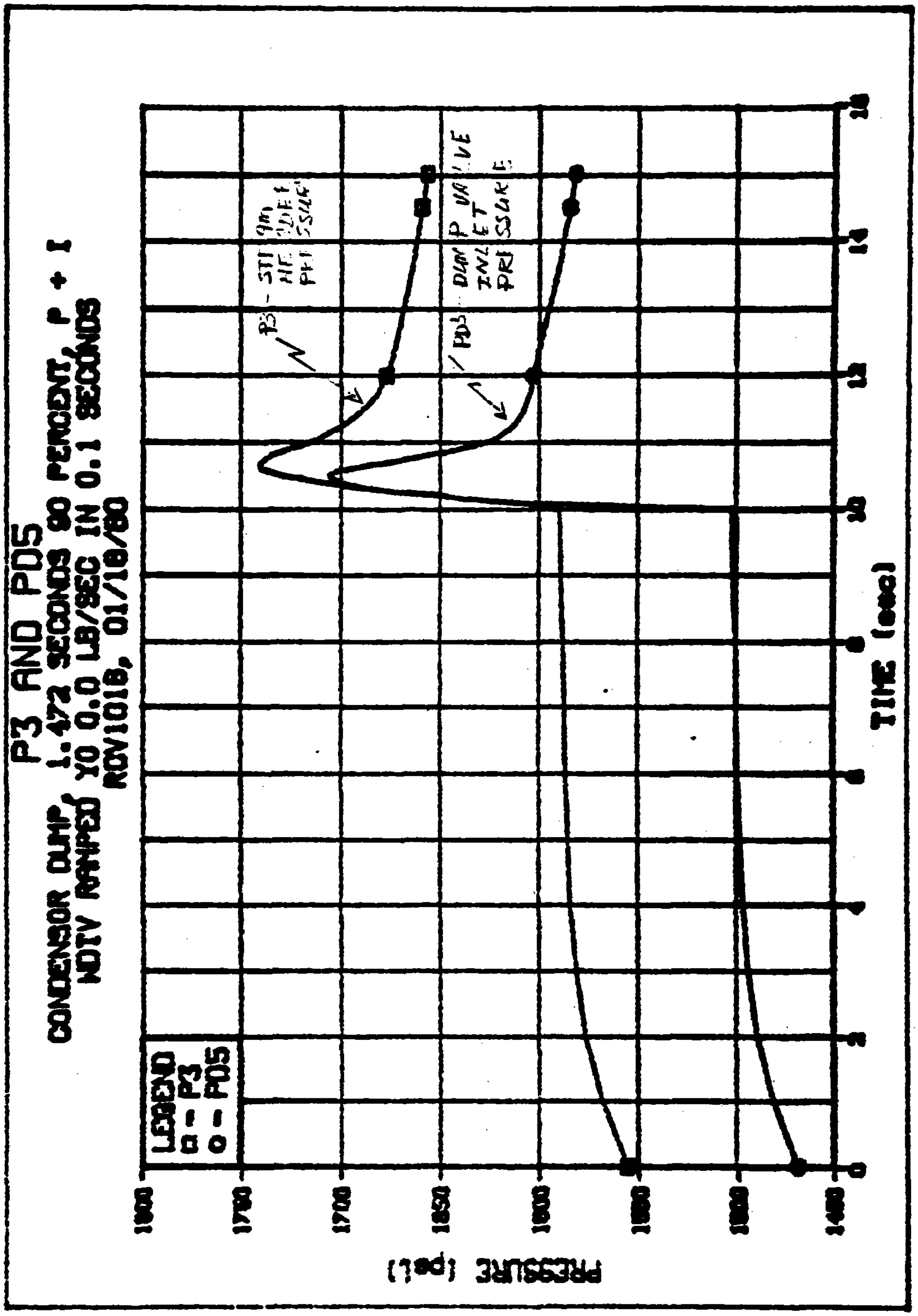
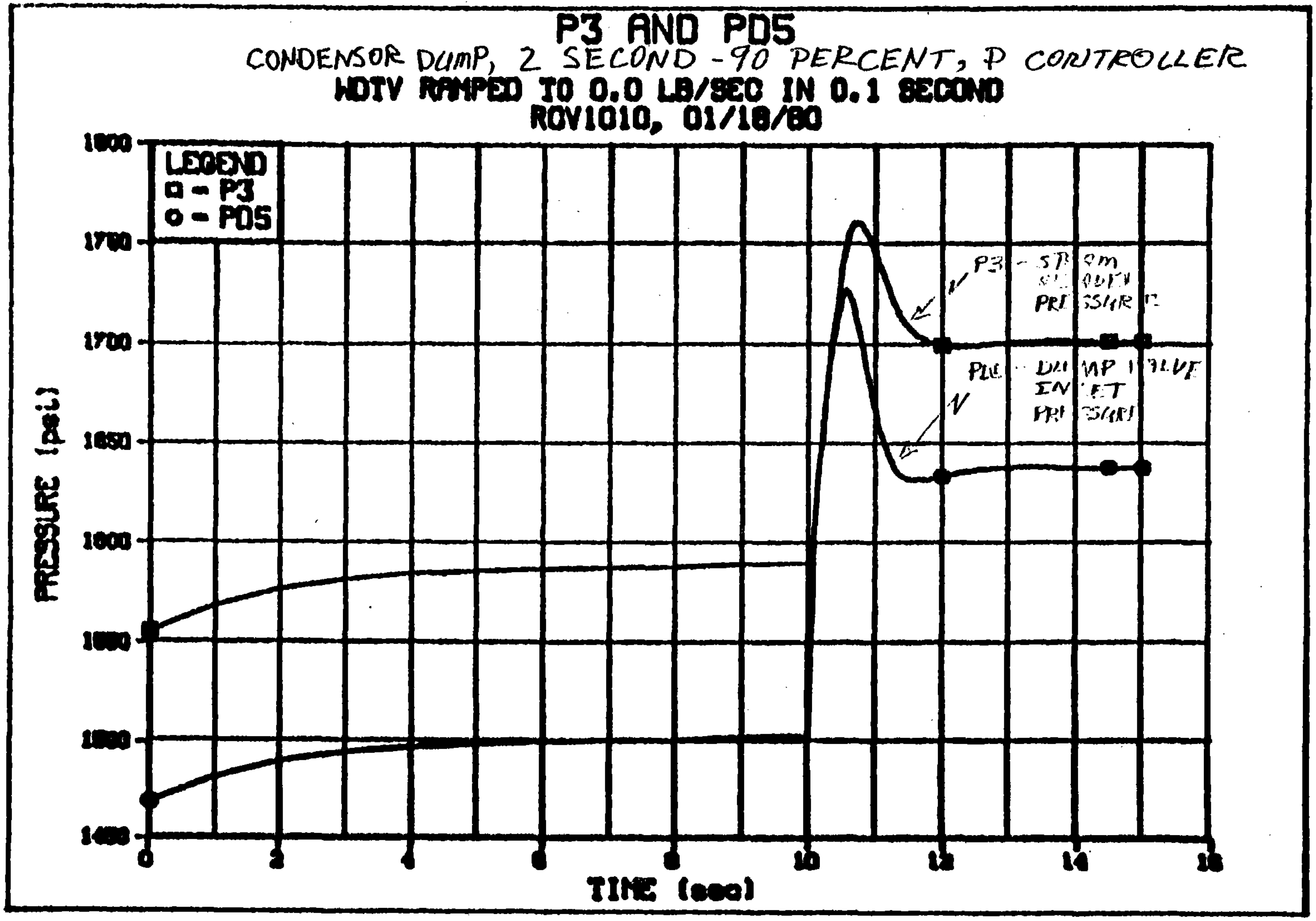

P3 AND PD5
CONDENSOR DUMP, 1.472 SECONDS 90 PERCENT, P + I
NDTV RAMPED YO 0.0 LB/SEC IN 0.1 SECONDS
RDV1018, 01/18/80
LEGEND
□ = P3
○ = PD5
P3 - STEAM HEADER PRESSURE
PD5 - DUMP VALVE INLET PRESSURE
PRESSURE (psi)
1800
1750
1700
1650
1600
1550
1500
1450
1400
TIME (sec)
0
2
4
6
8
10
12
14
16

FIGURE 4



P3 AND PD5

CONDENSOR DUMP, 2 SECOND -90 PERCENT, P CONTROLLER

WDTV RAMPED TO 0.0 LB/SEC IN 0.1 SECOND

ROV1010, 01/18/80

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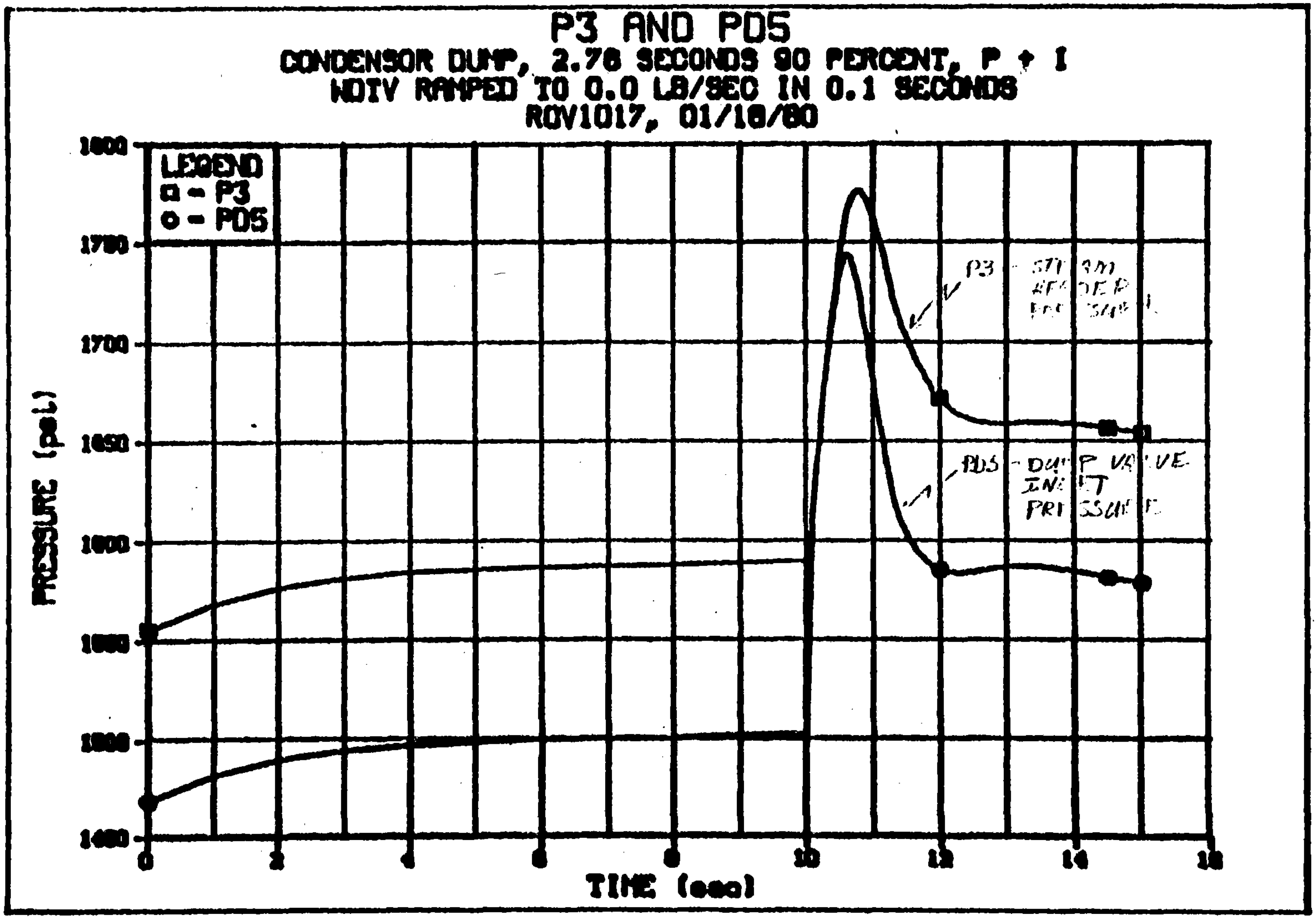
FIGURE 5



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DIVISION USAGE					
MM	P	PP	SH	FI	SP

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Company

ISSUED
REVISED

CONTROL VALVE DESIGN SHEET

CUSTOMER: ______

TAG NO.: SPRAY WATER CONTROL VALVE FOR CONDENSER DUMP DESUPERHEATER

PROJECT NO.: ______

SERVICE: CONDENSER DUMP

PROJECT: ______

FLUID: CONDENSATE

TV-1002

REV. NO.	1			
DATE	12/16			
BY	JER (MDAC)			

	FLUID CONDITIONS AT VALVE INLET				VALVE	SYSTEM FRICTION LOSS	APPROX. DESIRED
FLOW [✓ #/HR], GPM, SCFM	PRESS. PSIA	TEMP. °F	DENSITY #/FT³ OR S.V. [✓ FT³/#]	VISC., c_p or SSU	ΔP PSI	PSI	C_v
XIMUM 26372	140	121	.01621		~20		
DESIGN 26372	140	121	.01621		~20		
MINIMUM 170	140	108	.01616		140 (NOTE 1)		

Max. Design Temp.: 135 (NOTE 2) °F,   Max. Design Press.: 160 (NOTE 3) PSIA
Max. Shut-Off Press.: 140 (NOTE 4) PSI
Valve Service: OPEN/CLOSE ☐   MODULATION ☒

Is Flashing Expected in Valve? YES ☐   NO ☒

Pipe Size and Schedule: ______, Pipe Material: ______
Approx. Valve Body Size: ______ INCHES
Body Type: ______

Valve Characteristic: Linear ☐   Equal Percentage ☒
Quick Opening ☐   Other: ______

Is Tight Shut-Off Required? YES ☐   NO ☐
Allowable Leakage: ______
Is Handjack or Handwheel Required? YES ☐   NO ☐
Special Steam Packing Considerations: ______

Valve Action On Loss of Power: Locks in Pos. ☐   Opens ☒   Closes ☐
Valve Action On Loss of Power air/or sensing fluid   Opens ☒   Closes ☐

Form No. :   Date: 78 12/16/79

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SPRAY WATER CONTROL VALVE FOR CONDENSER DUMP DESUPERHEATER

(DESIGN NOTES)

1. $\Delta P = 140$ psi IS BASED ON A 140 psia UPSTREAM PRESSURE AND CONDENSER PRESSURE ~0 psia ON THE DOWNSTREAM SIDE. THIS IGNORES ANY STEAM PRESSURE DROP THROUGH THE DESUPERHEATER OR CONDENSER INLET MANIFOLD WHICH WOULD BE SMALL AT LOW STEAM FLOW.
2. BASED ON AN ASSUMED 5 IN Hg MAX CONDENSER PRESSURE (135 °F SATURATED WATER)
3. MAX DESIGN PRESSURE BASED ON AN ASSUMED 160 psia MAX HOTWELL PUMP OUTLET PRESSURE
4. BASED ON 140 psia UPSTREAM PRESSURE WITH CONDENSER DOWNSTREAM PRESSURE (~0 psia)

DIVISION USAGE

MM	P	PP	SH	FI	SP

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CONTROL VALVE DESIGN SHEET PV-1003

ISSUED
REVISED

CUSTOMER:

PROJECT NO.:

PROJECT:

TAG NO.: (V-11) MAIN STEAM To AUX STEAM — PRESS REDUCING

SERVICE: AUX STEAM

FLUID: STEAM

REV. NO.	1			
DATE	12/16			
BY	JER. (MDAC)			

	FLUID CONDITIONS AT VALVE INLET PRESS.	TEMP.	DENSITY #/FT³ OR S.V. [✓ FT³/#]	VISC., c_p or SSU	VALVE ΔP	SYSTEM FRICTION LOSS	APPROX. DESIRED C_v
FLOW [✓ #/HR.] GPM, SCFM	PSIA	°F			PSI	PSI	
XIMUM 13554. / 9880.	1465/1465	650/950	.3493/.5339		1390		
DESIGN SEE NOTE 1	1465	950	.5339		1390		
MINIMUM SEE NOTE 1	1465	950	.5339		1390		

Max. Design Temp.: 1010 °F, Max. Design Press.: 1780 (SEE NOTE 2) PSIA

Max. Shut-Off Press.: 1410 (NOTE 3) PSI

Valve Service: OPEN/CLOSE ☐ MODULATION ☒

Is Flashing Expected in Valve? YES ☐ NO ☒

Pipe Size and Schedule: , Pipe Material:

Approx. Valve Body Size: INCHES

Body Type:

Valve Characteristic: Linear ☐ Equal Percentage ☐

Quick Opening ☐ Other: MODIFIED PARABOLIC

Is Tight Shut-Off Required? YES ☐ NO ☐

Allowable Leakage:

Is Handjack or Handwheel Required? YES ☐ NO ☐

Special Steam Packing Considerations:

Valve Action On Loss of Power: Locks in Pos. ☐ Opens ☐ Closes ☒

Valve Action On Loss of Power air/or sensing fluid Opens ☐ Closes ☒

Form No. : Date: 80 12/16/79

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JER
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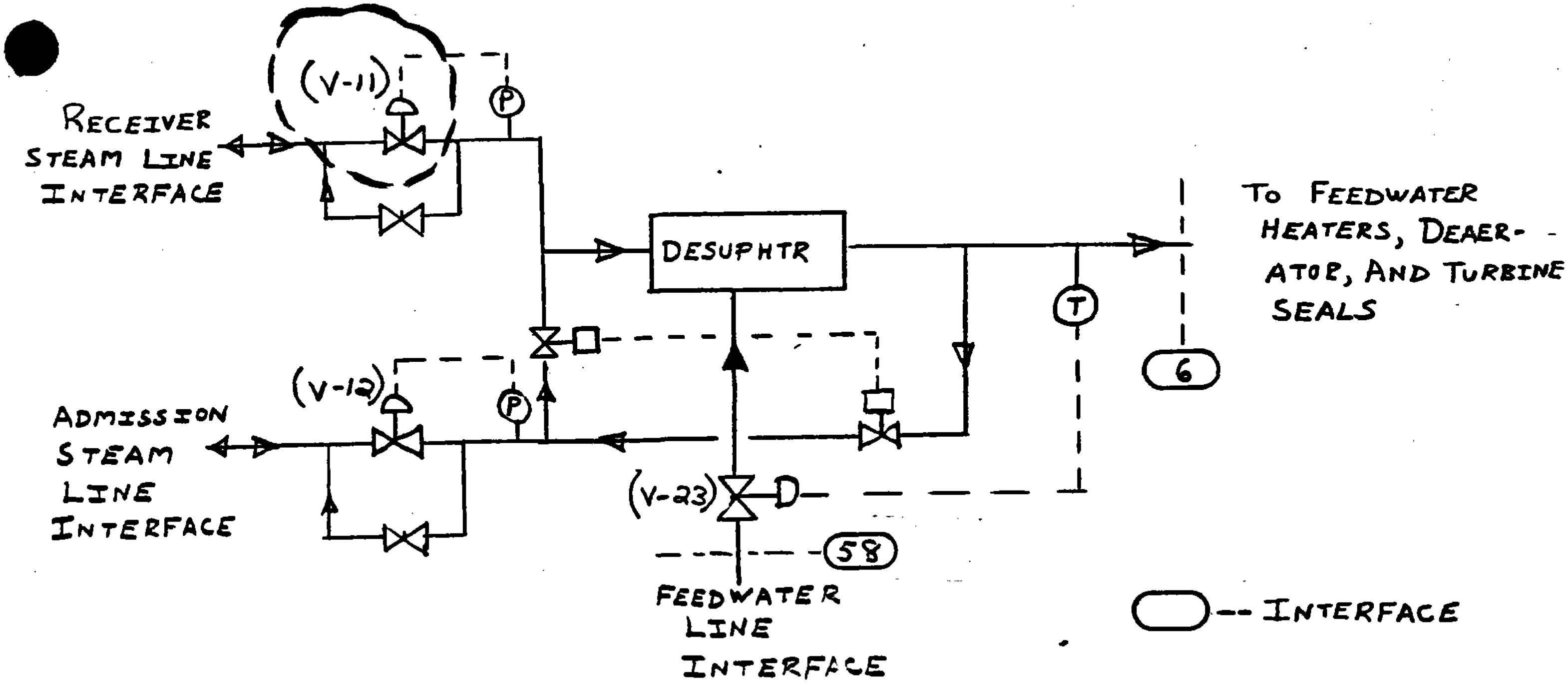
AUXILIARY STEAM NETWORK



V-11 NOTES

1. DURING NORMAL PLANT OPERATION (TIMES OTHER THAN RECEIVER STAND ALONE), VALVE (V-11) [AND (V-23)] WILL OPEN ONLY AS REQUIRED TO MAINTAIN 345°F 85psia STEAM CONDITIONS DOWNSTREAM OF THE DESUPERHEATER, THEREFORE, THE MAJORITY OF THE DUTY FOR (V-11) [AND (V-23)] WILL BE AT OR NEAR ZERO FLOW. AN ATTEMPT SHOULD BE MADE TO MAXIMIZE THE TURNDOWN CAPABILITY OF (V-11) [AND THE DESUPERHEATER AND (V-23)] TO ENHANCE CONTROL RANGE CAPABILITY SUBJECT TO COST AND ENGINEERING JUDGEMENT RELATED TO A <u>SINGLE</u> CONTROL VALVE.
2. MAX DESIGN PRESSURE SET BY RECEIVER (SEE INTERFACE CONDITIONS 1 AND RI3.
3. MAX SHUTOFF PRESSURE = UPSTREAM OPERATING PRESSURE − MIN AUX NETWORK PRESSURE = 1465 − 55 = 1410 PSI

DIVISION USAGE					
MM	P	PP	SH	FI	SP

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CONTROL VALVE DESIGN SHEET

PV 1005

ISSUED
REVISED

CUSTOMER: ____________________

PROJECT NO.: ____________________

PROJECT: ____________________

TAG NO.: (V-12) ADMISSION STEAM TO AUX STEAM

SERVICE: AUX STEAM

FLUID: STEAM

REV. NO.	1			
DATE	12/16			
BY	JER (MDAC)			

	FLUID CONDITIONS AT VALVE INLET				VALVE	SYSTEM	APPROX.
	PRESS.	TEMP.	DENSITY	VISC.,		FRICTION	DESIRED
FLOW [✓ #/HR], GPM, SCFM	PSIA	°F	#/FT^3 OR S.V. [✓ FT^3/#]	c_p or SSU	Δ P PSI	LOSS PSI	C_v
XIMUM 3765	385	525	1.39		320		
DESIGN SEE NOTE 1	385	525	1.39		320		
MINIMUM SEE NOTE 1	385	525	1.39		320		

Max. Design Temp.: 580 (NOTE 2) °F, Max. Design Press.: 465 (NOTE 2) PSIA
Max. Shut-Off Press.: 330 (NOTE 3) PSI
Valve Service: OPEN/CLOSE ☐ MODULATION ☒

Is Flashing Expected in Valve? YES ☐ NO ☒

Pipe Size and Schedule: ____________, Pipe Material: ____________
Approx. Valve Body Size: ____________ INCHES
Body Type: ____________

Valve Characteristic: Linear ☐ Equal Percentage ☒
Quick Opening ☐ Other: ____________

Is Tight Shut-Off Required? YES ☐ NO ☐
llowable Leakage: ____________
Is Handjack or Handwheel Required? YES ☐ NO ☐
Special Steam Packing Considerations: ____________

Valve Action On Loss of Power: Locks in Pos. ☐ Opens ☐ Closes ☒
Valve Action On Loss of Power air/or sensing fluid Opens ☐ Closes ☒

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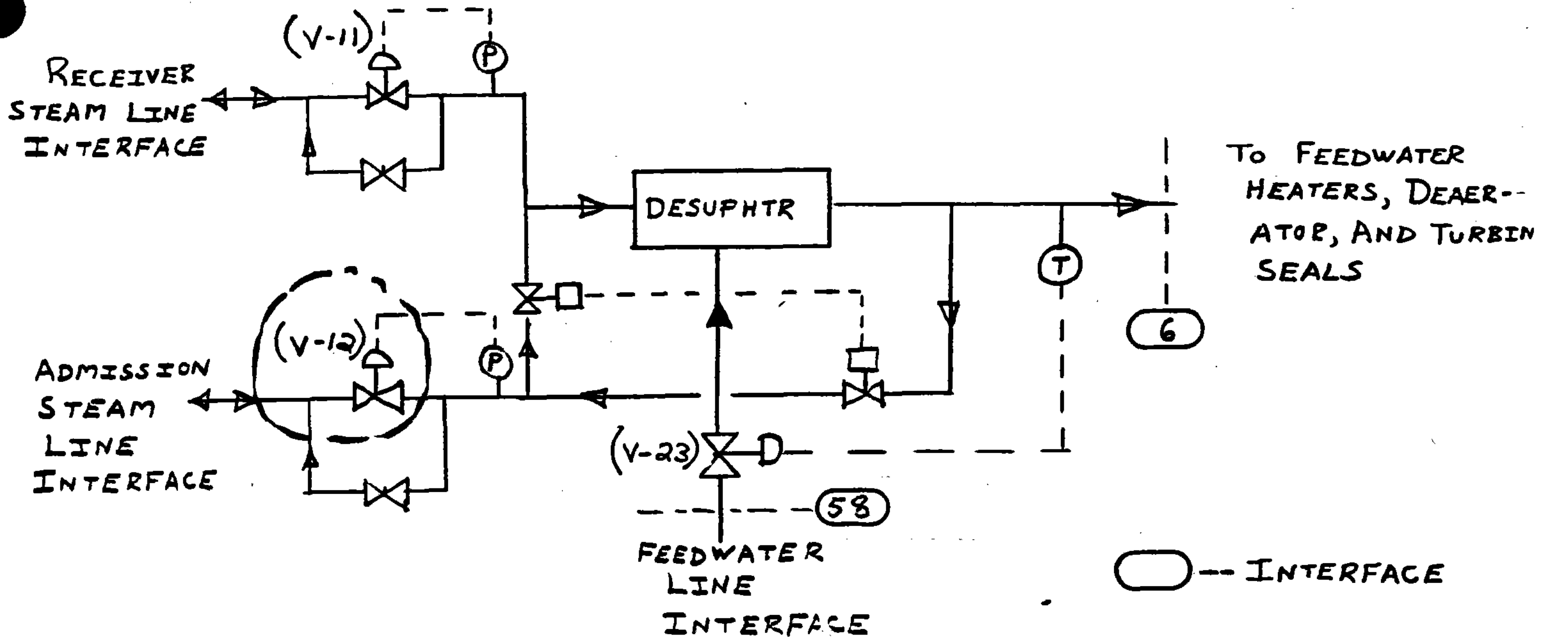
AUXILIARY STEAM NETWORK



(V-12) NOTES

1. DURING MOST PERIODS OF OPERATION, THE AUX STEAM DEMAND WILL BE AT OR NEAR ZERO. THEREFORE, IT IS DESIRABLE TO HAVE (V-12) TURNDOWN BE AS HIGH AS PRACTICAL SUBJECT TO LIMITATIONS OF THE DESUPERHEATER, (V-23), AND THE CAPABILITY OF A SINGLE VALVE.
2. MAX DESIGN TEMP AND PRESSURE CONDITION ESTABLISHED BY THERMAL STORAGE STEAM GENERATOR MAX DESIGN VALUES (SEE INTERFACES 2, 84I, AND 85I)
3. MAX SHUTOFF PRESSURE = MAX OPERATING PRESSURE - MIN AUX NETWORK PRESSURE = 385 - 55 psia = 330 psi

ISION USAGE					
M	P	PP	SH	FI	SP

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CONTROL VALVE DESIGN SHEET

ISSUED
REVISED

CUSTOMER:
TAG NO.: LV 74D TS FLASH TANK TO CONDENSER
PROJECT NO.:
SERVICE: TS FLASH TANK
PROJECT:
FLUID: CONDENSATE

REV. NO.	1			
DATE	12/15/79			
BY	JER (MDAC)			

	FLUID CONDITIONS AT VALVE INLET				VALVE	SYSTEM	APPROX.
	PRESS.	TEMP.	DENSITY	VISC.,		FRICTION	DESIRED
FLOW [✓ #/HR], GPM, SCFM	PSIA	°F	#/FT³ OR S.V. [✓ FT³/#]	c_p or SSU	△ P PSI	LOSS PSI	C_v
XIMUM 117,500	165 SEE NOTE 1	358	.01809		SEE NOTE 2		
DESIGN 117,500	165 SEE NOTE 1	358	.01809		SEE NOTE 2		
MINIMUM 133 (As Low As Practical)	165 SEE NOTE 1	358	.01809		SEE NOTE 2		

Max. Design Temp.: 360 °F, Max. Design Press.: 195 (NOTE 3) PSIA
Max. Shut-Off Press.: 165 (NOTE 4) PSI
Valve Service: OPEN/CLOSE ☐ MODULATION ☒

Is Flashing Expected in Valve? YES ☒ NO ☐

Pipe Size and Schedule: , Pipe Material:
Approx. Valve Body Size: INCHES
Body Type:

Valve Characteristic: Linear ☐ Equal Percentage ☒
Quick Opening ☐ Other:

Is Tight Shut-Off Required? YES ☐ NO ☐
llowable Leakage:
Is Handjack or Handwheel Required? YES ☐ NO ☐
Special Steam Packing Considerations:

Valve Action On Loss of Power: Locks in Pos. ☐ Opens ☐ Closes ☒
Valve Action On Loss of Power air/or sensing fluid Opens ☐ Closes ☒
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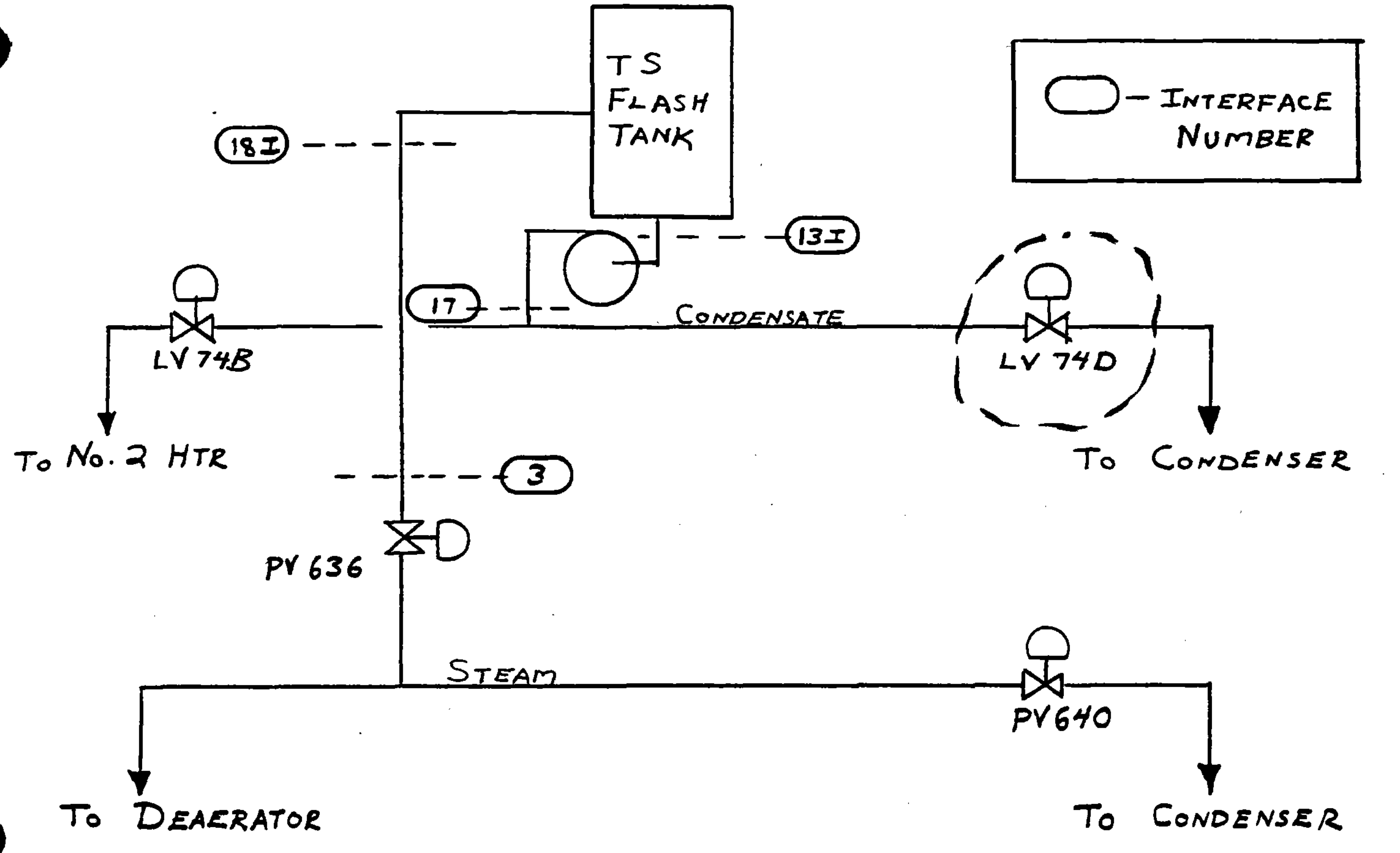

LV 74 D NOTES

1. TS FLASH TANK PRESSURE (150psia) + PUMP HEAD RISE (15psia). THE SPECIFIED VALUE (165psia) NEGLECTS FLOW FRICTIONAL LOSS AND GRAVITY HEAD RISE (IF ANY) BETWEEN THE TS CONDENSATE PUMP AND LV 74D.

2. PRESSURE DOWNSTREAM OF LV 74D WILL BE CONDENSER PRESSURE + CONDENSER INLET PRESSURE LINE LOSSES. IF A DOWNSTREAM ORIFICE IS USED, A HIGHER BACK PRESSURE WOULD BE EXPERIENCED, ESPECIALLY DURING HIGH FLOW.

3. MAX DESIGN PRESSURE = MAX DESIGN FLASH TANK PRESSURE + PUMP HEAD RISE = 180 + 15 = 195 psia (DIFFERENCES IN GRAVITY HEAD ARE IGNORED - IF ANY)

4. MAX SHUTOFF PRESSURE = MAX OPERATING PRESSURE - CONDENSER PRESSURE = 165psia - ~0 = 165psia.

ISION USAGE					
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CONTROL VALVE DESIGN SHEET

CUSTOMER: ______
PROJECT NO.: ______
PROJECT: ______

TAG NO.: LV 74C – RS FLASH TANK TO CONDENSER
SERVICE: RS FLASH TANK
FLUID: CONDENSATE

REV. NO.	1			
DATE	12/14			
BY	JER (MDAC)			

	FLUID CONDITIONS AT VALVE INLET				VALVE	SYSTEM	APPROX.
	PRESS.	TEMP.	DENSITY	VISC.,		FRICTION	DESIRED
FLOW [✓ #/HR], GPM, SCFM	PSIA	°F	#/FT^3 OR S.V. [✓ FT^3/#]	c_p or SSU	△ P PSI	LOSS PSI	C_v
XIMUM 40,000	SEE NOTE 1.	467	0.0198		SEE NOTE 3.		
DESIGN 16189	SEE NOTE 1.	467	0.0198		SEE NOTE 3.		
MINIMUM 4000	SEE NOTE 2.	439	0.01925		SEE NOTE 3.		

Max. Design Temp.: 486 °F, Max. Design Press.: SEE NOTE 4 PSIA
Max. Shut-Off Press.: SEE NOTE 5 PSI
Valve Service: OPEN/CLOSE ☐ MODULATION ☒

Is Flashing Expected in Valve? YES ☒ UNLESS DOWNSTREAM ORIFICE IS USED NO ☐

Pipe Size and Schedule: ______, Pipe Material: ______
Approx. Valve Body Size: ______ INCHES
Body Type: ______

Valve Characteristic: Linear ☐ Equal Percentage ☐
Quick Opening ☐ Other: MODIFIED PARABOLIC

Is Tight Shut-Off Required? YES ☐ NO ☐
llowable Leakage: ______
Is Handjack or Handwheel Required? YES ☐ NO ☐
Special Steam Packing Considerations: ______

Valve Action On Loss of Power: Locks in Pos. ☐ Opens ☐ Closes ☒
Valve Action On Loss of Power air/or sensing fluid Opens ☐ Closes ☒

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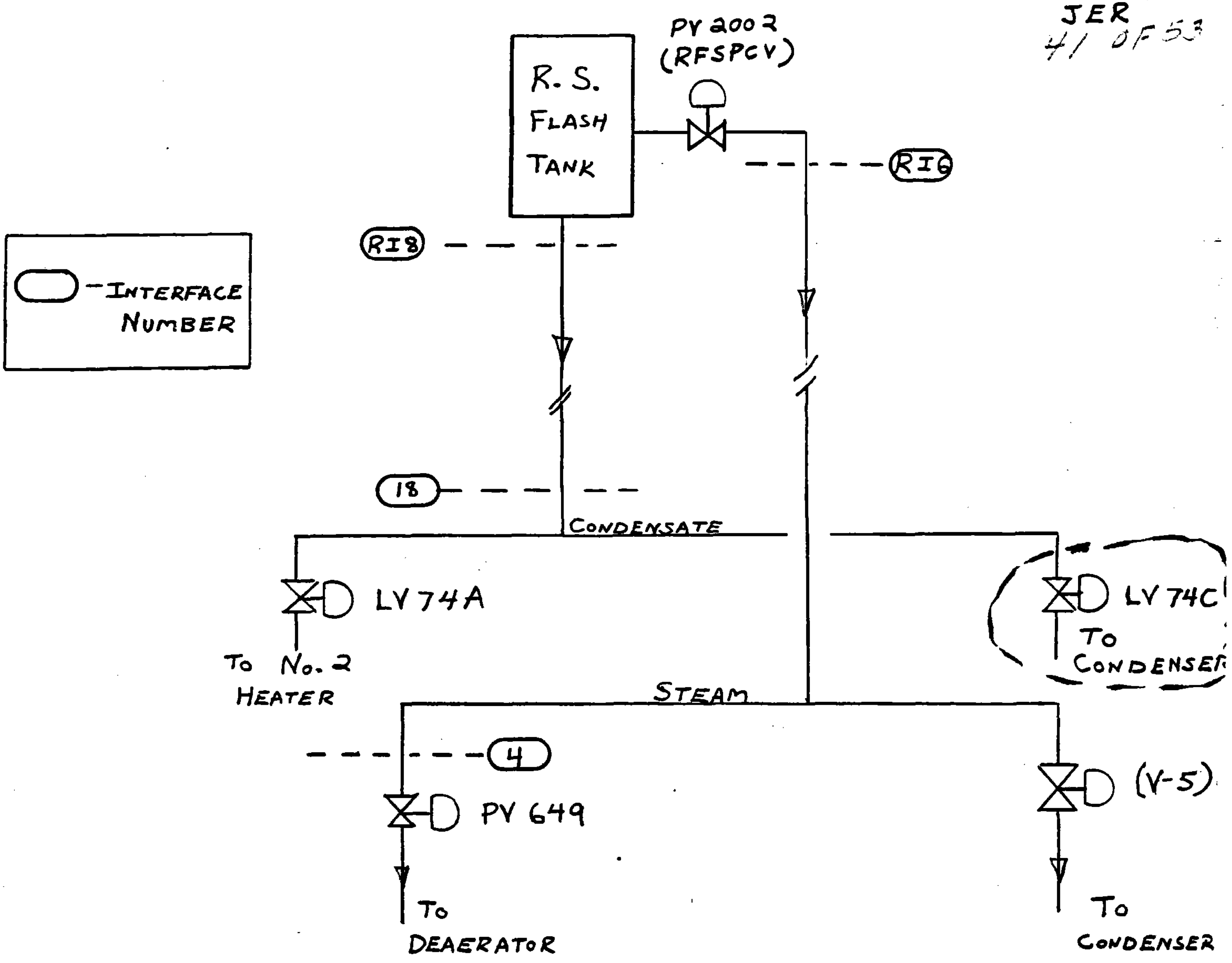

LV 74C NOTES

1. PRESSURE AT INTERFACE RI8 + (GRAVITY HEAD FROM FLASH TANK) − (FRICTION LOSS) = 500 psia + (H) − (F. Loss)

2. MIN PRESSURE AT INTERFACE RI8 + (GRAVITY HEAD FROM FLASH TANK) − (FLOW FRICTIONAL LOSS) = 380 psia + (H) − (F. Loss)

3. VALVE DOWNSTREAM PRESSURE EQUALS CONDENSER INLET MANIFOLD PRESSURE. MAY WANT TO PLACE AN ORIFICE DOWNSTREAM OF VALVE TO MINIMIZE FLASHING.

4. INTERFACE RI8 "DESIGN" PRESSURE + GRAVITY HEAD = 600 psia + (H)

5. MAX SHUTOFF PRESS. = 500 psia + (H) − 2½" Hg

CONDENSER PRESSURE

DIVISION USAGE					
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CONTROL VALVE DESIGN SHEET

CUSTOMER: ______________________

PROJECT NO.: ______________________

PROJECT: ______________________

TAG NO.: LV 74 A —RS FLASH TANK To No. 2 HTR

SERVICE: RS FLASH TANK

FLUID: CONDENSATE

REV. NO.	1			
DATE	12/14			
BY	JER (MDAC)			

	FLUID CONDITIONS AT VALVE INLET PRESS. PSIA	TEMP. °F	DENSITY #/FT³ OR S.V. [✓ FT³/#]	VISC., c_p or SSU	VALVE ΔP PSI	SYSTEM FRICTION LOSS PSI	APPROX. DESIRED C_v
FLOW [✓ #/HR.] GPM, SCFM							
XIMUM 23,811	SEE NOTE 1.	467	0.0198		SEE NOTE 3.		
DESIGN 23,811	SEE NOTE 1.	467	0.0198		SEE NOTE 3		
MINIMUM 4000	SEE NOTE 2.	439	0.01925		SEE NOTE 3		

Max. Design Temp.: 486 °F, Max. Design Press.: SEE NOTE 4 PSIA

Max. Shut-Off Press.: SEE NOTE 5 PSI

Valve Service: OPEN/CLOSE ☐ MODULATION ☒

Is Flashing Expected in Valve? YES ☒ UNLESS DOWNSTREAM ORIFICE IS USED NO ☐

Pipe Size and Schedule: ______________________ , Pipe Material: ______________________

Approx. Valve Body Size: ______________ INCHES

Body Type: ______________________

Valve Characteristic: Linear ☐ Equal Percentage ☐

Quick Opening ☐ Other: MODIFIED PARABOLIC

Is Tight Shut-Off Required? YES ☐ NO ☐

Allowable Leakage: ______________________

Is Handjack or Handwheel Required? YES ☐ NO ☐

Special Steam Packing Considerations: ______________________

Valve Action On Loss of Power: Locks in Pos. ☐ Opens ☐ Closes ☒

Valve Action On Loss of Power air/or sensing fluid Opens ☐ Closes ☒

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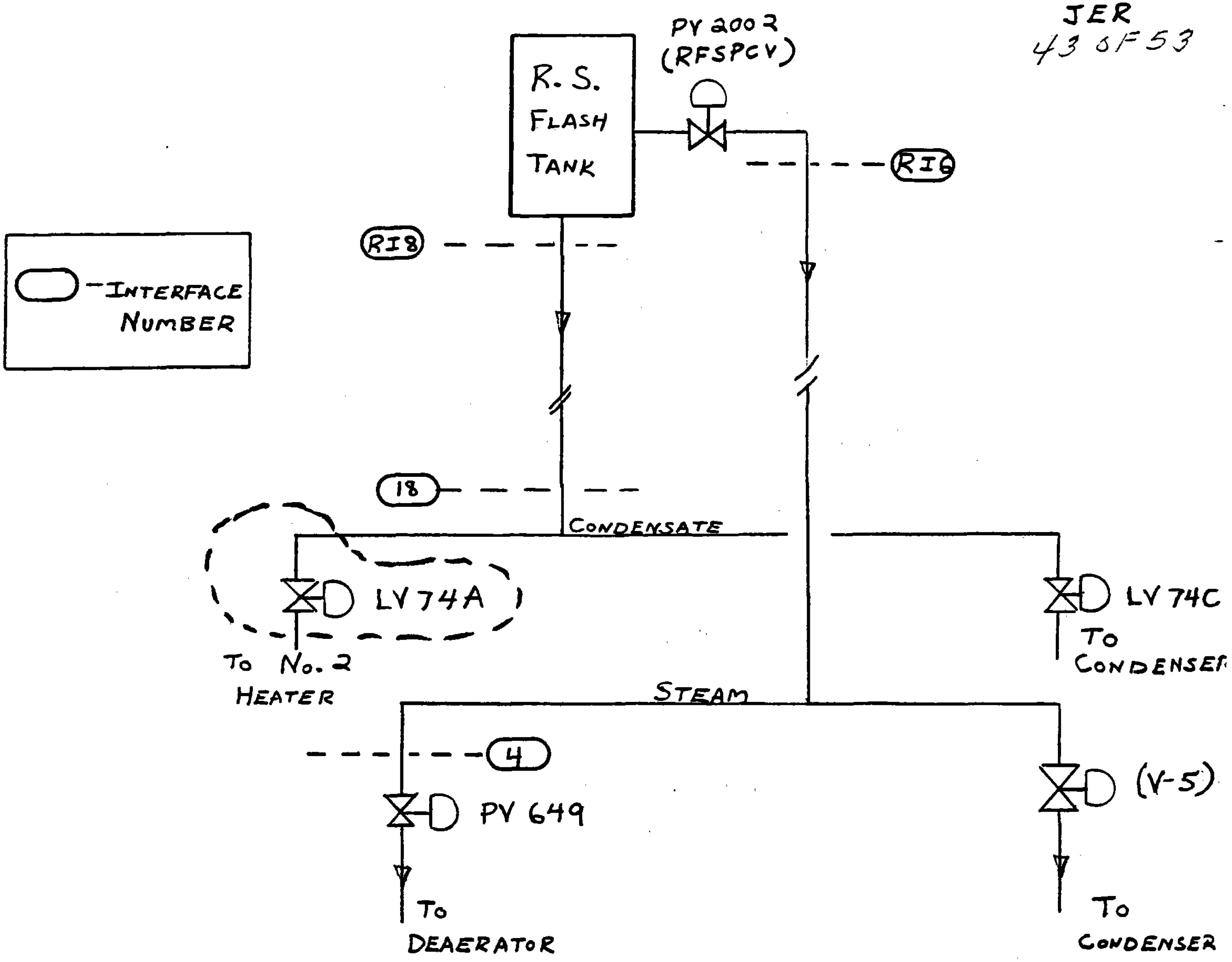

LV 74A NOTES

1. PRESSURE AT INTERFACE RI8 + GRAVITY HEAD FROM FLASH TANK − FLOW FRICTIONAL LOSS = 500 psia + (H) − (F. LOSS)

2. MIN PRESSURE AT INTERFACE RI8 + GRAVITY HEAD − FLOW FRICTIONAL LOSS = 380 psia + (H) − (F. LOSS)

3. DOWNSTREAM PRESSURE CAN VARY OVER THE RANGE OF 20 — 135 psia DEPENDING ON THE STATUS OF THE PLANT DURING RS FLASH TANK OPERATION

4. INTERFACE RI8 "DESIGN" PRESSURE + GRAVITY HEAD = 600 psia + (H)

5. MAX SHUTOFF PRESS. = 500 psia + (H) − 20 psia
LOWEST DOWNSTREAM PRESS.

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abbany						CONTROL VALVE DESIGN SHEET	ISSUED REVISED

CUSTOMER: ______

PROJECT NO.: ______

PROJECT: ______

TAG NO.: LV 74B TS FLASH TANK To #2 HTR

SERVICE: TS FLASH TANK

FLUID: CONDENSATE

REV. NO.	1			
DATE	12/15/79			
BY	JER (MDAC)			

	FLUID CONDITIONS AT VALVE INLET				VALVE	SYSTEM	APPROX.
	PRESS.	TEMP.	DENSITY	VISC.,		FRICTION	DESIRED
FLOW [✓ #/HR.], GPM, SCFM	PSIA	°F	#/FT³ OR S.V. [✓ FT³/#]	c_p or SSU	△ P PSI	LOSS PSI	C_v
XIMUM 117,500	165 SEE NOTE 1	358	.01809		SEE NOTE 2		
ESIGN 117,500	165 SEE NOTE 1	358	.01809		SEE NOTE 2		
INIMUM 5679	165 SEE NOTE 1	358	.01809		SEE NOTE 2		

ax. Design Temp.: 360 °F, Max. Design Press.: 195 (NOTE 4.) PSIA

ax. Shut-Off Press.: 145 (SEE 3.) PSI

alve Service: OPEN/CLOSE ☐ MODULATION ☒

s Flashing Expected in Valve? YES ☒ NO ☐

ipe Size and Schedule: ______, Pipe Material: ______

pprox. Valve Body Size: ______ INCHES

ody Type: ______

Valve Characteristic: Linear ☐ Equal Percentage ☒

Quick Opening ☐ Other: ______

s Tight Shut-Off Required? YES ☐ NO ☐

llowable Leakage: ______

s Handjack or Handwheel Required? YES ☐ NO ☐

pecial Steam Packing Considerations: ______

alve Action On Loss of Power: Locks in Pos. ☐ Opens ☐ Closes ☒

alve Action On Loss of Power air/or sensing fluid Opens ☐ Closes ☒

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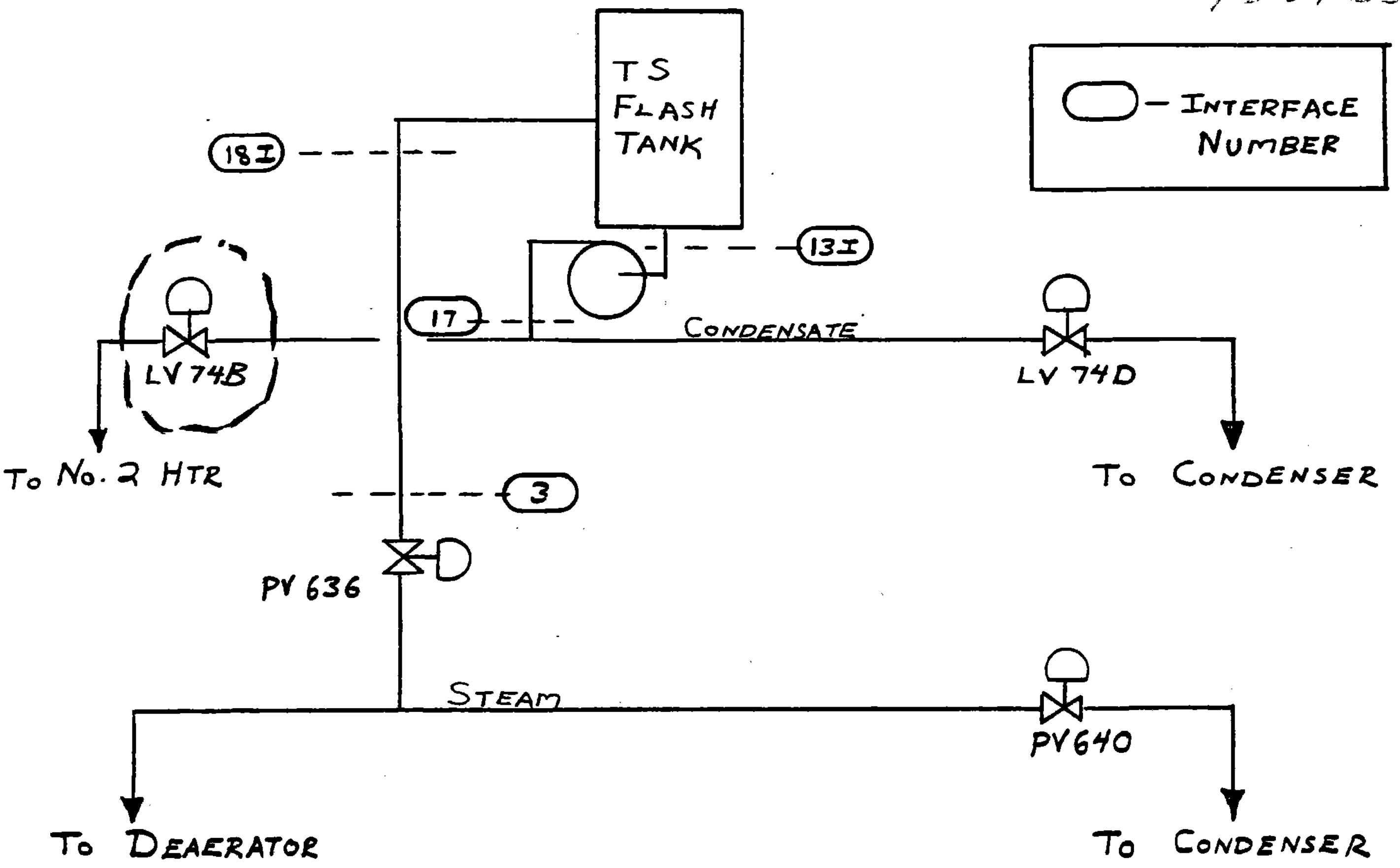

LV 74B Notes

1. TS Flash Tank Pressure (150 psia) + Pump Head Rise (15 psia). The Specified Value (165 psia) Neglects Flow Frictional Loss and Gravity Rise Between the TS Condensate Pump and LV 74B.

2. Pressure Downstream of LV74B Can Reach 135 psia During High Condensate Flow Periods (At 135 psia, A Pressure Control Override On LV74B Forces the Valve Closed) During Low Flow Periods, Downstream Pressure May Be As Low As 20 psia (Min Deaerator Pressure).

3. Max Shutoff Pressure = Max Operating Pressure − Min Shell Pressure (Min Deaerator Pressure) = 165 − 20 = 145 psia

4. Max Design Pressure = Max Design Flash Tank Pressure + Pump Head Rise . . = 180 + 15 = 195 psia.
(Differences In Gravity Head Are Ignored)

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CONTROL VALVE DESIGN SHEET

TV-1004

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CUSTOMER: ____________________

PROJECT NO.: ____________________

PROJECT: ____________________

TAG NO.: (V-23) DESUPERHEATER CONDENSATE CONTROL VALVE

SERVICE: AUX STEAM

FLUID: CONDENSATE

REV. NO.	1			
DATE	12/16			
BY	JER			

	FLUID CONDITIONS AT VALVE INLET				VALVE	SYSTEM	APPROX.
	PRESS.	TEMP.	DENSITY #/FT³ OR S.V. FT³/#	VISC., c_p or SSU	ΔP	FRICTION LOSS	DESIRED C_v
FLOW #/HR, GPM, SCFM	PSIA	°F			PSI	PSI	
XIMUM 2292 (NOTE 1) 430 (NOTE 2)	115 (NOTE 4)	121	.01621		10 (SEE NOTE 5)		
DESIGN SEE NOTE 3	115 (NOTE 4)	109	.01616		10 (SEE NOTE 5)		
MINIMUM SEE NOTE 3	115 (NOTE 4)	109	.01616		10 (SEE NOTE 5)		

Max. Design Temp.: 135 (NOTE 6) °F, Max. Design Press.: 160 (SEE NOTE 7) PSIA
Max. Shut-Off Press.: 60 (NOTE 8) PSI
Valve Service: OPEN/CLOSE ☐ MODULATION ☒

Is Flashing Expected in Valve? YES ☐ NO ☒

Pipe Size and Schedule: ____________, Pipe Material: ____________
Approx. Valve Body Size: ____________ INCHES
Body Type: ____________

Valve Characteristic: Linear ☐ Equal Percentage ☒
Quick Opening ☐ Other: LARGE TURNDOWN

Is Tight Shut-Off Required? YES ☐ NO ☐
llowable Leakage: ____________
Is Handjack or Handwheel Required? YES ☐ NO ☐
Special Steam Packing Considerations: ____________

Valve Action On Loss of Power: Locks in Pos. ☐ Opens ☒ Closes ☐
Valve Action On Loss of Power air/or sensing fluid Opens ☒ Closes ☐

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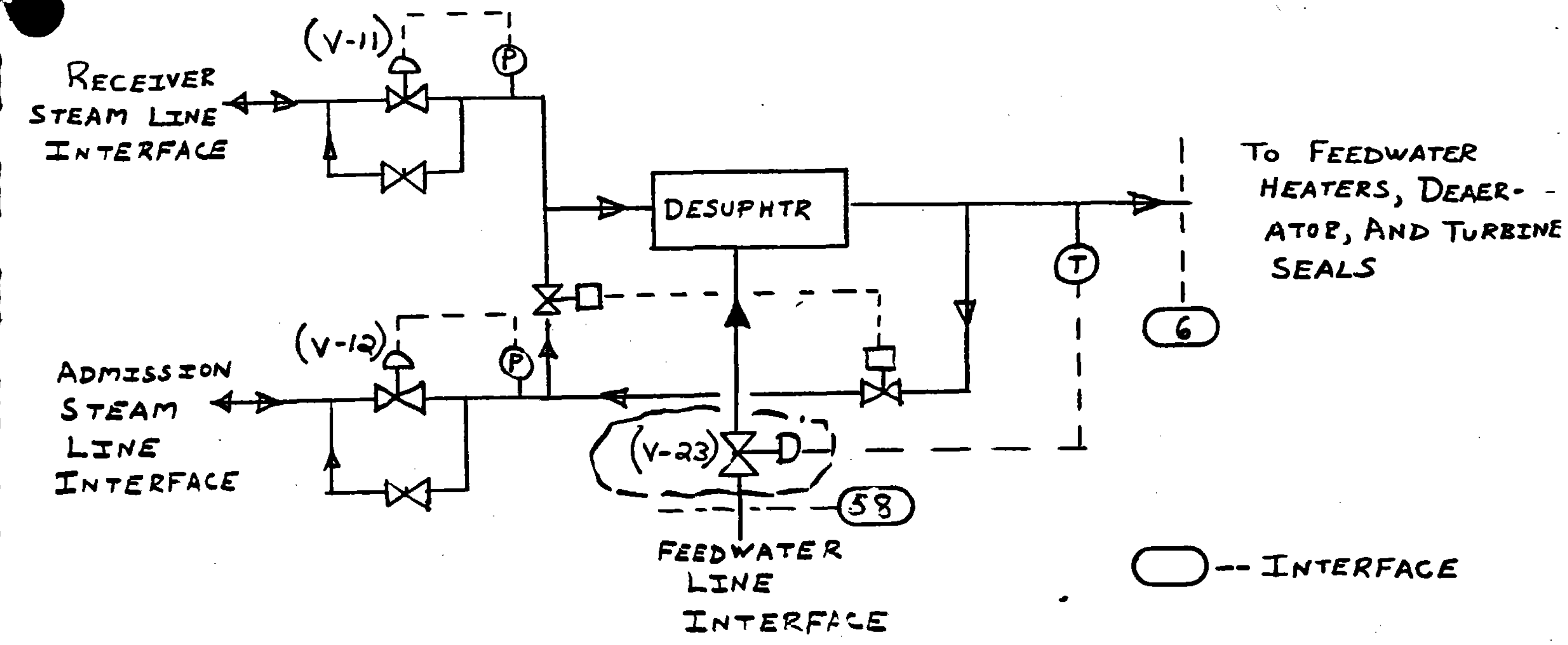
JER

AUXILIARY STEAM NETWORK



(V-23) NOTES

1. MAX FLOW DURING RECEIVER STAND ALONE WITH RECEIVER PRODUCING 960°F STEAM.
2. MAX FLOW DURING RECEIVER STAND ALONE WITH RECEIVER PRODUCING 660°F STEAM.
3. SINCE THE AUX STEAM SYSTEM WORKS "ON DEMAND", IT SHALL HAVE A GOOD CONTROL CAPABILITY AT LOW (NEAR ZERO FLOW), THEREFORE, (V-23) SHALL HAVE A HIGH TURNDOWN CAPABILITY SUBJECT TO LIMITS OF TURNDOWN ON (V-11), (V-12), AND THE DESUPERHEATER. A TURNDOWN TO LESS THAN 50 LB/HR IS DESIRABLE.
4. A HIGHER PRESSURE (< 160 PSIA → ESTIMATED HOTWELL PUMP MAX PRESSURE AT MIN FLOW) MAY EXIST AT SOME PERIODS DURING LOW TOTAL FEEDWATER FLOW.
5. BASED ON 85 PSIA DOWNSTREAM STEAM PRESSURE, A 20 PSIA ΔP THROUGH THE DESUPERHEATER AND A 115 PSIA WATER INLET INTERFACE PRESSURE.
6. BASED ON AN ASSUMED 5 IN Hg MAX CONDENSER PRESSURE (135°F SATURATED WATER)
7. 160 PSIA ASSUMED MAX HOTWELL PUMP OUTLET PRESSURE
8. MAX SHUTOFF PRESSURE ≐ NOMINAL OPER. PRESS. − MIN AUX NETWORK PRESS. ≐ 115 − 55 = 60 PSIA (THIS VALUE IS 105 PSIA IF PUMP PRESS ≐ 160 PSIA)

DIVISION USAGE					
MM	P	PP	SH	FI	SP

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CONTROL VALVE DESIGN SHEET

CUSTOMER: ______
TAG NO.: (V-24) ADMISSION STEAM TO AUX STEAM DESUPERHEATER

PROJECT NO.: ______
SERVICE: AUX STEAM

PROJECT: ______
FLUID: STEAM

REV. NO.	1			
DATE	1/14/80			
BY	JER. (MDAC)			

	FLUID CONDITIONS AT VALVE INLET				VALVE	SYSTEM	APPROX.
	PRESS.	TEMP.	DENSITY	VISC.,		FRICTION LOSS	DESIRED
FLOW #/HR. GPM, SCFM	PSIA	°F	#/FT³ OR S.V. FT³/#	c_p or SSU	△ P PSI	PSI	C_v
XIMUM 3765	72	460	8.285		NOTE 1		
DESIGN 3765	72	460	8.285		NOTE 1		
MINIMUM 0 (SHUT OFF VALVE)	—	—	—		—		

Max. Design Temp.: 860 (NOTE 2) °F, Max. Design Press.: 90 (NOTE 3) PSIA
Max. Shut-Off Press.: 75 PSI
Valve Service: OPEN/CLOSE ☒ MODULATION ☐

Is Flashing Expected in Valve? YES ☐ NO ☒

Pipe Size and Schedule: ______, Pipe Material: ______
Approx. Valve Body Size: ______ INCHES
Body Type: ______

Valve Characteristic: Linear ☐ Equal Percentage ☐
Quick Opening ☐ Other: ______

Is Tight Shut-Off Required? YES ☐ NO ☐
Allowable Leakage: ______
Is Handjack or Handwheel Required? YES ☐ NO ☐
Special Steam Packing Considerations: ______

Valve Action On Loss of Power: Locks in Pos. ☐ Opens ☐ Closes ☒
Valve Action On Loss of Power air/or sensing fluid Opens ☐ Closes ☒

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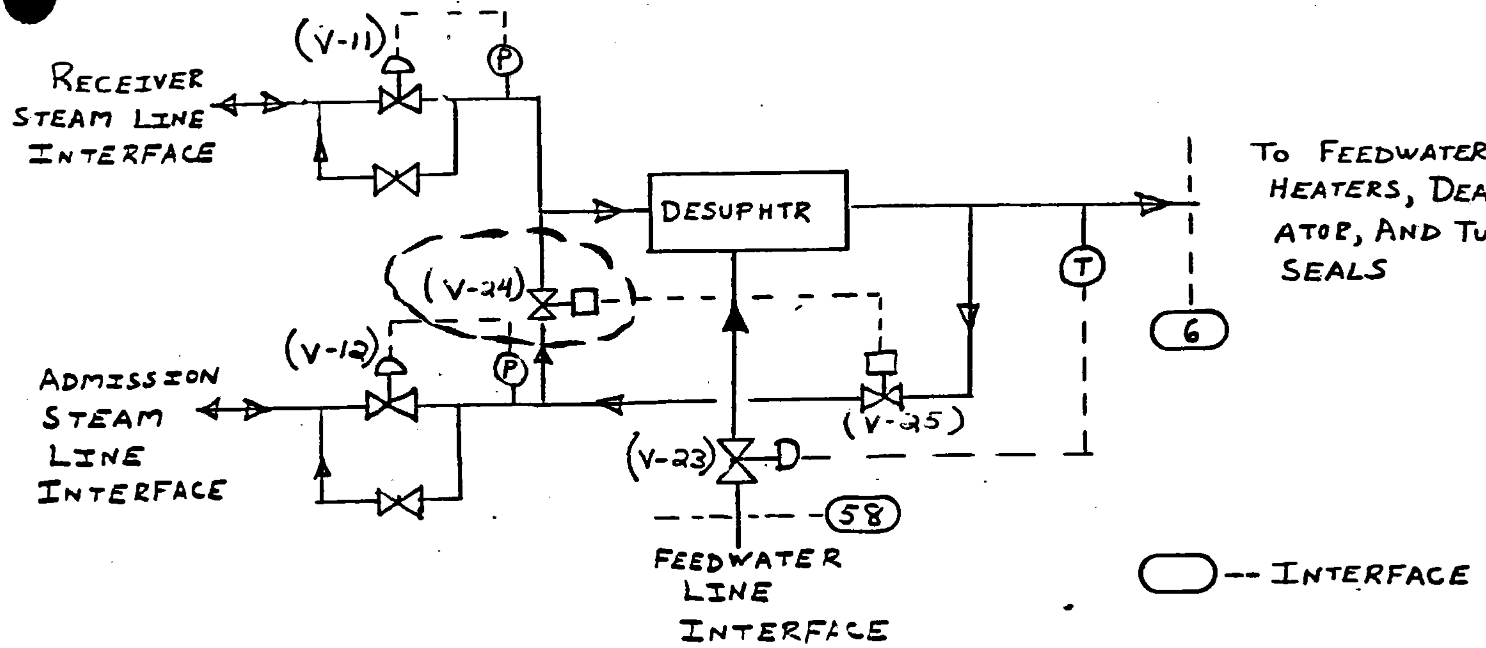
AUXILIARY STEAM NETWORK



V-24 NOTES

- VALVE (V-24) MUST BE SIZED TO ACCOMODATE MAXIMUM OUTLET CONDITIONS FROM VALVE (V-12)
- DURING OPERATION OF THE AUX STEAM NETWORK (V-24) AND (V-25) MUST BE INTERLOCKED SO THAT ONLY ONE CAN BE OPEN AT A TIME. WHEN THERMAL STORAGE STEAM GENERATOR(S) ARE OPERATING (AT DESIGN OR BLANKET STEAM PRESSURE), (V-24) IS OPEN. WHEN THE TS STEAM GENERATORS ARE PRODUCING NO STEAM PRESSURE AND BLANKETING OF THE STEAM GENERATORS ARE DESIRED, (V-25) IS OPEN.

1. FULL FLOW VALVE PRESSURE DROP SHOULD BE AS LOW AS PRACTICAL CONSISTENT WITH NORMAL ISOLATION VALVE SELECTION PRACTICES ($\Delta P \leq \sim 2$ psi ESTIMATED VALUE)
2. 860°F BASED ON EXPANDING MAIN STEAM FROM 1465 psia, 950°F TO 85 psia (POSSIBLE CONDITION ON DOWNSTREAM SIDE OF (V-24))
3. AUX NETWORK SAFETY VALVE SETTING

DIVISION USAGE					
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CONTROL VALVE DESIGN SHEET

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CUSTOMER:

PROJECT NO.:

PROJECT:

TAG NO.: (V-25) AUX STEAM CONNECTION TO BLANKET TS

SERVICE: AUX STEAM

FLUID: STEAM

REV. NO.	1			
DATE	1/14/80			
BY	JER (MDAC)			

	FLUID CONDITIONS AT VALVE INLET				VALVE	SYSTEM	APPROX.
	PRESS.	TEMP.	DENSITY	VISC.,		FRICTION	DESIRED
FLOW [✓ #/HR], GPM, SCFM	PSIA	°F	#/FT³ OR S.V. [✓ FT³/#]	c_p or SSU	△ P PSI	LOSS PSI	C_v
XIMUM 400	75	345	5.40		NOTE 1		
DESIGN 100	75	345	5.40		NOTE 1		
MINIMUM 0 (ISOLATION VALVE)	75	345	5.40		—		

Max. Design Temp.: 460 (NOTE 2) °F, Max. Design Press.: 90 (NOTE 3) PSIA
Max. Shut-Off Press.: 75 PSI
Valve Service: OPEN/CLOSE ☒ MODULATION ☐

Is Flashing Expected in Valve? YES ☐ NO ☒

Pipe Size and Schedule: , Pipe Material:
Approx. Valve Body Size: INCHES
Body Type:

Valve Characteristic: Linear ☐ Equal Percentage ☐
Quick Opening ☐ Other:

Is Tight Shut-Off Required? YES ☐ NO ☐
llowable Leakage:
Is Handjack or Handwheel Required? YES ☐ NO ☐
Special Steam Packing Considerations:

Valve Action On Loss of Power: Locks in Pos. ☐ Opens ☐ Closes ☒
Valve Action On Loss of Power air/or sensing fluid Opens ☐ Closes ☒

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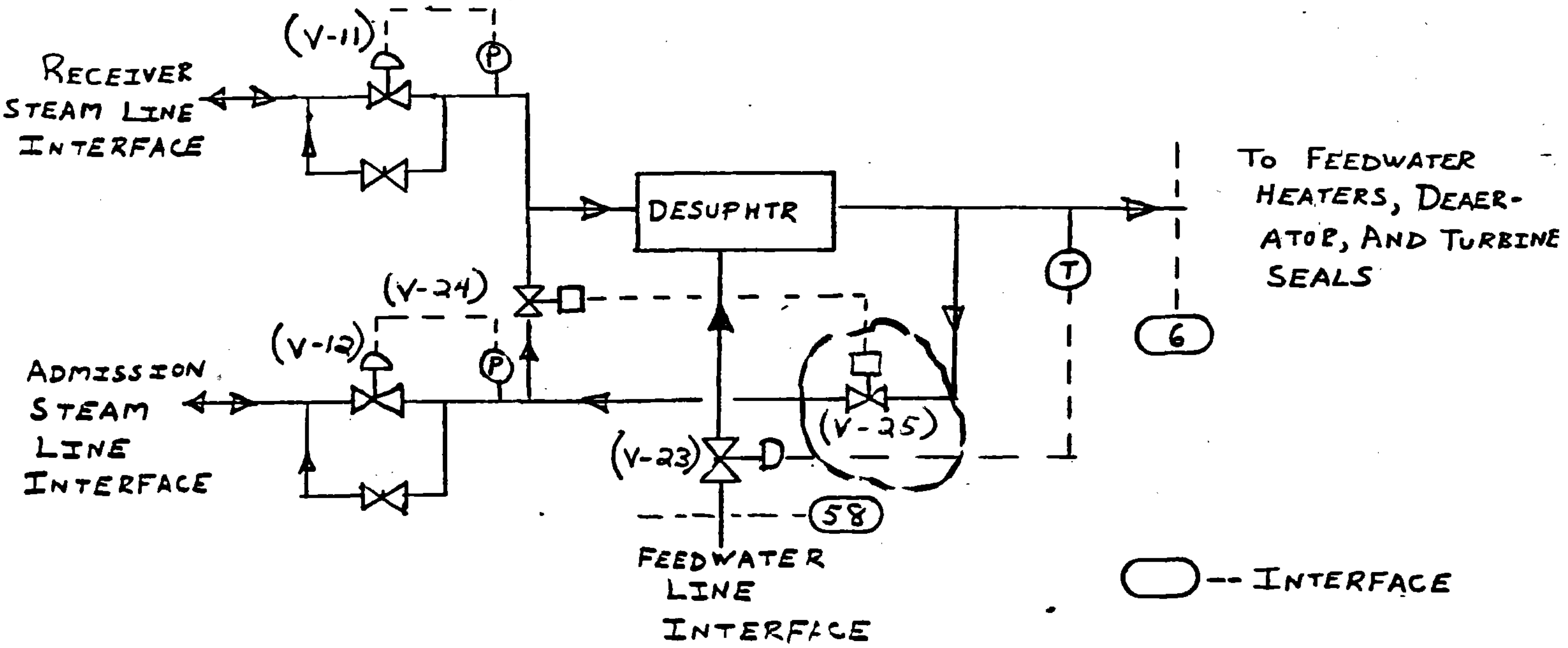
Auxiliary Steam Network



V-25 Notes

- During Operation Of The Aux Steam Network, (V-24) And (V-25) Must Be Interlocked So That Only One Can Be Open At A Time. When Thermal Storage Steam Generator(s) Are Operating (At Design Or Blanket Steam Pressure), (V-24) Is Open. When The TS Steam Generators Are Producing No Steam Pressure And TS Blanketing Is Desired, (V-25) Is Open.

1. Valve Pressure Drop At Full Flow Should Be As Low As Practical Consistent With Normal Isolation Valve Selection Practices (Estimated Value: ΔP~1 psi)
2. Normal Steam Temperature Leaving (V-12) Which Will Be Present Downstream Of (V-25).
3. Aux Network Safety Valve Setting

DIVISION USAGE					
MM	P	PP	SH	FL	SP

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CONTROL VALVE DESIGN SHEET

ISSUED
REVISED

CUSTOMER: ____________

PROJECT NO.: ____________

PROJECT: ____________

TAG NO.: TBD (FORMERLY LV-1)

SERVICE: AUX STEAM

FLUID: CONDENSATE

REV. NO.				
DATE				
BY				

FLOW #/HR. GPM, SCFM	FLUID CONDITIONS AT VALVE INLET PRESS. PSIA	TEMP. °F	DENSITY #/FT^3 OR S.V. FT^3/#	VISC., c_p or SSU	VALVE △ P PSI	SYSTEM FRICTION LOSS PSI	APPROX. DESIRED C_v
XIMUM 4880	122	281	57.9		≤2		
DESIGN 4880	122	228	59.4		≤2		
MINIMUM 0 SHUT OFF	170	281	57.9		—		

Max. Design Temp.: 285 °F, Max. Design Press.: 615. SEE NOTE 1 PSIA
Max. Shut-Off Press.: 585 (NOTE 2) PSI
Valve Service: OPEN/CLOSE ☒ MODULATION ☐

Is Flashing Expected in Valve? YES ☐ NO ☒

Pipe Size and Schedule: 1" SEE NOTE 3, Pipe Material: ____________
Approx. Valve Body Size: ____________ INCHES
Body Type: ____________

Valve Characteristic: Linear ☐ Equal Percentage ☐
Quick Opening ☐ Other: ____________

Is Tight Shut-Off Required? YES ☐ NO ☒
llowable Leakage: ____________
Is Handjack or Handwheel Required? YES ☐ NO ☐
Special Steam Packing Considerations: ____________

Valve Action On Loss of Power: Locks in Pos. ☐ Opens ☐ Closes ☒
Valve Action On Loss of Power air/or sensing fluid Opens ☐ Closes ☒

Form No. : Date: 4/24/80 JER (MDAC)

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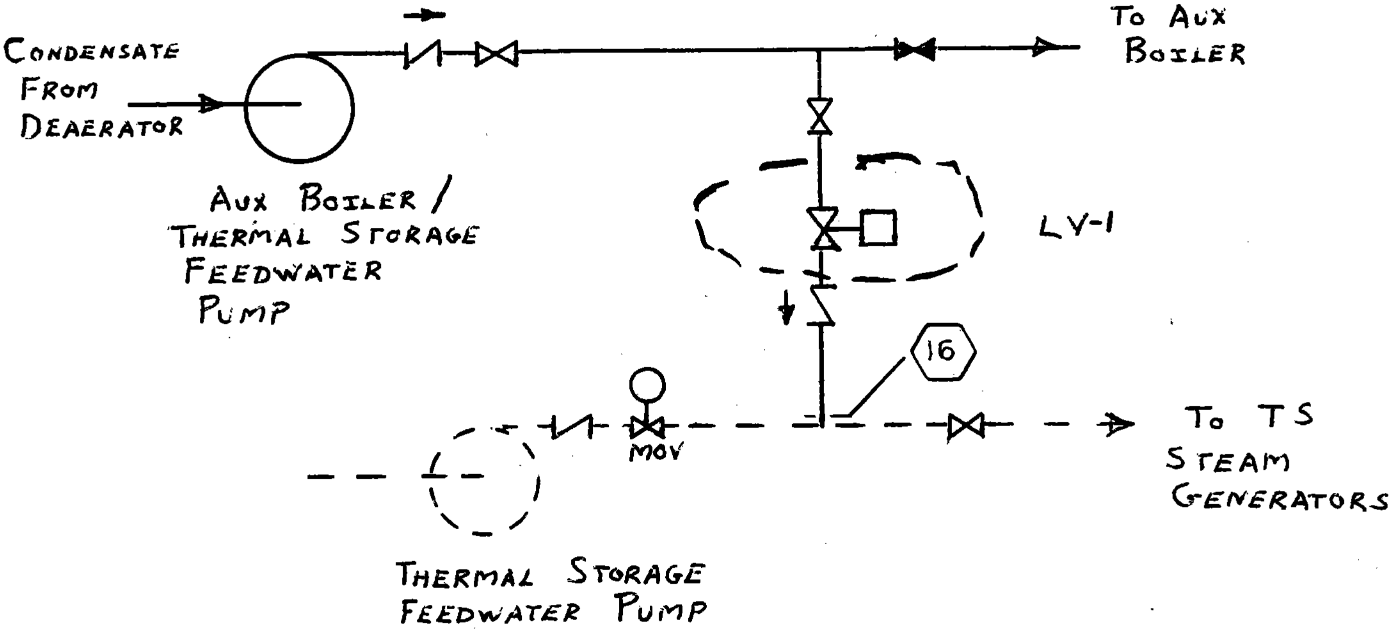
AUXILIARY STEAM CONDENSATE SUPPLY



NOTES ON VALVE LV-1

1. MAX DESIGN PRESSURE = 615 psia OCCURS WHEN THE TS FEEDWATER PUMP IS RECIRCULATING BACK TO THE DEAERATOR AND THE CHECK VALVE DOWNSTREAM OF LV-1 LEAKS.

2. MAX SHUTOFF PRESSURE OCCURS DURING HIGH DOWNSTREAM PRESSURE / LOW UPSTREAM PRESSURE CONDITION WHEN TS FEED PUMP IS OPERATING AND CHECK VALVE LEAKS.

$$\Delta P = \left(\text{MAX DOWNSTREAM PRESS}\right) - \left(\text{MIN DA PRESSURE}\right) - \left(\text{UPSTREAM GRAVITY HEAD FROM DA}\right)$$

$$\Delta P = 615\,\text{psia} - 20\,\text{psia} - \sim 10\,\text{psia} = 585\,\text{psi}$$

3. PER AGREEMENT WITH SCE (4/24/80), THE ENTIRE LINE CONTAINING THIS VALVE WILL BE 1 IN AND COMPLY WITH SCE PIPE SPEC "R".

RECEIVER SUBSYSTEM CALCULATIONS

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CALCULATION OF HEAT FLUX ENVIRONMENT ON HORIZONTAL PLANE ABOVE RECEIVER

- APPROACH

1) DEFINE ZONES OF FIELD AND IMPACT OF EACH ZONE ON RECEIVER FLUX

2) BREAKDOWN ZONE COMPONENTS INTO HORIZONTAL AND VERTICAL ELEMENTS

3) PROJECT COMPONENTS TO HORIZONTAL PLANE ABOVE THE RECEIVER

4) SUPERIMPOSE VERTICAL COMPONENTS THAT STRIKE SAME ZONE ON HORIZONTAL PLANE

5) INTEGRATE 360° FIELD OF VIEW THAT IS APPROPRIATE TO THE HORIZONTAL ZONE IN QUESTION

TRANSMITTED TO $\overline{R}$ 6/6/80

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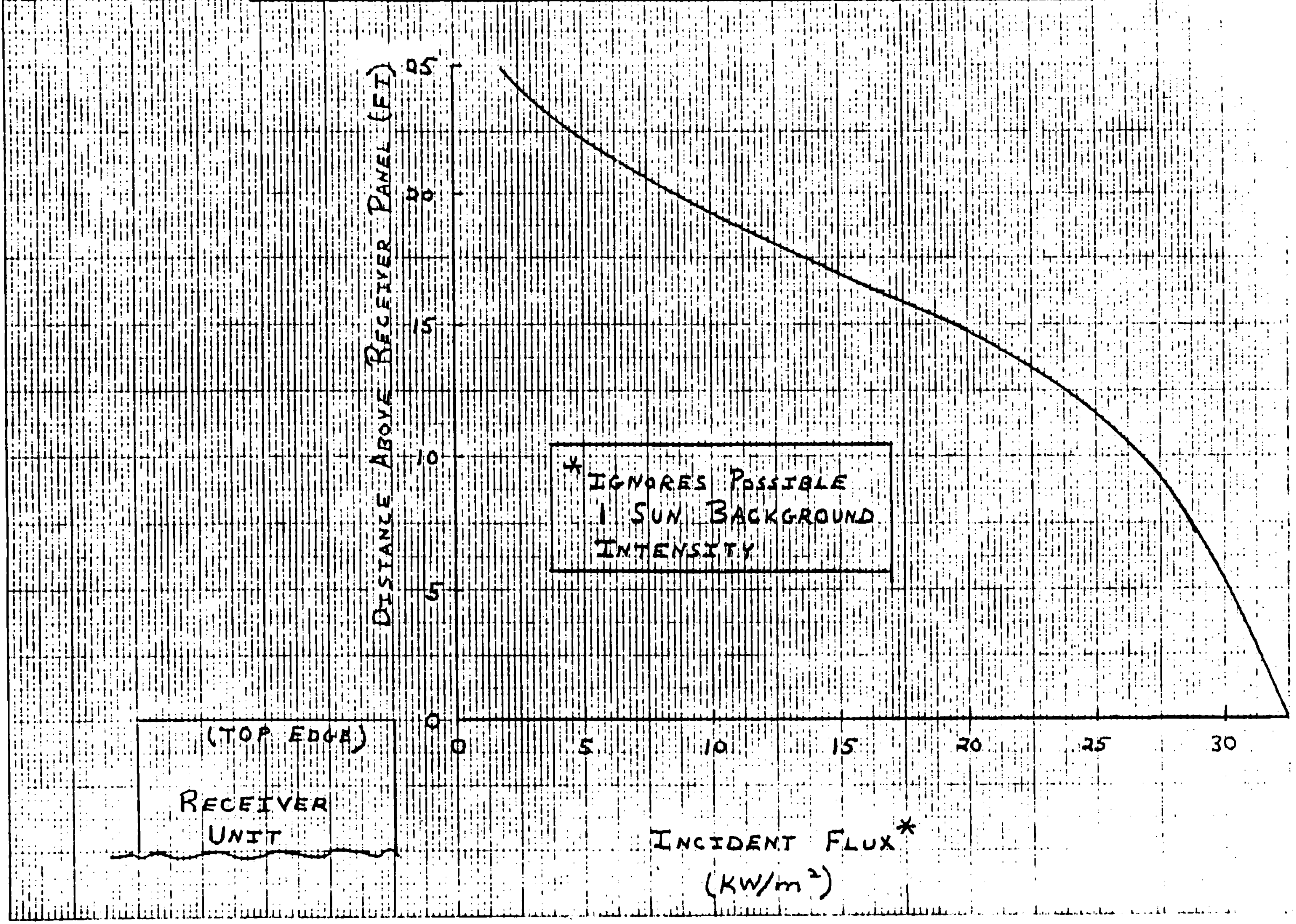
FIGURE 3.2-2 INCIDENT HEAT FLUX PROFILE ABOVE RECEIVER UNIT



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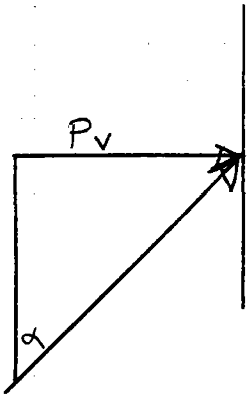

- DATA BASE EXPRESSED FOR VERTICAL SURFACE

- INTENSITY FROM DIRECTION i

$$C_i > 1$$

$$\sum C_i = 1 \quad \text{SUM TO UNITY}$$

- COMPONENT ATTRIBUTABLE TO i DIRECTION

$$P_{Vi} = C_i \; P_V$$

- PROJECTION BACK TO i DIRECTION

$$\overline{P}_{Vi} = \frac{P_{Vi}}{\cos\alpha_i} = \frac{C_i \, P_V}{\cos\alpha_i}$$

- PROJECTION INTO HORIZONTAL PLANE

$$\hat{P}_{Vi} = \overline{P}_{Vi} \,\text{SIN}\, \alpha_i = \frac{P_{Vi}}{\cos\alpha_i} \,\text{SIN}\, \alpha_i = C_i \, P_V \,\text{TAN}\, \alpha_i$$

$$\hat{P}_{Vi} = C_i \; P_V \;\text{TAN}\; \alpha_i$$

<u>PROGRAM LABEL FUNCTIONS</u>

LBL A	PARAMETER 1 —	$\alpha_1 = 15.8^\circ$ STO 01	$C_1 = 0.154$ STO 05
LBL B	PARAMETER 2 —	$\alpha_2 = 25.^\circ$ STO 02	$C_2 = 0.287$ STO 06
LBL C	PARAMETER 3 —	$\alpha_3 = 35^\circ$ STO 03	$C_3 = 0.296$ STO 07
LBL D	PARAMETER 4 —	$\alpha_4 = 44.3^\circ$ STO 04	$C_4 = 0.262$ STO 08
LBL E	ZERO COEFFICIENTS		

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$\hat{P}_{V1}$ STO 09

$\hat{P}_{V2}$ STO 10

$\hat{P}_{V3}$ STO 11

$\hat{P}_{V4}$ STO 12

PV_1 →

```
LBL
A
*
RCL
0
1
TAN
*
RCL
0
5
=
STO
0
9
HLT
```

PV_3 →

```
LBL
C
*
RCL
0
3
TAN
*
RCL
0
7
=
STO
1
1
HLT
```

```
LBL
A'
RCL
0
9
+
RCL
1
0
+
RCL
1
1
+
RCL
1
2
=
HLT
```

PV_2 →

```
LBL
B
*
RCL
0
2
TAN
*
RCL
0
6
=
STO
1
0
HLT
```

PV_4 →

```
LBL
D
*
RCL
0
4
TAN
*
RCL
0
8
=
STO
1
2
HLT
```

```
LBL
E
0
STO
0
9
STO
1
0
STO
1
1
STO
1
2
HLT
```

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POWER POINT SUMMARY (HORIZONTAL SURFACE)

(a)	1.42 KW/m^2	(-10 FT)
(b)	5.72 KW/m^2	(-1.5 FT)
(c)	12.3 KW/m^2	(3.5 FT)
(d)	20.3 KW/m^2	(6.5 FT)
(e)		
(f)	19.08 KW/m^2	(11.5 FT)
(g)		
(h)		
(i)	18.27 KW/m^2	(13.5 FT)
(j)	17.86 KW/m^2	(14.5 FT)
(k)	17.21 KW/m^2	(16.5 FT)
(l)	15.86 KW/m^2	(19 FT)
(m)	13.25 KW/m^2	(22 FT)
(n)	9.13 KW/m^2	(26 FT)

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SOUTH FIELD IMAGE SPILLAGE DATA BASE

LBL A	PARAMETER 1	$\alpha = 28.5^\circ$ STO 01	$C_1 = .318$ STO 04
LBL B	PARAMETER 2	$\alpha = 36.5^\circ$ STO 02	$C_2 = .336$ STO 05
LBL C	PARAMETER 3	$\alpha = 44.5^\circ$ STO 03	$C_3 = .346$ STO 06

POWER POINT SUMMARY (HORIZONTAL SURFACE)

(O)	3.04 KW/m²	(1.5 FT)
(P)	7.16 KW/m²	(4 FT)
(Q)	11.7 KW/m²	(6 FT)
(R)	11.4 KW/m²	(7 FT)
(S)	10.9 KW/m²	(8 FT)
(T)	10.8 KW/m²	(11.5 FT)
(U)	10.4 KW/m²	(14.5 FT)
(V)	10.2 KW/m²	(15.5 FT)
(W)	9.7 KW/m²	(17.5 FT)
(X)	8.9 KW/m²	(19 FT)
(Y)	7.8 KW/m²	(21.5 FT)
(Z)	5.6	(26 FT)

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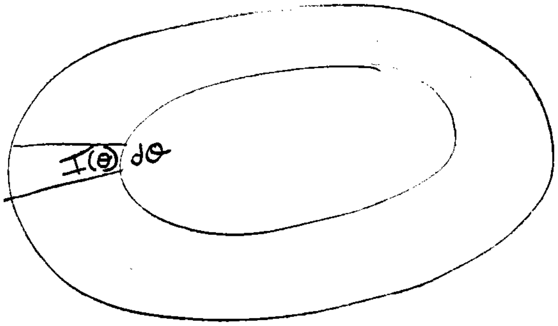
THREE DIMENSIONAL EFFECT



$$I_{TOT} = \int_0^{2\pi} I(\theta)\,d\theta$$

$$I(\theta) = I_0\, f(\theta)$$

$$f(\theta) = \cos\frac{\theta}{2}$$

HALF CONTRIBUTION

$$I_0 = 7 \text{ KW/m}^2$$

$$I_{TOT} = 2\int_0^{\pi} I_0 \cos\frac{\theta}{2}\,d\theta$$

$$= 2 I_0 \int_0^{\pi} \cos\frac{\theta}{2}\,d\theta$$

$$\frac{\theta}{2} = x \rightarrow \theta = 2x \rightarrow d\theta = 2dx$$

$$= 4 I_0 \int_0^{\pi/2} \cos x\,dx$$

$$= 4 I_0 \left[\sin x\right|_0^{\pi/2} = 4 I_0 [1 - 0]$$

$$I_{TOT} = 4 I_0 = 28 \text{ KW/m}^2$$

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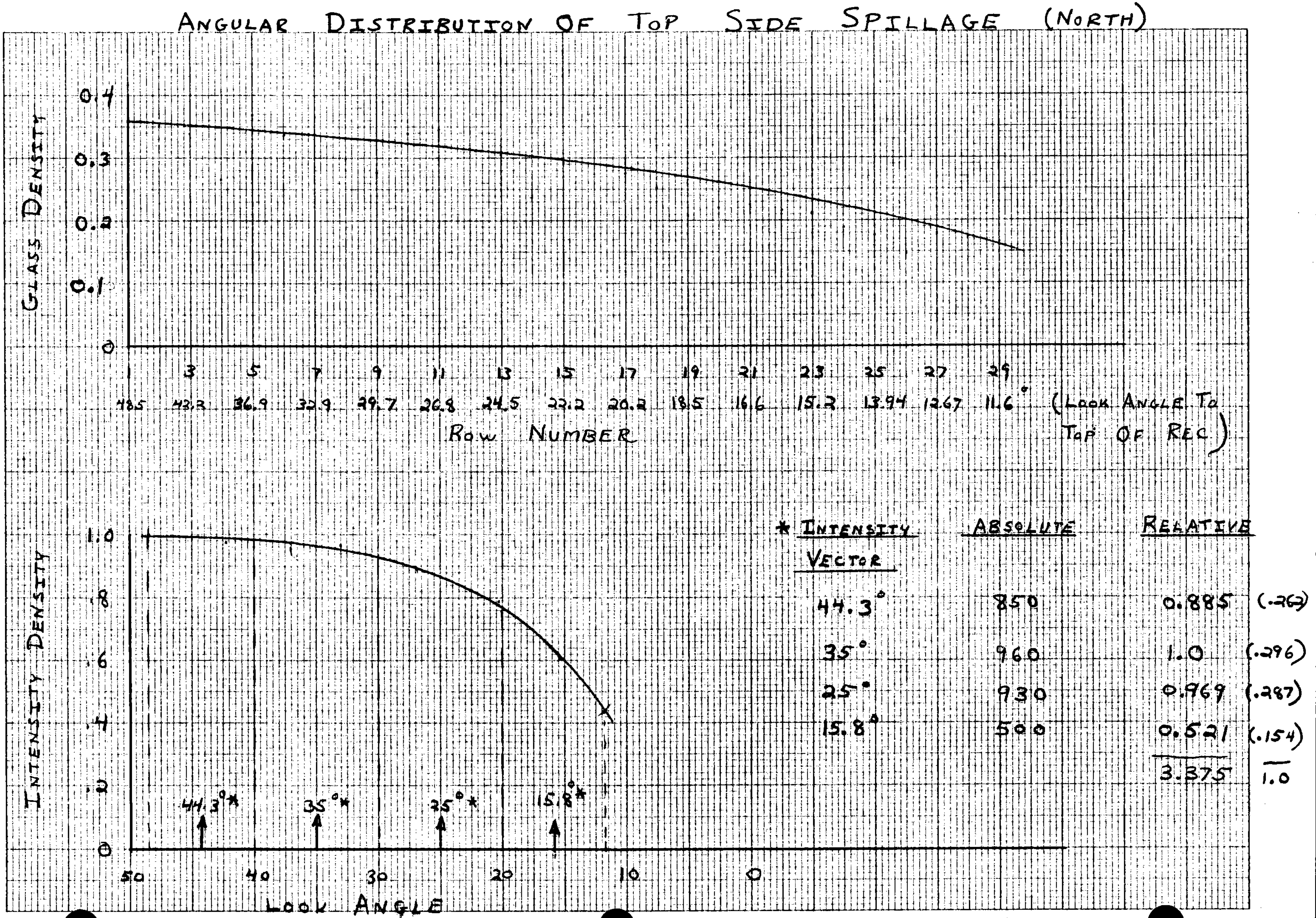
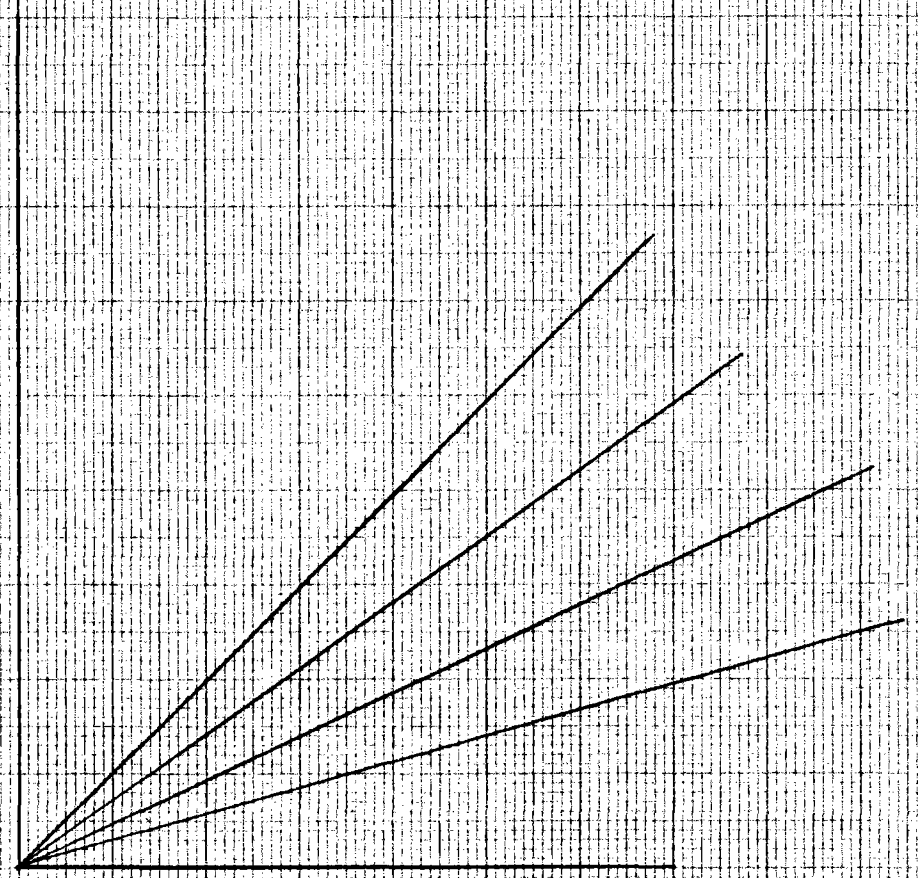
ANGULAR DISTRIBUTION OF TOP SIDE SPILLAGE (NORTH)



* INTENSITY VECTOR	ABSOLUTE	RELATIVE	
44.3°	850	0.885	(.262)
35°	960	1.0	(.296)
25°	930	0.969	(.287)
15.8°	500	0.521	(.154)
		3.375	1.0

NORTH FIELD INTENSITY VECTORS



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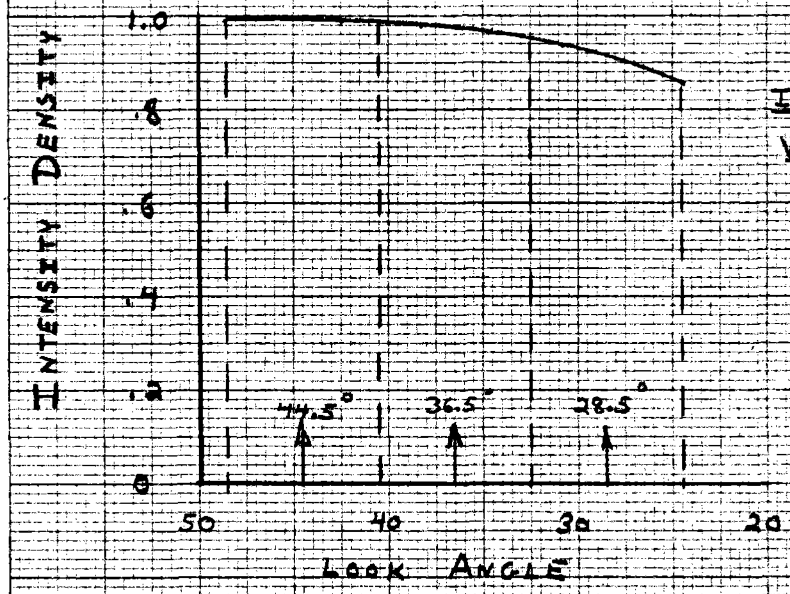
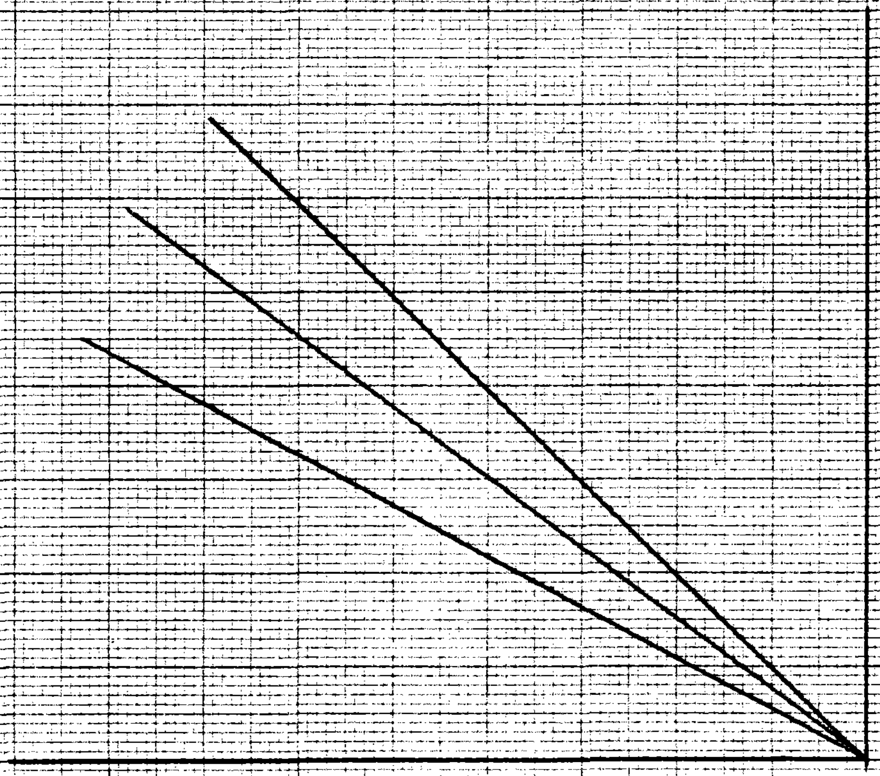
ANGULAR DISTRIBUTION OF TOP SIDE SPILLAGE (SOUTH)



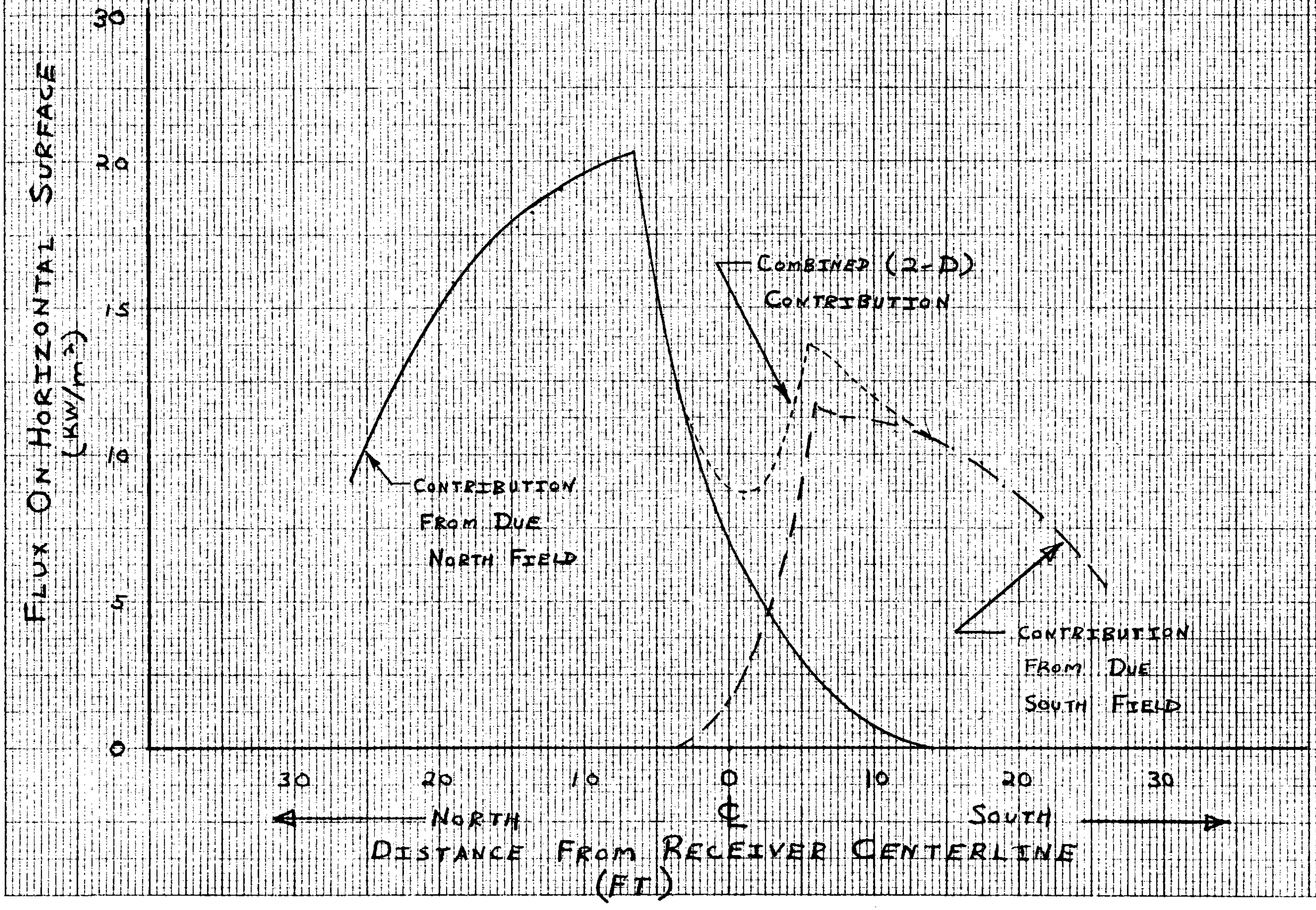
INTENSITY VECTOR	ABSOLUTE	RELATIVE	
44.5	800	1.00	(.346)
36.5	776	.97	(.336)
28.5	736	.92	(.318)
		2.89	

INTENSITY VECTORS



FLUX ON N-S DOWNWARD FACING SURFACE 6 FT ABOVE RECEIVER

(2 DIMENSIONAL ANALYSIS)



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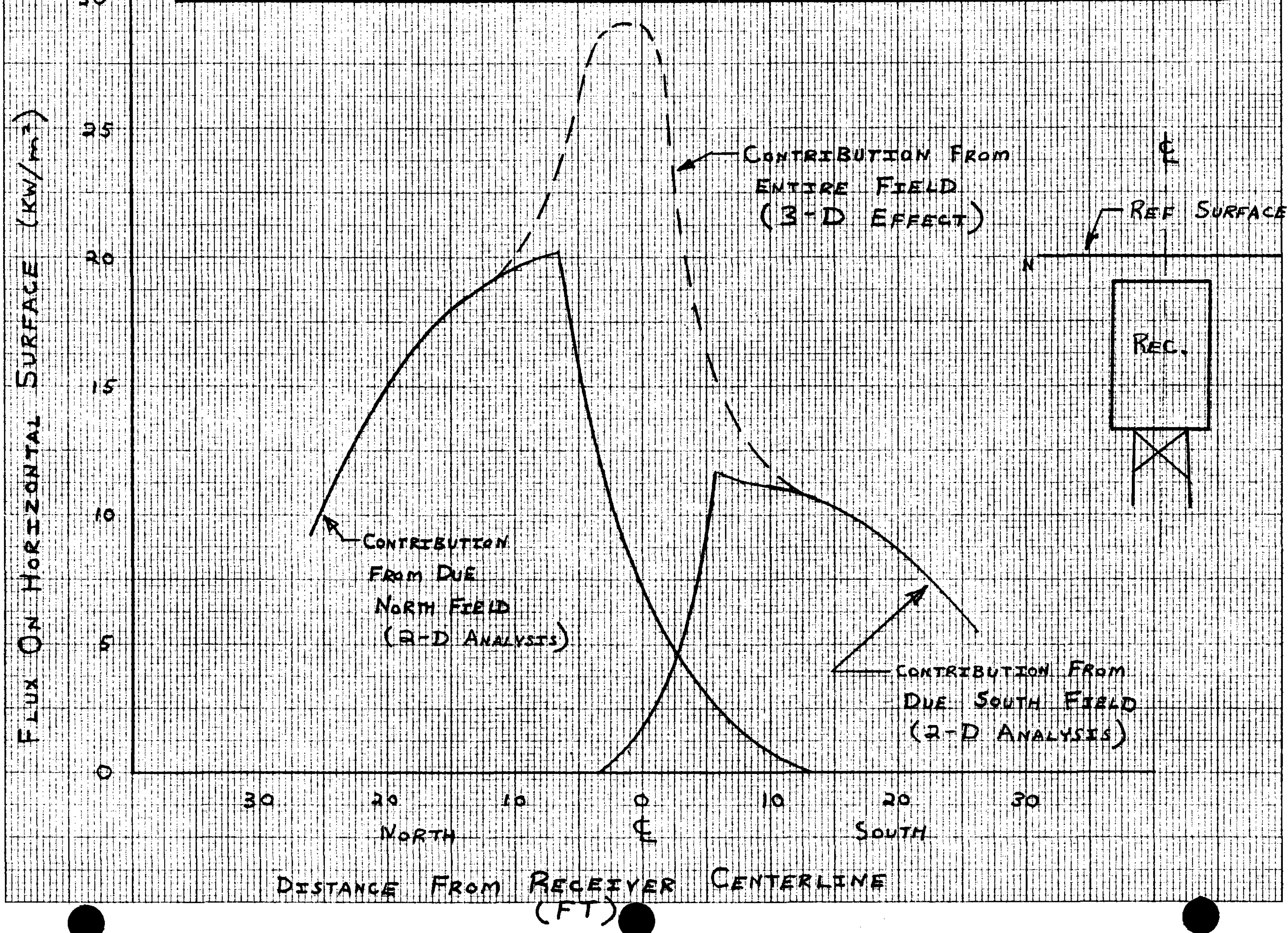
FLUX ON DOWNWARD FACING SURFACE 6 FEET ABOVE RECEIVER



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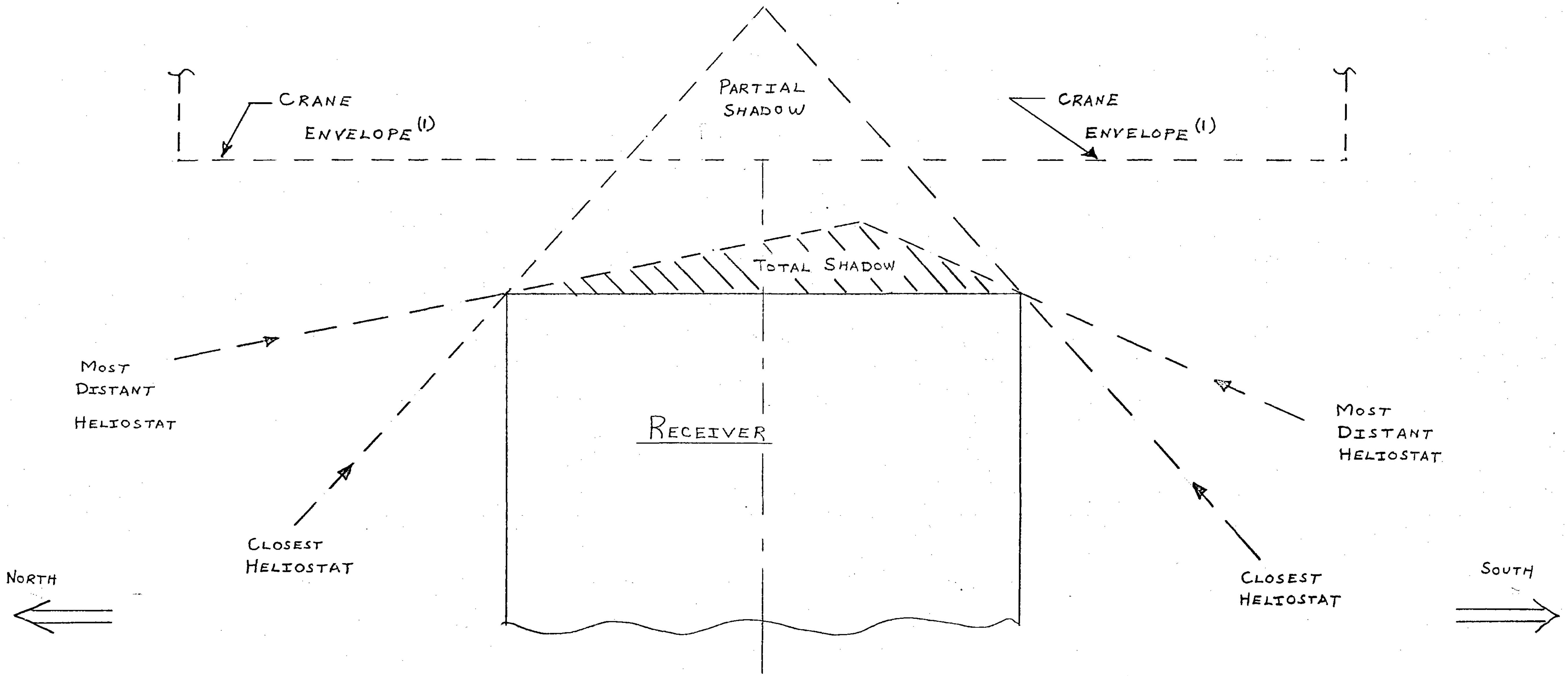
SCALE
10 FT

NOTES:

1. CRANE STOWED WITH BOOM POINTING SOUTH AND COUNTER WEIGHT POINTING NORTH



4/14/80
/ JFS

Recommended Receiver Flash Tank Design Criteria

- Tank Diameter - 26 In (ID)
- Max Steam Pressure - 600 psig
- Max Steam Temperature - 950°F (limited by interlock function)
- Design Basis - ASME Section Sec VIII Division 1
- Corrosion Allowance - 0*
- Material - Alloy Steel SA-335 P22 (2 1/4 Cr - 1 Mo)

* Tank wall thickness shall be minimized subject to the above design criteria to minimize thermal shock operating limitations.

Receiver Flash Tank Design and Operating Constraints

1. During receiver operation (steam flowing to the main steam downcomer) when the flash tank is out of service, the flash tank shall be maintained at a temperature of 465-675°F to permit an instantaneous flow switch over. With the above temperature conditioning constraint, any fluid condition from 300°F feedwater to 950°F steam could be introduced into the flash tank.

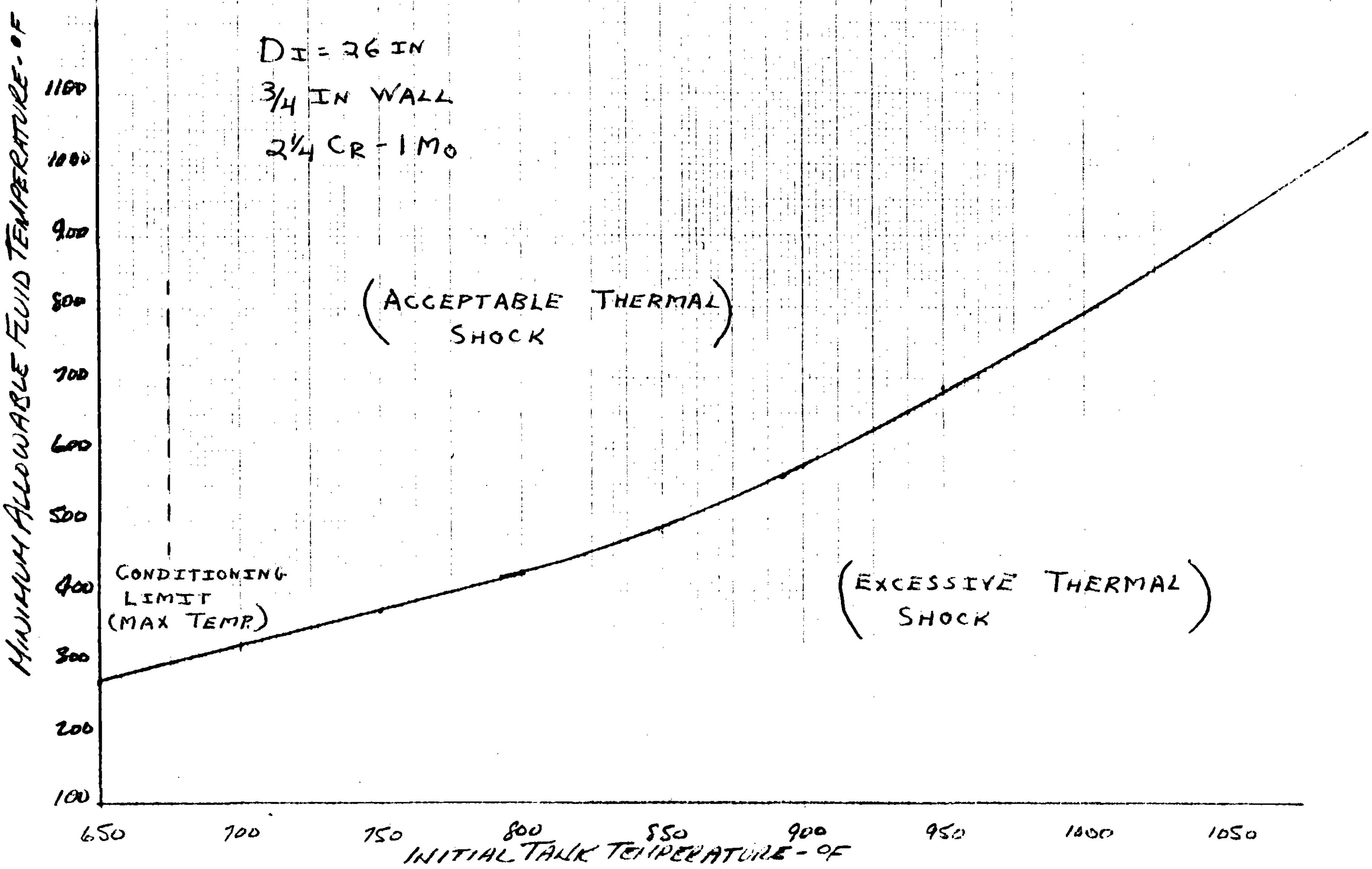
2. If bypass orifices are used to thermally condition the flash tank, the orifice isolation valve RFSOV must be configured with a remote actuator which will be closed during receiver startup to prevent the startup nitrogen charge from flowing to the condenser. The valve shall be interlocked to flash tank pressure in a manner in which it is commanded open when PT 2906A or B (select function) signal is greater than 500 psia.

3. If bypass orifices are used, the orifice isolation valve RFSIS must have a remote actuator to prevent GN_2 back flow into the receiver during initial flow circulation through PV-2002 (RWBV).

4. A 400 psig nitrogen line must be routed directly to the flash tank for tank pressurization during initial flow circulation.

ALLOWABLE INSTANTANEOUS WATER TEMPERATURE — "HOT" TANK

(ASSUMES BOILING HEAT TRANSFER)



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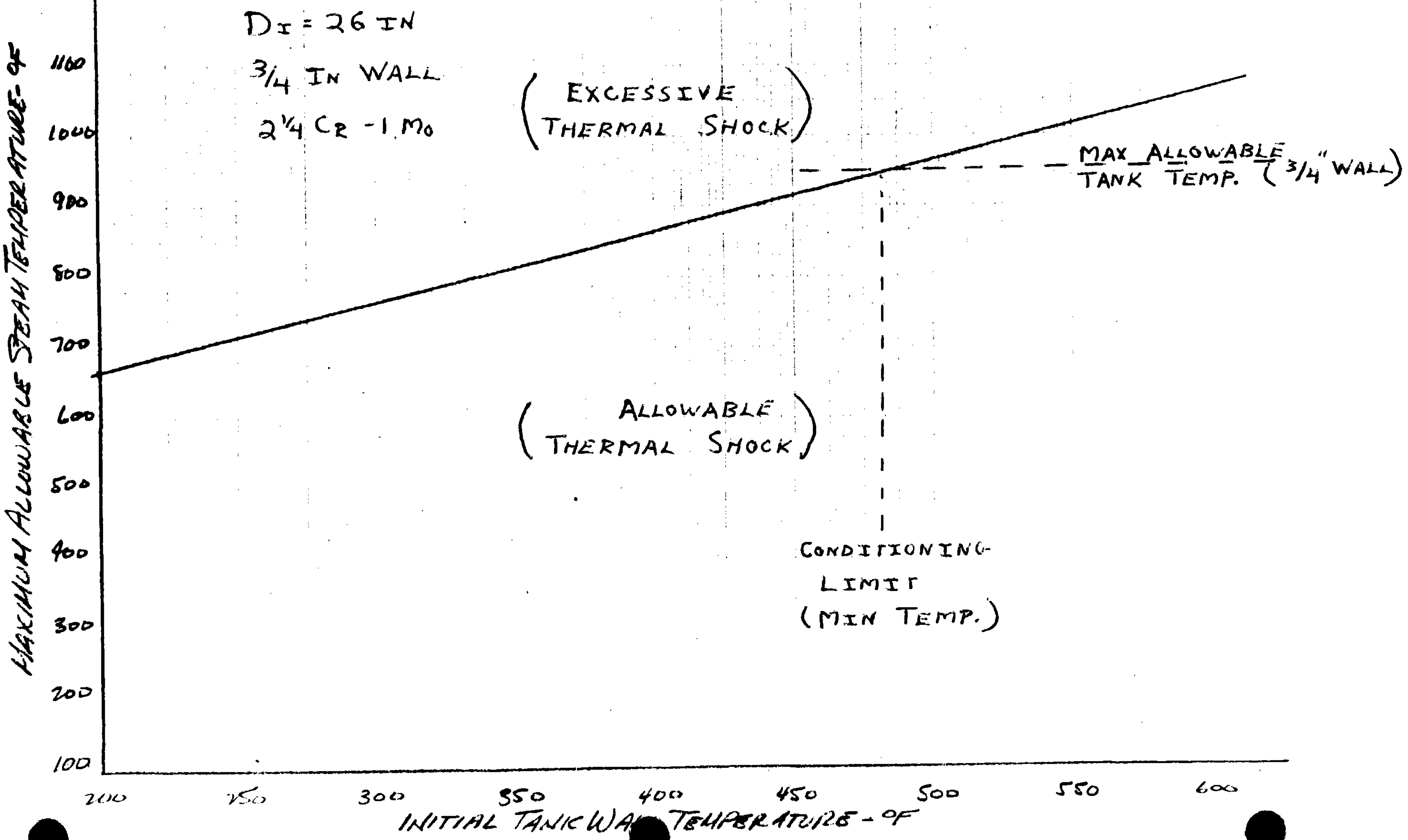
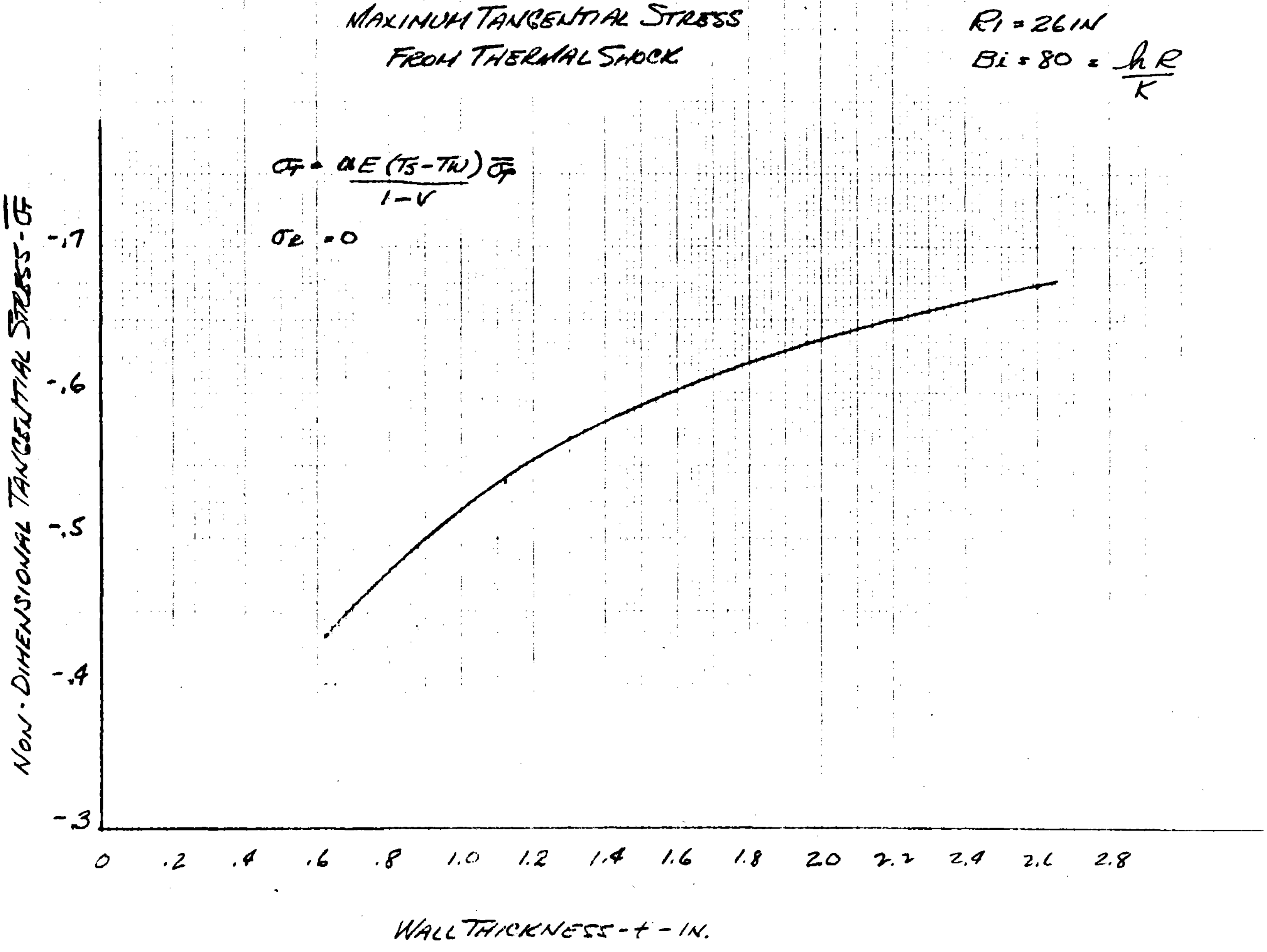
ALLOWABLE INSTANTANEOUS STEAM TEMPERATURE — "COLD" TANK

(ASSUMES CONDENSATION HEAT TRANSFER)




MAXIMUM TANGENTIAL STRESS
FROM THERMAL SHOCK
$R_1 = 26\,IN$
$Bi = 80 = \frac{hR}{K}$
$\sigma_T = \frac{\alpha E (T_S - T_W)}{1-\nu} \overline{\sigma_T}$
$\sigma_R = 0$
NON-DIMENSIONAL TANGENTIAL STRESS - $\overline{\sigma_T}$
-.7
-.6
-.5
-.4
-.3
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
WALL THICKNESS - t - IN.

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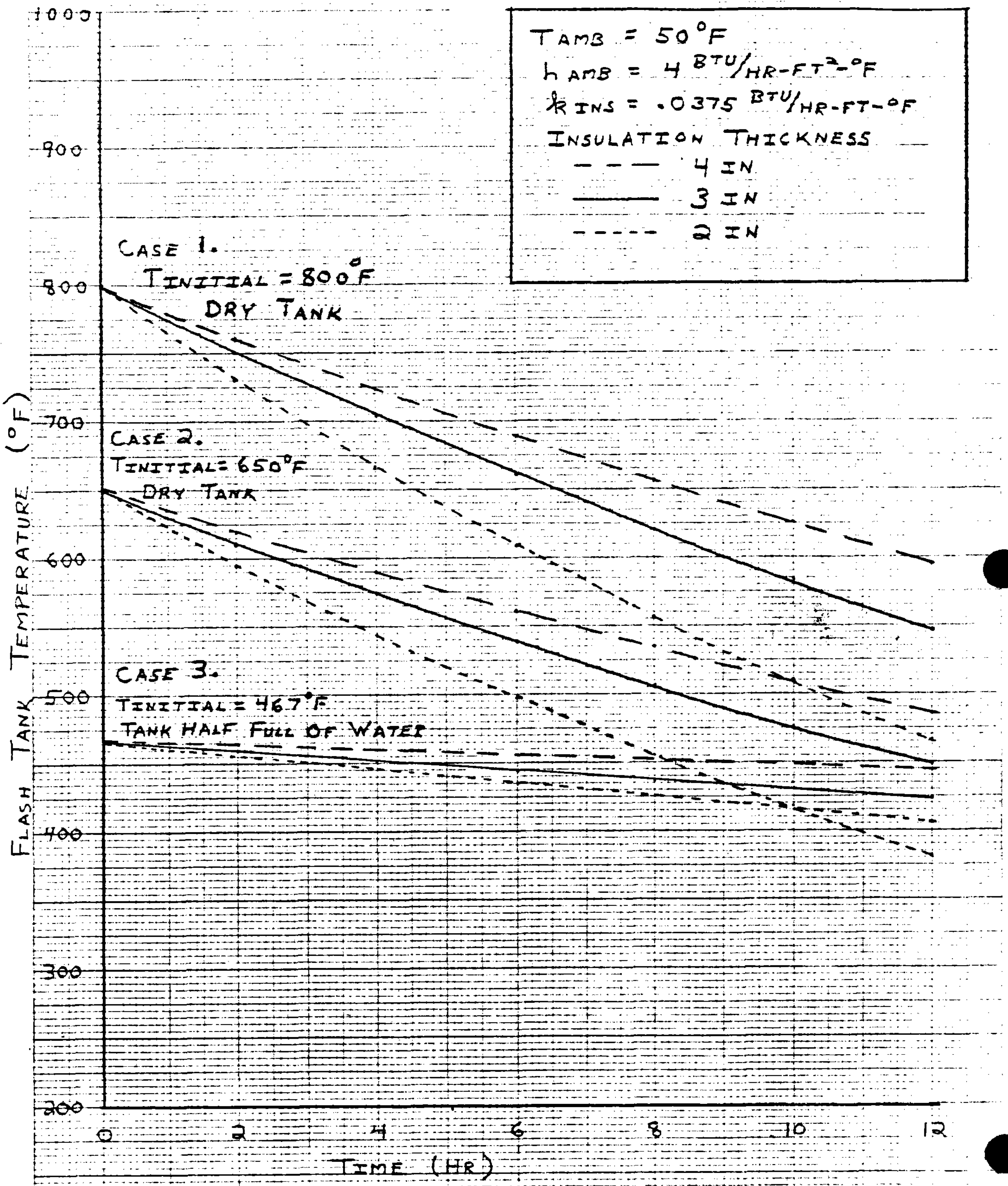
RECEIVER FLASH TANK TEMPERATURE DECAY
(NO ORIFICES)



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RECEIVER GN_2 PRESSURIZATION AND VENT ANALYSIS

OBJECTIVE:

- DEFINE THE QUANTITY OF GN_2 CONTAINED IN THE RECEIVER DURING STARTUP WHEN PRESSURIZATION IS REQUIRED TO PREVENT CAVITATION ACROSS THE CONTROL VALVES PRIOR TO APPLYING HEAT TO THE RECEIVER SURFACE

- CALCULATE FILL TIME (GN_2 PRESSURIZATION TIME) AS A FUNCTION OF GN_2 SYSTEM FLOW RATING
  → ESTABLISH FLOW RATE REQUIREMENT

- ESTIMATE THE RATE AT WHICH THE GN_2 WILL FLOW FROM THE FLASH TANK TO THE DEAERATOR AND CONDENSER ONCE STEAM PRESSURE BUILDS IN THE FLASH TANK

- DEFINE DEAERATOR VENTING IMPLICATIONS. TO PREVENT PLANT TRIP DUE TO A HIGH DEAERATOR PRESSURE.

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GN_2 VOLUME (UNMODIFIED DESIGN)

LINE DESCRIPTION	LENGTH	VOLUME (TOTAL)
1. HORIZONTAL MANIFOLD OUTLET SECTION TO MOISTURE SEPARATOR 3" Sch 160	7' (x18)	4.73 FT
2. MOISTURE SEPARATOR (ESTIMATED) 6" Sch XXS	1' (x18)	2.35 FT
3. MOISTURE SEPARATOR STEAM LINE TO 3 → 1 JUNCTION 2" Sch 80	24' (x18)	8.86 FT^3
4. STEAM LINE 3 → 1 JUNCTION TO MAIN STEAM LINE 4" Sch 160	4.5' (x6)	1.74 FT^3
5. MAIN STEAM LINE 6" XXS	9' (x1)	1.18 FT^3
6. SAFETY VALVE INLET LINES 3" Sch 160 (ESTIMATED)	2' (x2)	0.15 FT^3

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3 OF 11

GN_2 VOLUME (UNMODIFIED DESIGN)

LINE DESCRIPTION	LENGTH	VOLUME-(TOTAL)
7. STEAM LINE TO FLASH TANK 4" XXS (ASSUME ALL "HORIZONTAL" PIPING SHOWN WITH 30° PROJECTION)		
HORIZONTAL [÷ .866]	$\frac{25}{.866} = 28.86'$	
VERTICAL	$29.70'$ $58.56'$	3.17 FT^3
8. MOISTURE SEPARATOR WATER OUTLET TO RING MANIFOLD 1" Sch 80 (DIFFERENT DESIGN FROM P+ID)		
HORIZONTAL [÷ .866]	$15/.866 = 17.32'$	
VERTICAL	$12'$ $29.32'$ (x18)	2.63 FT^3
9. RING MANIFOLD (CENTERLINE DIAMETER = 3.2 FT → EQUIVALENT STRAIGHT LENGTH 3" XXS	$10.05'$	0.29 FT^3

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GN2 VOLUME (UNMODIFIED DESIGN)

LINE DESCRIPTION	LENGTH	VOLUME
10. WATER LINE FROM RING MANIFOLD TO FLASH TANK		
3" Sch 160		
HORIZONTAL (÷ .866) 30 FT	34.64'	
VERTICAL	32.50'	
	67.14	2.52 FT^3
11. RECEIVER FLASH TANK (ESTIMATED MINIMUM ACCEPTABLE VOID VOLUME)		
FILL TO WITHIN 3' OF THE TOP		
26" TANK ID		11.06 FT^3
TOTAL GN2 VOLUME		38.68 FT^3

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VOLUME FILL TIME TO 400 psia (GN_2)

$$SCF = 38.68\ FT^3 \left(\frac{400}{14.7}\right) = 1052\ SCF$$

FILL TIME	GN_2 SYSTEM CAPACITY
21.05 min	50 SCFM
10.52 MIN	100 SCFM
5.26 MIN	200 SCFM
3.51 MIN	300 SCFM

3/1/80
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ESTIMATED DEAERATOR VENT VALVE REQUIREMENTS

$$C_V = \frac{q_m' \sqrt{S_g T_1}}{13.9 P_1}$$

GAS SERVICE
CHOKED FLOW

S_g = SPEC GRAVITY REL TO AIR = .97 FOR GN_2
T_1 = ABSOLUTE TEMP °R
P_1 = UPSTREAM (INLET) PRESSURE (PSIA)
q_m' = GAS FLOW (SCFM)

ASSUME $P_1 = 50 \text{psia}$
$T_1 = 281 + 460 = 741 \text{°R}$

$$C_V = q_m' \left(\frac{\sqrt{(.97)(741)}}{(13.9)(50)}\right) = .03858\ q_m'$$

STEAM LOSS ($^{LB}/_{HR}$)	C_V	q_m'	ESTIMATED VALVE SIZE	VENT TIM
175.6 [.39 gpm]	1.93	50 SCFM	3/4"	21.0 MIN
351 [.78 gpm]	3.86	100	3/4"	10.52 MI
702 [1.56 gpm]	7.72	200	3/4"	5.26
1404 [3.12 gpm]	15.43	400	1½"	2.63
2105 [4.68 gpm]	23.14	600	1½ - 2"	1.75
2808 [6.24 gpm]	30.86	800	2"	1.32
3510 [7.80 gpm]	38.57	1000	2 - 3"	1.05

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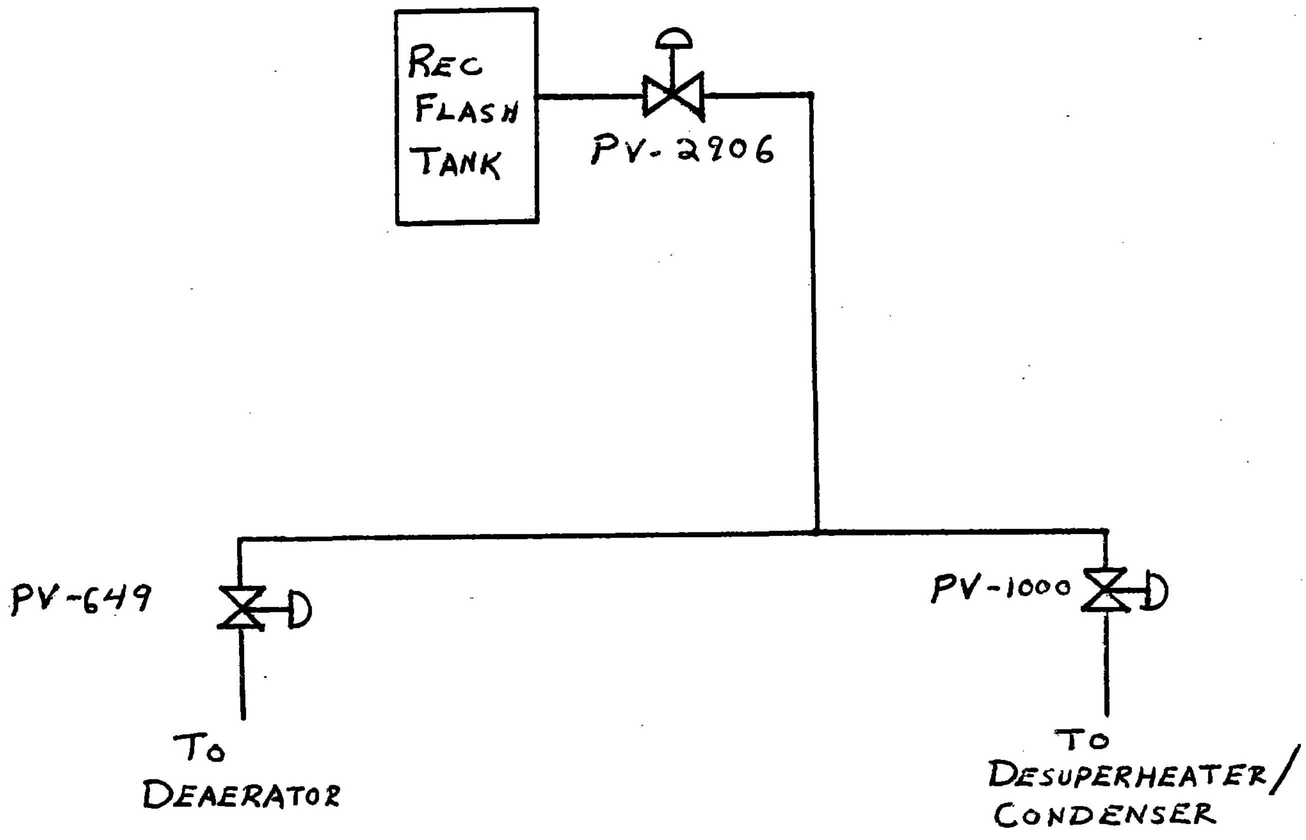
RECEIVER FLASH TANK VENT CONTROL NETWORK



VALVE (BASED ON STEAM DUTY)	Cv
PV-2906	Cv = 18.5 – 185
PV-649	Cv = 1.33 – 10.49
PV-1000	Cv = 7.89 – 78.89

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VALVE PV-2906
(ASSUME VALVE WIDE OPEN, CHOKED FLOW)

ASSUME $P_1 = 500$ psia $T_1 = 467 + 460 = 927\ ^\circ R$

$S_g = .97$

$$q'_m = \frac{(13.9)\ P_1\ C_V}{\sqrt{S_g\ T_1}}$$

$$= \frac{(13.9)(500)(185)}{\sqrt{(.97)(927)}}$$

VENT R[illegible]

$= 42877$ SCFM @ $C_V = 185$ 1.47 Sec

$= 4287$ SCFM @ $C_V = 18.5$ 14.7 Se[illegible]

ASSUME $P_2 = 450$ psia (NOT CHOKED)

$$q'_m = 16\ C_V \sqrt{\frac{\Delta P\ (P_1 + P_2)}{T_1\ S_g}}$$

$$= 16 \sqrt{\frac{50\ (950)}{927\ (.97)}}\ C_V = (116.3)\ C_V$$

VENT R[illegible]

$= 21513$ SCFM @ $C_V = 185$ 2.93 SEC

$= 2151$ SCFM @ $C_V = 18.5$ 29.3 S[illegible]

3/1/80
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VALVE PV-649

(ASSUME VALVE WIDE OPEN AND CHOKED)

ASSUME $P_1 = 380$ psia $T_1 = 467°F + 460 = 927°R$

$P_2 = 50$ psia $S_g = .97$

$$q'_m = \frac{(13.9)(380\text{psia})(10.49)}{\sqrt{(.97)(927)}}$$

VENT RATE

$= 1847$ SCFM @ $C_v = 10.49$ 34.1 Sec

$= 234$ SCFM @ $C_v = 1.33$ 270 Sec

VALVE PV-1000

(ASSUME $P_1 = 380$ psia $T_1 = 467 + 460 = 927°R$

$P_2 = 5$ psia $S_g = .97$)

$$\dot{q}_m = \frac{(13.9)(380\text{psia})(78.89)}{\sqrt{(.97)(927)}}$$

VENT RATE

$= 13896$ SCFM @ $C_v = 78.89$ 4.5 SEC

$= 1389$ SCFM @ $C_v = 7.89$ 45 SEC

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CONDENSER VACUUM SYSTEM CAPABILITY
(PER BOB WILLIAMSON 1/30/80)

7.5 SCFM @ 1"Hg CONDENSER PRESSURE
170 SCFM @ 10"Hg TRIP PRESSURE
(4.91psia)

GN_2 REMOVAL RATE = 140 MIN @ 7.5 SCFM
(1"Hg)

= 6.19 MIN @ 170 SCFM
(10"Hg)

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CONSIDER VENT OPERATION THROUGH RMSVV-1
(POWER VENT VALVE PV 2902)

$C_V = 65$

ASSUME $P_1 = 500 psia$ $T_1 = 467°F + 460°R = 927°R$
$P_2 = ATM$ $S_g = .97$

$$q_m' = \frac{(13.9)(500 psia)(65)}{\sqrt{(.97)(927)}}$$

VENT TIME

= 15065 SCFM @ 500psia 4.2 SEC

= 12052 SCFM @ 400psia 5.2 SEC

2/10/80
1 OF 7

RECEIVER PANEL BY PANEL POWER SUMMARY

(ESTIMATED IMPACT OF REDUCING THE COLLECTOR FIELD SIZE)

OBJECTIVE:

ESTIMATE THE IMPACT OF REDUCED COLLECTOR FIELD SIZING ON RECEIVER PANEL POWER.

DEVELOP SUFFICIENT DATA TO DEFINE ANTICIPATED PANEL GRADIENTS.

2/1[illegible]80

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RECEIVER PANEL POWER COMPARISON TABLE

INCIDENT POWER — MWt

SUMMER NOON
(DAY 93)

RECEIVER PANEL (CLOCKWISE FROM SOUTH)	COLLECTOR FIELD DEFINED ON 30 JULY 1979 (1968 MMC HELIOSTATS) ASSUMPTIONS: $\rho_{HELIO} = .86$ $\alpha_{REC} = .93$ CONTINGENCY = 32 HELIO. (10 MWe WINTER 2PM) 1.8 MWe PARASITIC	COLLECTOR FIELD DEFINED ON 18 DEC 1979 (1818 MMC HELIOSTATS) ASSUMPTIONS: $\rho_{HELIO} = .89$ $\alpha_{REC} = .95$ CONTINGENCY = 0 (10 MWe WINTER 2PM) 1.7 MWe PARASITIC	POTENTIAL (FUTURE) REDUCED POWER COLLECTOR FIELD ESTIMATED VALUES ASSUMPTIONS: $\rho_{HELIO} = .89$ $\alpha_{REC} = .95$ CONTINGENCY = 0 (10 MWe WINTER NOON) 1.7 MWe PARASITIC
1	.984	.736	.707
2	1.116	.913	.876
3	1.347	1.171	1.124
4	1.569	1.444	1.229
5	1.788	1.689	1.438
6	2.063	1.925	1.639
7	2.382	2.236	1.904
8	2.686	2.589	2.204
9	2.892	2.862	2.437
10	2.984	3.009	2.562
11	2.957	3.040	2.588
12	2.910	2.997	2.552
13	2.912	2.997	2.553
14	2.960	3.040	2.588
15	2.990	3.009	2.562
16	2.902	2.862	2.437
17	2.696	2.589	2.204
18	2.392	2.236	1.904
19	2.071	1.925	1.639
20	1.792	1.689	1.438
21	1.571	1.444	1.229
22	1.348	1.171	1.124
23	1.116	.913	.876
24	.984	.736	.707
TOTAL	51.411	49.223	43.243

WORKSHEET

2/10/80

3 OF 7

RECEIVER PANEL POWER COMPARISON TABLE

INCIDENT POWER — MW_t

SUMMER — 10°
AFTERNOON SUN
(DAY 93 — 6.28 PM)

RECEIVER PANEL (CLOCKWISE FROM SOUTH)	COLLECTOR FIELD DEFINED ON 30 JULY 1979 (1968 MMC HELIOSTATS) ASSUMPTIONS: ρ_{HELIO} = .86 α_{REC} = .93 CONTINGENCY = 32 HELIO. (10 MWe WINTER 2 PM) 1.8 MWe PARASITIC	COLLECTOR FIELD DEFINED ON 18 DEC 1979 (1818 MMC HELIOSTATS) ASSUMPTIONS: ρ_{HELIO} = .89 α_{REC} = .95 CONTINGENCY = 0 (10 MWe WINTER 2 PM) 1.7 MWe PARASITIC	POTENTIAL (FUTURE) REDUCED POWER COLLECTOR FIELD <u>ESTIMATED VALUES</u> ASSUMPTIONS: ρ_{HELIO} = .89 α_{REC} = .95 CONTINGENCY = 0 (10 MWe WINTER NOON) 1.7 MWe PARASITIC
1	.327	.247	.237
2	.363	.304	.292
3	.419	.373	.358
4	.442	.418	.356
5	.433	.421	.358
6	.421	.398	.339
7	.425	.398	.339
8	.460	.439	.374
9	.526	.518	.441
10	.617	.633	.539
11	.706	.750	.639
12	.792	.834	.710
13	.881	.914	.778
14	.993	1.022	.870
15	1.114	1.115	.949
16	1.159	1.135	.966
17	1.093	1.034	.880
18	.952	.870	.741
19	.802	.749	.638
20	.678	.664	.565
21	.578	.558	.475
22	.480	.438	.420
23	.386	.328	.315
24	.333	.253	.243
TOTAL	15.381	14.814	13.014

2/10/[illegible]0
7 OF 7

RECEIVER PANEL POWER
COMPARISON TABLE

INCIDENT POWER — MW_t

EQUINOX
NOON
(DAY 186)

RECEIVER PANEL (CLOCKWISE FROM SOUTH)	COLLECTOR FIELD DEFINED ON 30 JULY 1979 (1968 MMC HELIOSTATS) ASSUMPTIONS: ρ_{HELIO} = .86 α_{REC} = .93 CONTINGENCY = 32 HELIO. (10 MWe WINTER 2 PM) 1.8 MWe PARASITIC	COLLECTOR FIELD DEFINED ON 18 DEC 1979 (1818 MMC HELIOSTATS) ASSUMPTIONS: ρ_{HELIO} = .89 α_{REC} = .95 CONTINGENCY = 0 (10 MWe WINTER 2 PM) 1.7 MWe PARASITIC	POTENTIAL (FUTURE) REDUCED POWER COLLECTOR FIELD ESTIMATED VALUES ASSUMPTIONS: ρ_{HELIO} = .89 α_{REC} = .95 CONTINGENCY = 0 (10 MWe WINTER NOON) 1.7 MWe PARASITIC
1	.821	.621	.596
2	.943	.776	.745
3	1.162	1.015	.974
4	1.392	1.280	1.090
5	1.640	1.541	1.312
6	1.963	1.818	1.548
7	2.343	2.189	1.864
8	2.712	2.608	2.220
9	2.981	2.946	2.508
10	3.121	3.151	2.683
11	3.127	3.221	2.742
12	3.095	3.197	2.722
13	3.097	3.197	2.722
14	3.131	3.221	2.742
15	3.129	3.151	2.683
16	2.990	2.946	2.508
17	2.723	2.608	2.220
18	2.353	2.189	1.864
19	1.970	1.818	1.548
20	1.644	1.541	1.312
21	1.393	1.280	1.090
22	1.163	1.015	.974
23	.943	.778	.745
24	.821	.621	.596
TOTAL	50.657	48.728	42.809

2/10/ 0
1.5 of 7

RECEIVER PANEL POWER COMPARISON TABLE

INCIDENT POWER — MW_t

EQUINOX — 10°
AFTERNOON
SUN
(DAY 186 —
5.17 PM)

RECEIVER PANEL (CLOCKWISE FROM SOUTH)	COLLECTOR FIELD DEFINED ON 30 JULY 1979 (1968 MMC HELIOSTATS) ASSUMPTIONS: ρ_{HELIO} = .86 α_{REC} = .93 CONTINGENCY = 32 HELIO. (10 MWe WINTER 2 PM) 1.8 MWe PARASITIC	COLLECTOR FIELD DEFINED ON 18 DEC 1979 (1818 MMC HELIOSTATS) ASSUMPTIONS: ρ_{HELIO} = .89 α_{REC} = .95 CONTINGENCY = 0 (10 MWe WINTER 2 PM) 1.7 MWe PARASITIC	POTENTIAL (FUTURE) REDUCED POWER COLLECTOR FIELD ESTIMATED VALUES ASSUMPTIONS: ρ_{HELIO} = .89 α_{REC} = .95 CONTINGENCY: 0 (10 MWe WINTER NOON) 1.7 MWe PARASITIC
1	.346	.267	.256
2	.338	.278	.267
3	.347	.306	.294
4	.351	.329	.280
5	.368	.351	.299
6	.428	.388	.330
7	.539	.482	.410
8	.694	.653	.556
9	.856	.847	.721
10	.981	1.001	.852
11	1.050	1.094	.931
12	1.120	1.181	1.005
13	1.225	1.314	1.119
14	1.325	1.425	1.213
15	1.350	1.422	1.211
16	1.291	1.314	1.119
17	1.185	1.174	1.000
18	1.042	1.032	.879
19	.889	.870	.758
20	.753	.766	.652
21	.652	.646	.550
22	.559	.523	.502
23	.460	.402	.385
24	.386	.306	.294
TOTAL	18.535	18.391	16.157

2/10/ 0
6 OF 7

RECEIVER PANEL POWER COMPARISON TABLE

INCIDENT POWER — MW$_t$

WINTER NOON
(DAY 276)

RECEIVER PANEL (CLOCKWISE FROM SOUTH)	COLLECTOR FIELD DEFINED ON 30 JULY 1979 (1968 MMC HELIOSTATS) ASSUMPTIONS: ρ_{HELIO} = .86 α_{REC} = .93 CONTINGENCY = 32 HELIO. (10 MWe WINTER 2PM) 1.8 MWe PARASITIC	COLLECTOR FIELD DEFINED ON 18 DEC 1979 (1818 MMC HELIOSTATS) ASSUMPTIONS: ρ_{HELIO} = .89 α_{REC} = .95 CONTINGENCY = 0 (10 MWe WINTER 2PM) 1.7 MWe PARASITIC	POTENTIAL (FUTURE) REDUCED POWER COLLECTOR FIELD ESTIMATED VALUES ASSUMPTIONS: ρ_{HELIO} = .89 α_{REC} = .95 CONTINGENCY = 0 (10 MWe WINTER NOON) 1.7 MWe PARASITIC
1	.651	.496	.476
2	.765	.636	.610
3	.978	.856	.822
4	1.221	1.117	.951
5	1.498	1.392	1.185
6	1.350	1.700	1.447
7	2.262	2.099	1.787
8	2.662	2.540	2.162
9	2.957	2.900	2.469
10	3.118	3.120	2.656
11	3.136	3.202	2.726
12	3.114	3.186	2.712
13	3.115	3.186	2.712
14	3.141	3.202	2.726
15	3.126	3.120	2.656
16	2.967	2.900	2.469
17	2.673	2.540	2.162
18	2.272	2.099	1.787
19	1.857	1.700	1.447
20	1.501	1.392	1.185
21	1.222	1.117	.951
22	.978	.856	.822
23	.765	.636	.610
24	.651	.496	.476
TOTAL	48.482	46.487	40.840

FORM 30-1030 (REV 10-67)

2/10/ 0

70A7

RECEIVER PANEL POWER COMPARISON TABLE

INCIDENT POWER — MW_t

WINTER ~ 10°
AFTERNOON
SUN
(DAY 276 —
3.85 PM)

RECEIVER PANEL (CLOCKWISE FROM SOUTH)	COLLECTOR FIELD DEFINED ON 30 JULY 1979 (1968 MMC HELIOSTATS) ASSUMPTIONS: $\rho_{HELIO} = .86$ $\alpha_{REC} = .93$ CONTINGENCY = 32 HELIO. (10 MWe WINTER 2PM) 1.8MW PARASITIC	COLLECTOR FIELD DEFINED ON 18 DEC 1979 (1818 MMC HELIOSTATS) ASSUMPTIONS: $\rho_{HELIO} = .89$ $\alpha_{REC} = .95$ CONTINGENCY = 0 (10 MWe WINTER 2PM) 1.7MWe PARASITIC	POTENTIAL (FUTURE) REDUCED POWER COLLECTOR FIELD ESTIMATED VALUES ASSUMPTIONS: $\rho_{HELIO} = .89$ $\alpha_{REC} = .95$ CONTINGENCY = 0 (10 MWe WINTER NOON) 1.7MWe PARASITIC
1	.274	.203	.195
2	.269	.218	.209
3	.300	.258	.248
4	.344	.312	.266
5	.419	.386	.329
6	.556	.513	.437
7	.741	.704	.599
8	.921	.879	.765
9	1.051	1.057	.900
10	1.149	1.190	1.013
11	1.228	1.313	1.118
12	1.276	1.399	1.191
13	1.297	1.420	1.209
14	1.313	1.409	1.200
15	1.330	1.392	1.185
16	1.299	1.327	1.130
17	1.201	1.177	1.002
18	1.061	1.002	.853
19	.935	.876	.746
20	.823	.787	.670
21	.701	.665	.566
22	.557	.509	.489
23	.418	.358	.344
24	.323	.248	.238
TOTAL	19.784	19.621	17.238

2/5/80
1 OF 16

RECEIVER TEMPERATURE HISTORY DURING LOSS OF ELECTRICAL POWER

- THIS PACKAGE DEFINES RECEIVER METAL TEMPERATURE HISTORIES DURING LOSS OF COOLANT AND COLLECTOR FIELD ELECTRICAL POWER.

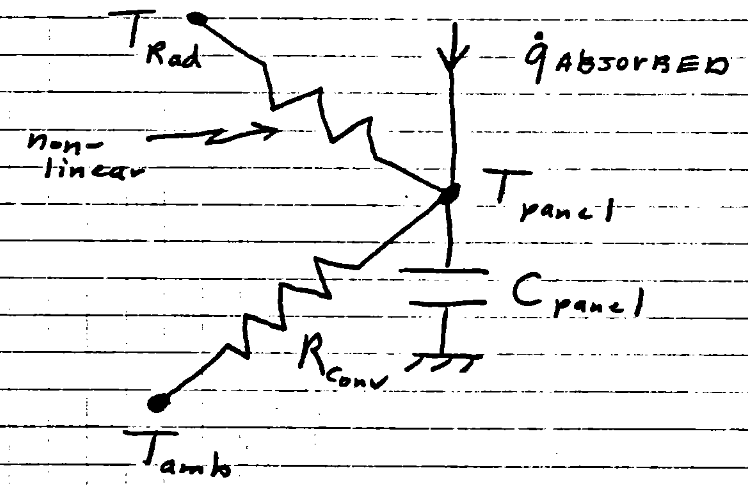
- THE FOLLOWING PARAMETRIC CASES ARE TREATED

(STANDBY POINT 2½ REC. DIAMETERS FROM REC CENTERLINE)			(STANDBY POINT 5½ REC. DIA. FROM REC. ℄)		
[POWER SWITCHOVER TIME]	+	[MEM. RELOAD TIME]	[PWR SWITCHOVER TIME]	+	[MEM RELOAD TIME]
30 SEC	+	135 SEC	30 SEC	+	135 SEC
30	+	100	30	+	100
30	+	70	30	+	70
30	+	40	30	+	40
30	+	10	30	+	10
15	+	10	15	+	10

- DEFOCUS STRATEGY :

  DEFOCUS ON RING BY RING BASIS STARTING FROM THE OUTSIDE OF THE FIELD

Figure 1 -- Temperature response model



$$C_{panel} \frac{dT_{panel}}{dt} = \dot{q}_{ABSORBED} + \epsilon_2 \sigma A \left(T_{RAD}^4 - T_{panel}^4\right) + \frac{1}{R_{conv}}\left(T_{amb} - T_{panel}\right)$$

$\dot{q}_{ABSORBED} = \epsilon_1 \dot{q}_{incident}$

$R_{conv} = 1/(hA)$

C_{panel} = panel capacitance (197.6 Btu/°F)

A = panel area (131.27 ft^2)

ϵ_1 = emissivity (.93)

ϵ_2 = emissivity (.89)

σ = Stefan - Boltzmann constant

h = heat transfer coefficient (4.6 $\frac{Btu}{hr-ft^2-°F}$)

$T_{amb} = T_{RAD}$ = 80°F

Note: 45 ft panel assumed with water capacitance neglected.

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TITLE PANEL TRANSIENT HEAT UP PAGE 1 OF

PROGRAMMER RAETZ DATE 3/4/80

SR-52 Coding Form

LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LABELS
000 112		LBL				2				8		A
		A				−				÷		B
		RCL		040 152		RCL				RCL		C
		0				0				0		D
		1				0		080 192		3		E
005 117		y^x				=				=		A'
		4				*				+		B'
		−		045 157		RCL				RCL		C'
		(				0				0		D'
		RCL				7		085 197		0		E'
010 122		0				*				=		REGISTERS
		0				RCL				STO		00 T_P (°F)
		+		050 162		1				0		01 T_{RAD} (°R)
		4				1				0		02 T_{AMB} °F
		6				=		090 202		RCL		03 C_P
015 127		0				STO	$\}$ $hA(T_A-T_P)$			1		04 $\alpha = .95$
		)				1				4		05 $\epsilon = .89$
		y^x		055 167		3				+		06 $\sigma = .1715 \times 10^{-8}$
		4				RCL				RCL		07 $h = 4.6$ BTU/HR-FT²-°F
		=				1		095 207		0		08 $\Delta\tau$
020 132		*				0				8		09 $T_P + 460$ °F
		RCL				*				=		10 q_{inc}
		1		060 172		RCL				STO		11 $A = 131.27$ FT²
		1				0				1		12 $\epsilon\sigma A(T_R^4 - T_P^4)$
		*				4		100 212		4		13 $hA(T_{AMB} - T_P)$
025 137		RCL				=				RCL		14 $\Sigma\Delta\tau$
		0				+				0		15 Q_{REF}
		6		065 177		RCL				0		16
		*				1				HLT		17
		RCL				2		105 217		LBL	load new q	18
030 142		0				+				B		19
		5				RCL				*		FLAGS
		=		070 182		1				RCL	STO	0
		STO	$\}$ $\epsilon\sigma A(T_R^4 - T_P^4)$			3				1	1	1
		1				=		110 222		5	0	2
035 147		2				*				=	HLT	3
		RCL				RCL						4
		0		075 187		0						

TEXAS INSTRUMENTS
INCORPORATED

4 OF 16

$$T_p' - T_p = \frac{\Delta\tau}{C_p}\left\{ \underbrace{\dot{q}_{ABS}}_{(q_{INC})(\alpha)} + \epsilon_2 \sigma A \left(T_{RAD}^4 - T_P^4\right) + \frac{1}{R_{CONV}}\left(T_{AMB} - T_P\right)\right\}$$

REGISTER

00	$T_P = 1150°F$	06	$\sigma = .1715 \times 10^{-8}$ BTU/HR-FT^2-°R^4
01	T_{RAD} (°R) $= 540°F$	07	$h = 4.6$ BTU/HR-FT^2-°F
02	$T_{AMB} = 80°F$	08	$\Delta\tau = \frac{10}{3600} = .0027777$
03	$C_P = 197.6$ BTU/°F	09	$T_P + 460°F$
04	$\alpha = .95$	10	q_{inc} fn (T) INPUT
05	$\epsilon = .89$	11	$A = 131.27$ ft^2
		12	$\epsilon_2 \sigma A \left(T_{RAD}^4 - T_P^4\right)$
		13	$hA\left(T_{AMB} - T_P\right)$
LBL		14	$\Sigma \Delta\tau$
		15	$Q_{REF} = 3.25 \times 3.413 \times 10^6$

WORKSHEET
FORM 30-103-1 (REV. 10-67)

30 SEC POWER SWITCHOVER
135 SEC MEMORY RELOAD
CASE 1 A

TIME	TEMP	TIME	TEMP
165	2105	280	1349
170	2094	300	1268
175	2071	32.0	1198
180	2043	340	1137
185	2009	360	1083
190	1973	380	1034
195	1930	400	990
200	1891		
205	1850		
210	1807		
215	1762		
220	1721		
240	1566		
260	1446		

30 SEC POWER SWITCHOVER
100 SEC MEMORY RELOAD CASE 2A

STANDBY @
2½ REC. DIA.

TIME	TEMP	TIME	TEMP
130	2052	280	1205
135	2047	300	1142
140	2027	320	1088
145	2004	340	1039
150	1974	360	995
155	1940	380	954
160	1900	400	917
165	1864		
170	1825		
175	1783		
180	1740		
200	1580		
220	1458		
240	1359		
260	1276		

WORKSHEET
FORM 30-103-1 (REV. 10-67)

30 SEC POWER SWITCHOVER
70 SEC MEMORY RELOAD
CASE 3A

TIME	TEMP	TIME	TEMP
100	1964.5	280	1105
105	1967	300	1054
110	1955	320	1009
115	1938	340	967
120	1913	360	929
125	1884	380	894
130	1849	400	862
135	1816		
140	1781		
145	1742		
150	1702		
160	1627		
180	1494		
200	1389		
220	1301		
240	1227		
260	1162		

6 OF 16

30 SEC POWER SWITCHOVER
40 SEC MEMORY RELOAD CASE 4A

TIME	TEMP	TIME	TEMP	STANDBY @ 2½ REC DIA.
70	1814	280	1010	
75	1828	300	968	
80	1827	320	930	
85	1820	340	895	
90	1804	360	863	
95	1783	380	833	
100	1755	400	805	
105	1729			
110	1700			
115	1660			
120	1631			
140	1497			
160	1391			
180	1303			
200	1228			
220	1163			
240	1106			
260	1056			

WORKSHEET
FORM 30-103-1 (REV. 10-67)

30 SEC POWER SWITCHOVER
10 SEC MEMORY LOAD

CASE 5A

TIME	TEMP	TIME	TEMP
40	1584	220	1037
45	1612	240	993
50	1624	260	953
55	1630	280	916
60	1626	300	882
65	1617	320	851
70	1599	340	822
75	1582	360	794
80	1561	380	768
85	1535	400	744
90	1506		
100	1452		
120	1354		
140	1272		
160	1202		
180	1140		
200	1086		

[illegible]

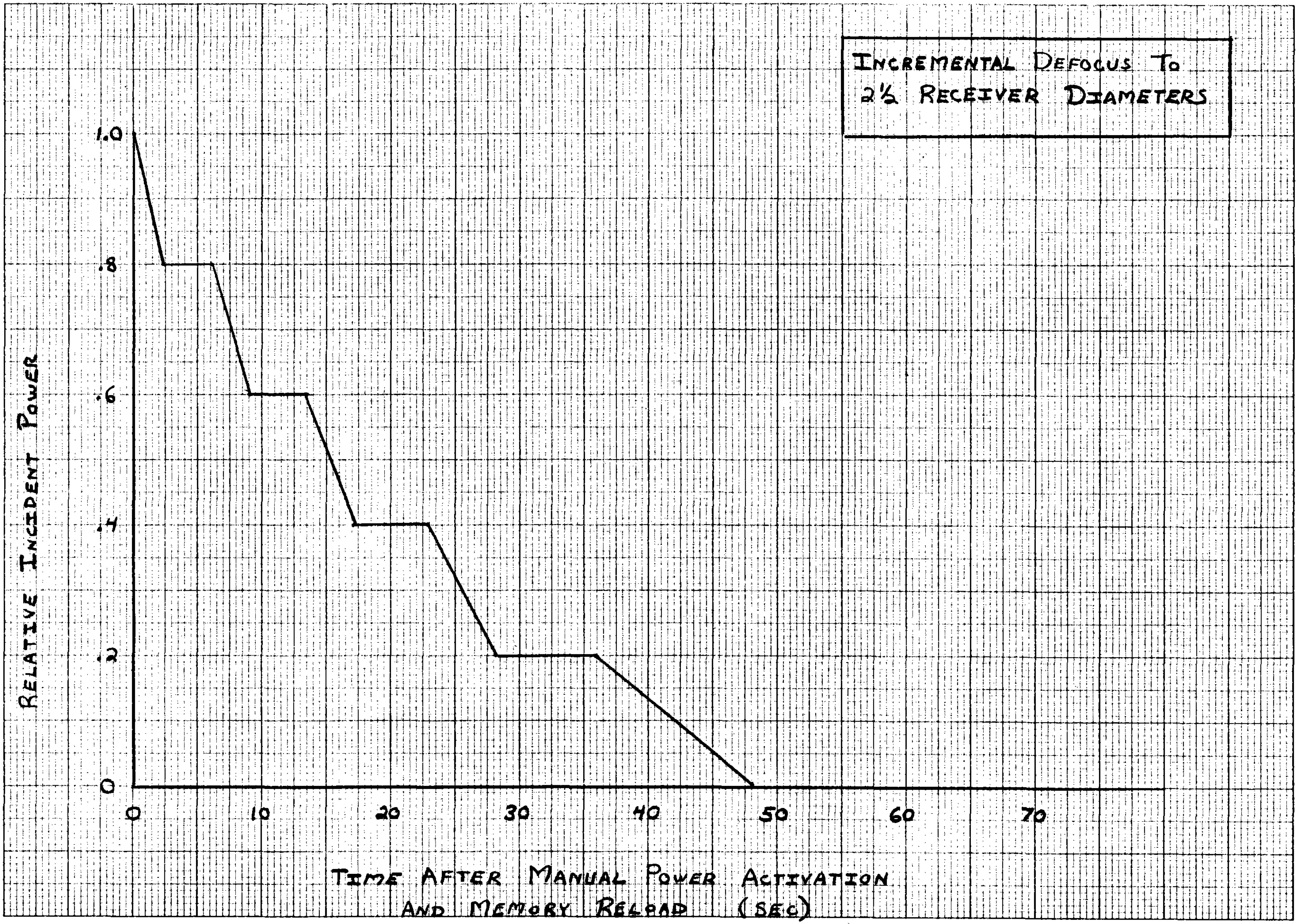
15 SEC POWER SWITCHOVER
10 SEC MEMORY RELOAD

CASE 6A

TIME	TEMP	TIME	TEMP	STANDBY		@
25	1436	220	969	2½	REC	DIA.
30	1471	240	931			
35	1490	260	896			
40	1502	280	864			
45	1505	300	834			
50	1502	320	806			
55	1490	340	779			
60	1479	360	755			
65	1463	380	731			
70	1441	400	710			
75	1417					
80	1394					
100	1306					
120	1231					
140	1166					
160	1108					
180	1057					
200	1011					

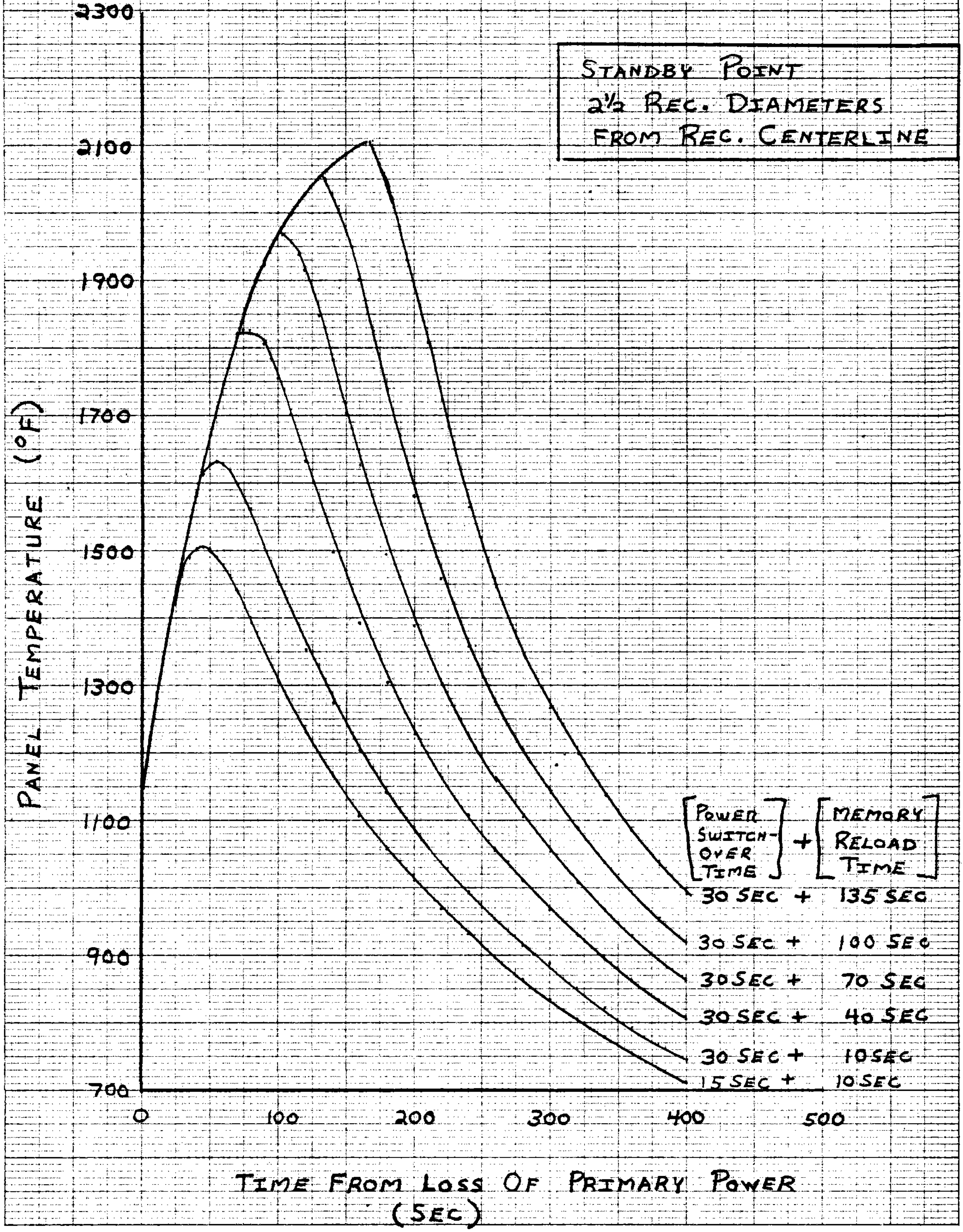
SLEW OFF TIMES

RING	DISTANCE	TIME CLEAR RECEIVED (→ 23 FT)	@ 13.5°/min HELIOSTAT MOTION (27°/MIN BEAM) MOVE 2½ DIAMETERS (→ 57.5 FT)	MOVE 5½ DIA (126.5 FT)
5	1317.5 FT	2.22 Sec	5.56 Sec	12.22 Sec
	1202.3 FT	2.43 Sec	6.09 Sec	13.39 Sec
4	1140.3 FT	2.57 Sec	6.42 Sec	14.12 Sec
	995.0 FT	2.94 Sec	7.36 Sec	16.18 Sec
3	950.7 FT	3.08 Sec	7.70 Sec	16.95 Sec
	770.3 FT	3.80 Sec	9.50 Sec	20.90 Sec
2	734.8 FT	3.98 Sec	9.96 Sec	21.91 Sec
	564.3 FT	5.19 Sec	12.97 Sec	28.52 Sec
1	535.2 FT	5.47 Sec	13.67 Sec	30.08 Sec
	239.6 FT	12.18 Sec	30.46 Sec	67.01 Sec


INCREMENTAL DEFOCUS TO
2½ RECEIVER DIAMETERS
RELATIVE INCIDENT POWER
1.0
.8
.6
.4
.2
0
0
10
20
30
40
50
60
70
TIME AFTER MANUAL POWER ACTIVATION
AND MEMORY RELOAD (SEC)

10 of 16

RECEIVER PANEL TEMPERATURE DURING LOSS OF POWER EMERGENCY DEFOCUS



WORKSHEET
FORM 30-103-1 (REV. 10-67)

PANEL HEATUP

— 30 SEC WER SWITCHOVER
— 135 SEC MEMORY RELOAD

CASE 11 OF 16

	TIME	TP	TIME	TP	TIME	TP	STANDBY @		
							5½	REC	DIAM
	0	1150°F	170	2095	270	1551			
	10 Sec	1270	175	2086	280	1493			
	20 Sec	1383	180	2069	290	1440			
	30 Sec	1488	185	2048	300	1392			
	40 Sec	1584	190	2028	310	1348			
	50 Sec	1670	195	2009	320	1308			
	60 Sec	1747	200	1978	330	1270			
	70 Sec	1814	205	1950	340	1235			
	80 Sec	1872	210	1925	350	1202			
	90 Sec	1923	215	1901	360	1171			
	100 Sec	1964.5	220	1866	370	1142			
	110 Sec	1999	225	1832	380	1115			
	120 Sec	2028	230	1801	390	1089			
	130 Sec	2052	235	1772	400	1065			
	140 Sec	2071	240	1744					
	150 Sec	2087	245	1717					
	160 Sec	2100	250	1686					
	165 Sec	2105	255	1651					
START DEFOCUS			260	1616					

WORKSHEET
FORM 30-103-1 (REV. 10-67)

30 Sec Power Switchover
100 Sec Memory Reload
CASE 2

TIME	TP	TIME	TP
130	2052	250	1473
135	2047	260	1421
140	2042	270	1375
145	2030	280	1332
150	2012	290	1293
155	1996	300	1256
160	1980	310	1222
165	1951	320	1190
170	1926	330	1160
175	1901	340	1132
180	1880	350	1105
190	1847	360	1079
195	1814	370	1055
200	1784	380	1033
205	1756	390	1011
210	1728	400	990
215	1697		
220	1661		
230	1591		
240	1528		

30 SEC POWER SWITCHOVER 12 OF 16
70 SEC MEMORY RELOAD
CASE 3
STAND BY @

TIME	TP	TIME	TP	5½ REC	DIA
100	1964.5	200	1558		
105	1967.2	210	1499		
110	1969	220	1445		
115	1964	230	1397		
120	1952	240	1353		
125	1941	250	1312		
130	1929	260	1274		
135	1905	270	1238		
140	1883	280	1205		
145	1863	290	1174		
150	1844	300	1145		
155	1813	310	1117		
160	1783	320	1092		
165	1755	330	1067		
170	1729	340	1043		
175	1705	350	1021		
180	1680	360	1000		
185	1657	370	980		
190	1624	380	960		
		390	941		
		400	923		

WORKSHEET
FORM 30-103-1 (REV. 10-67)

30 c POWER SWITCHOVER
40 SEC MEMORY RELOAD
CASE 4

TIME	TP	TIME	TP
70	1814	170	1517
75	1828	180	1462
80	1842	190	1412
85	1846	200	1366
90	1843	210	1324
95	1841	220	1285
100	1837	240	1213
105	1820	260	1150
110	1804	280	1095
115	1790	300	1045
120	1776	320	1000
125	1750	340	959
130	1724	360	922
135	1700	380	887
140	1678	400	856
145	1656		
150	1635		
155	1609		
160	1578		

30 EC POWER SWITCHOVER
10 SEC MEMORY RELOAD
CASE 5

13 F 16

TIME	TP	TIME	TP
40	1584	140	1450
45	1612	160	1352
50	1639	180	1270
55	1656	200	1200
60	1666	220	1139
65	1675	240	1084
70	1682	260	1036
75	1676	280	992
80	1669	300	952
85	1663	320	915
90	1658	340	881
95	1639	360	850
100	1620	380	821
105	1602	400	794
110	1585		
115	1569		
120	1552		
125	1530		
130	1504		

STANDBY @

5½	REC	DIA

14 OF 16

WORKSHEET
FORM 30-103-1 (REV. 10-67)

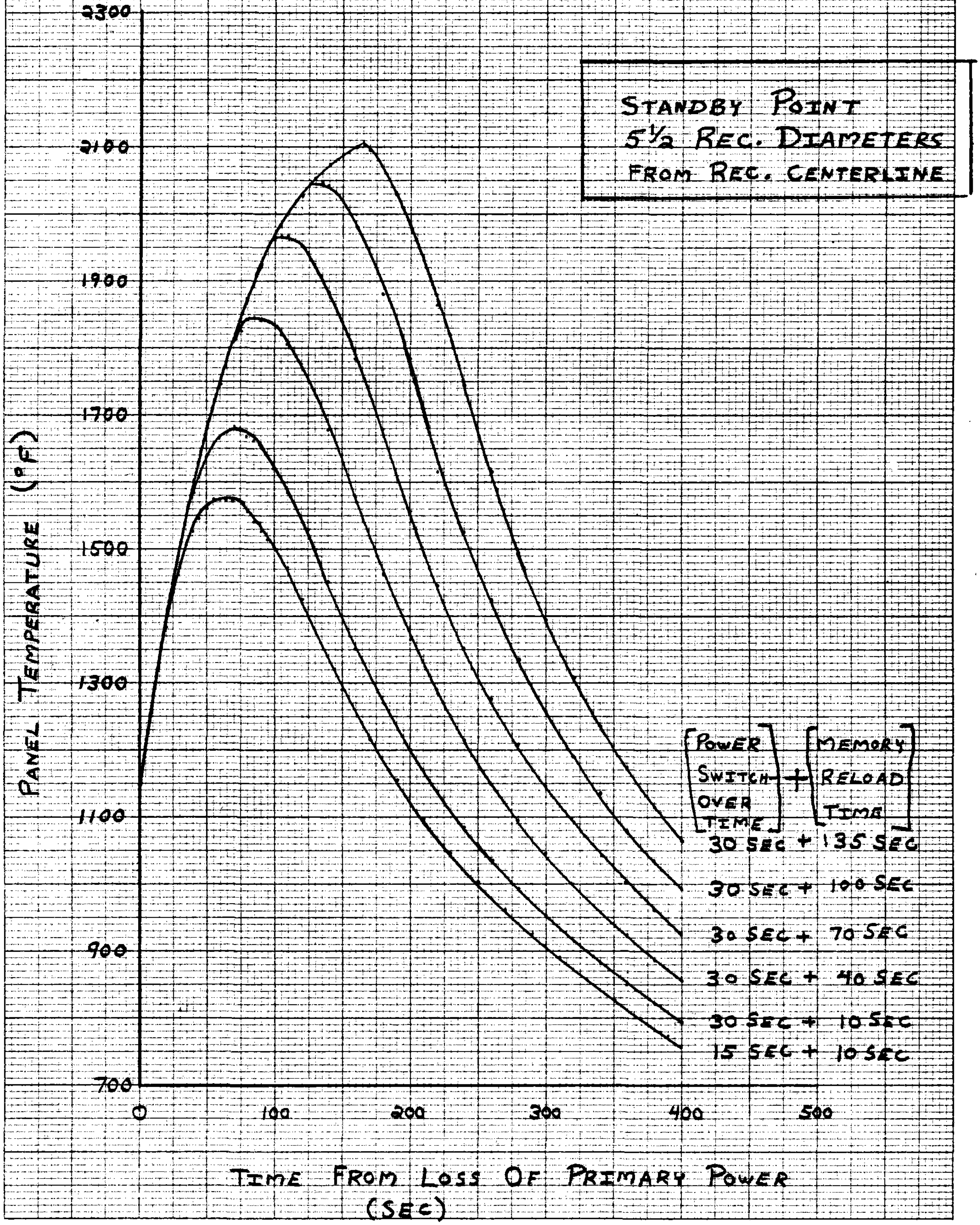
15 SEC POWER SWITCHOVER
10 SEC MEMORY RELOAD
CASE 6

STANDBY @
5½ REC DIA

TIME	TEMP	TIME	TEMP
25	1436	130	1376
30	1471	150	1290
35	1505	170	1218
40	1529	190	1154
45	1545	210	1098
50	1561	230	1048
55	1574	250	1003
60	1574	270	962
65	1573	290	925
70	1573	310	890
75	1572	330	858
80	1558	350	828
85	1543	370	800
90	1529	390	774
95	1516		
100	1503		
105	1490		
110	1471		
115	1447		
120	1423		

15 OF 16

RECEIVER PANEL TEMPERATURE DURING LOSS OF POWER EMERGENCY DEFOCUS



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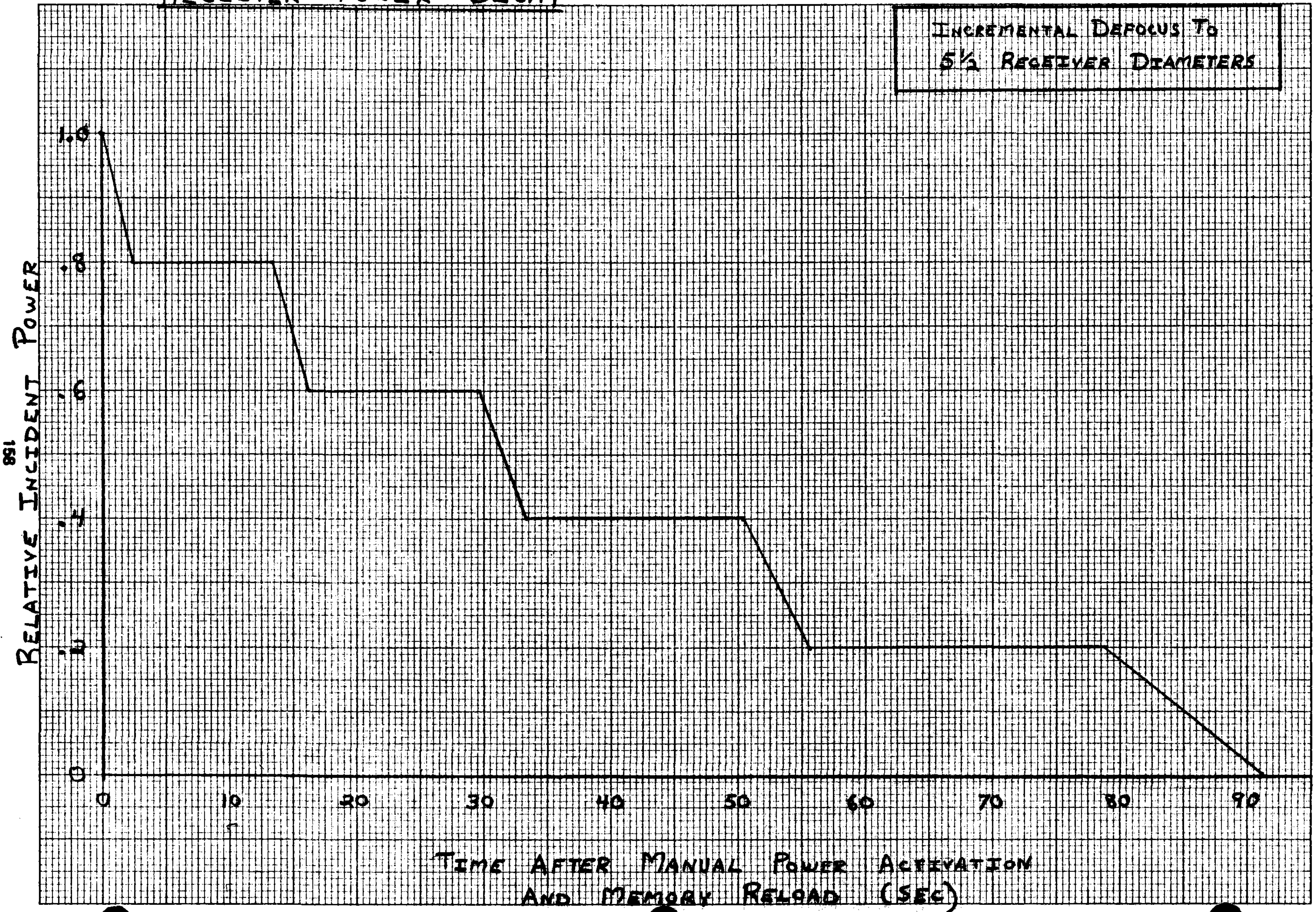
RECEIVER POWER DECAY



1/30/80
1 OF 2

Receiver Drain Calc.

ROM water volume to be drained

- tube .269 ID → $A = .0003947\ ft^2$
  $V = (70\ \text{TUBES})(24\ \text{PANELS})(51\ \text{FT})(.0003947) = 33.815$ F

- Manifolds ID = 11 in $A = .6599\ ft^2$
  $V = (1.5\ \text{FT LENGTH})(.6599\ FT^2)(48\ \text{MANIFOLDS}) = 47.517$ FT

- Vertical pipes (sch 160)
  2½ in → $A = .02463\ FT^2$
  4 in → $A = .06447\ FT^2$
  (~~2½" pipe~~)(3 pipes)(45 FT)(.02463) = 3.325 F
  4 in pipe: (45 FT)(.06447) = 2.901 F

total drain volume 87.558 F

assume 220°F water
$\rho = 60\ LB/FT^3$
1 gal = 8.02 lb

total water
5253 lb
655 gal

assume $\Delta P = 10$ PSI frictional drop in drain line
" L = 400 ft

1½" Sch 40 → 30 gal/~~min drain rate~~
14,436 lb/hr
4.01 CFM
21 min drain rate

3" Sch 40 → 175 gal/min drain rate
84210 lb/hr
23.39 CFM
3.7 minutes drain ra

1/30/80
2 OF 2

ASSUME 200 psia ΔP
L = 400 FT

1½" Sch 40 → 134 gal/min
4.88 min drain time
17.9 CFM

3" Sch 40 → 781.6 gal/min
.838 min drain time
104 CFM

GRAVITY HEAD – 280 ft of 220°F WATER

$$\rho = \frac{1}{.01677} = 60 \text{ lb/FT}^3$$

$$\Delta P = \rho h = \frac{(60 \text{ lb/FT}^3)(280 \text{ FT})}{144} = 117 \text{ psia}$$

MAX TEMP

1 OF 12

MEMORANDUM

A3-233-EP-RES-1106
11 December 1979

To: J. E. Raetz

Subject: DOWNCOMER START-UP RAMP RATE RECOMMENDATION

From: R. E. Snyder

Copies to: R. G. Riedesel, E. J. Riel, G. C. Coleman, R. J. Perkins

The purpose of this memo is to determine the maximum allowable temperature ramp rate of the downcomer during plant start-up.

Standard practice for a 600 MW plant allows a ramp rate of 15°F/minute. This temperature is measured by a thermocouple welded to the outside of the pipe. The following analysis tracks the outside temperature of the 660 MW main steam line for several start-up weight flows representing different Biot numbers (Bi) in order to bracket the 15°F/minute case. The Biot number measures the influence of the film coefficient to conduction of the heat transfer process. Conduction controls at high numbers and the film coefficient controls at low Biot numbers.

Three equivalent cases were analysed for the downcomer and the results were corrolated to the 660 MW steam line case. It was assumed that both the downcomer and the 660 MW steam line operated under the same conditions i.e., initial temperature 200°F (auxiliary steam blanket) and 500 psia steam condensing on the walls (467°F saturation temperature).

As a result of the analysis it is recommended that the start-up weight flow be limited to 11300 #/Hr for start-up, corresponding to a Biot number of 5. This results in a maximum stress of approximately 70% of that (-25061 $\#/in^2$) developed in the 660 MW steam line (-35381 $\#/in^2$).

The method used (Reference 1) is summarized as follows:

> At T = 0 the steam line is assumed to be at uniform temperature (200°F). When steam is introduced into the pipe it condenses on the wall at saturation temperature which is assumed to be constant during warm up, i.e., the pressure is held constant (500 psia, 467°F). The external pipe surface is assumed to be perfectly insulated and heating of the insulation is disregarded.

The differential equation for heat conduction is of the form $\frac{dt}{dT} = a\left[\frac{dt}{dr^2} + \frac{dT}{dr}\right]$ (1)

The initial and boundary conditions are:

$$T(r,0) = T_0 \qquad (2)$$

$$dt(r_n,T) = -\frac{X}{\lambda}(T_s - T) \qquad (3)$$

$$\frac{dt(r_{ex},T)}{dr} = 0$$

The general solution in terms of dimensionless quantities and parameters is as follows:

$$\frac{\theta}{\theta_o} = \sum_{m=1}^{\infty} e^{-\mu_n{}^2 FO} A_N M_N \qquad (4)$$

Where =

$$A_N = \frac{\P Bi}{\mu_n} X \frac{[J_1(\mu_n) + \frac{Bi}{\mu_m} Jo(\mu_n)]\ J1(\beta o\, \mu_n)}{[J_o(\mu_n) + \frac{Bi}{\mu_n} Jo(\mu_n)]^2 - [1 + (\frac{Bi}{\mu_n})^2]\ Ji^2(\beta o \mu_n)}$$

$$M_N = J_1\ (\beta o \mu_n) \gamma o(\beta \mu_n)\ - \gamma.(\beta o \mu_n)\ Jo(\beta \mu_n)$$

μ_n = roots of the characteristic equation are obtained from the boundary condition (3)

$$\frac{Y_1\ (\beta o\, \mu_n)}{J_1\ (\beta o\, \mu_n)} \frac{[J_1(\mu_n) + \frac{Bi}{\mu_n} Jo\ (\mu_n)]}{[Y_1(\mu_n) + \frac{Bi}{\mu_n} Yo\ (\mu_n)]} = 1 \qquad (5)$$

Where Jo & Yo = Bessel functions of the first and second kind of zero order.

J_1 & Y_1 = Bessel functions of the first and second kind of the first order.

Bi = Biot number = $\frac{hr_{in}}{K}$

$\beta = r_{in}$

$\beta o = rex/r_{in}$

r = radius of pipe-ft

T = time from initial shock-sec.

3 OF 12

k = thermal conductivity of steel - BTU/FT HR °F

h = heat transfer coeffiecent - BTU/FT^2 °F

$a = \frac{K}{PC}$

Fo = Fourier number = aT/r_n^2

p = Density of steel - #/FT^3

c = Specific heat of steel - BTU/# °F

T = temperature -°F

$$\frac{\theta}{\theta_o} = \frac{T\ steam - Tr}{T\ steam - Tr_o}$$

The downcomer is 6 5/8 in. OD with a .864 in. wall. Typical 660 MW power plant main steam line is 26 5/8 in. OD with a 4 3/16 in. wall.

It was assumed that βo for the downcomer was 1.4 (actual βo = 1.353) this was conservative as the stress rises as βo increases.

Roots (μn) were determined for βo = 1.4 and Bi = 5, 10 & 20 for the downcomer, and βo = 1.459 and Bi = 10, 20, 40, 60, & 80 for the 600 MW main steam line, Table I.

Equation (4) converges so rapidly that only 3 roots per case were required for high accuracy.

Outside wall temperatures were determined by evaluating equation (4) for each of the above cases for various times from initial shock. The 660 MW main steam line was evaluated from 0 to 1800 sec. (.5 Hrs.) and the downcomer was evaluated from 0 to 120 sec. (2 min.) so that both pipes were evaluated over the same range of Fourier numbers (dimensionless time). Due to the difference in inside radius the equivalent time for the main steam line is 13.9 times that of the downcomer.

The results of this evaluation is shown in Figures 1 & 2.

Figure 3 shows curves of nondimensional stress ($\bar{\sigma}_T$) versus Fourier number from reference 1 for various combinations of Bi and βo.

$$\text{The absolute stress } \sigma_T = \frac{E(TS-To)}{(1-v)} \bar{\sigma}_T$$

Where ε = Coefficient of expansion - in/u°F

E = Modulus of elasticity - #/in^2

V = Poissons Ratio

4 of 12

The resulting maximum targential stress is shown in Figures 1 & 2 for the two pipes in question.

For any given pipe configuration the Biot number defines the required heat transfer coefficient (h) to satisfy that condition. Film wise condensation is defined by reference 2.

$$h = 0.65 \frac{(D-F\ f)}{2D-G}^{1/2} (NPR)^{-1/2}\ C_P - \frac{W}{A}$$

Where:

$$f = \frac{\frac{.046}{(W2r_n)}.2}{A\mu_g}$$

$$h = Bi\ \frac{K}{r_{in}}$$

Substituting and rearranging

$$W = A\left[\frac{\frac{K}{r_{in}}\ Bi\ (NPR)^{1/w}}{.065\ Cp\left\{\frac{.046\ D-F}{2D-G\ \frac{(2r_{in})}{\mu}^{.2}}\right\}^{1/2}}\right]\ \frac{1}{.9}$$

The weight flow and heat tranfer coefficient for each case of interest was computed and tabulated in Table II.

Table III tabulates corresponding equivalent times from beginning of shock for the downcomer compared to 660 MW main steam line times.

The maximum tangential stress, as a function of time for the downcomer was calculated at a Biot number of 5 and its maximum stress is always below that of the 660 MW main steam line calculated at a Biot number of 10. It should be noted that the peak maximum stress for the downcomer is approximately 70% of the 660 MW steam line (corresponding roughly to a temperature ramp of 15°/minute). It shoudl also be noted that the maximum stress in the 660 MW line occurs (Bi = 10) at approximately a Fourier number of .025 corresponding to 102 seconds after the initial shock and reduces to approximately half the maximum value in about 10 minutes. On the other hand the downcomer reaches its maximum stress (Bi = 5) at a Fourier number of approximately .025 corresponding to 7.3 seconds after the initial shock and reduces to one half its maximum value in about 48 seconds. It is also interesting to note that a 15°F/minute ramp rate in the 660 MW pipe is equivalent to a ramp rate of 208°F/minute in the downcomer.

Therefore to be conservative it is recommended that during initial start-up of the 10 MW plant a Biot number of 5 be maintained (essentially reducing the maximum stress to about 70% of that occuring in the 660 MW main steam pipe operating at a Biot number of 10). In addition it is recommended that the ramp rate during start up be limited to 200°F/minute for conservatism. The recommended

5 OF 12

Biot number of 5 for the downcomer corresponds to a weight flow of approximately 11300 #/hr of steam.

References = 1 Teploenergetika, 1971 18 (2) 78 - 12
2 GE Heat Transfer and Fluid Flow Data Book, April 1979

For further information contact the undersigned.

R. E. Snyder

RES:1p

Attachments as noted

6 of 12

TABLE I
ROOTS (μ_m) OF CHARACTERISTIC EQUATION FOR DOWNCOMER & 660 MW STEAMLINE

DOWNCOMER

Bi=5.
β=1.4

μ-1.
2.470703125

μ-2.
9.103515625

μ-3.
16.454[illegible]38

Bi=10.
β=1.4

μ-1.
2.914453125

μ-2.
9.801953125

μ-3.
17.2[illegible]

Bi=20.
β=1.4

μ-1.
3.135546875

μ-2.
10.5028125

μ-3.
17.7[illegible]

660 MW MAIN STEAMLINE

Bi=[illegible]
β=1.45890411

μ-1.
2.990234375

μ-2.
9.671191406

μ-3.
16.23271484

Bi=50.
β=1.45890411

μ-1.
3.046171875

μ-2.
9.8328125

μ-3.
16.[illegible]

Bi=80.
β=1.45890411

μ-1.
3.0751875

μ-2.
9.9178125

μ-3.
16.6209375

Bi=10.
β=1.45890411

μ-1.
2.577734375

μ-2.
8.687578125

μ-3.
14.96835938

Bi=20.
β=1.45890411

μ-1.
2.834765625

μ-2.
9.253515625

μ-3.
15.6409375

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TABLE I WEIGHT FLOW & HEAT TRANSFER COEFF. VS BIOT NUMBER ([illegible])
SHEET 1 OF 2

WHERE: RAD = INSIDE PIPE RADIUS - IN
K = THERMAL CONDUCTIVITY - BTU/FT °F
NPR = PRANDL NUMBER
Cp = SPECIFIC HEAT VAPOR - BTU/# °F
D-F = DENSITY FLUID - #/FT³
D-G = DENSITY GAS - #/FT³
MU-G = VISCOSITY GAS -
W = WEIGHT FLOW STEAM - #/HR
H = HEAT TRANSFER COEF - BTU/FT² °F

```
          Bi=20.                              Bi= 80.
          Bo=1.4                          Bo=1.45890411

   W, H, VS BIOT NO.                  W, H, VS BIOT NO.

          2.448       RAD                      9.125      RAD
            25.         K                        25.        K
            20.       B-I                        80.      B-I
        0.84222       NPR                    0.84222      NPR
      0.8516275       C-P                  0.8516275      C-P
        50.6408       D-F                    50.6408      D-F
       1.077324       D-G                   1.077324      D-G
    0.000011515      MU-G                0.000011515     MU-G
     52974.1175         W                921384.1479        W
    3142.374638         H                3372.069311        H

          Bi= 10.                             Bi= 60.
          Bo= 1.4                         Bo=1.45890411

   W, H, VS BIOT NO.                  W, H, VS BIOT NO.

          2.448       RAD                      9.125      RAD
            25.         K                        25.        K
            10.       B-I                        60.      B-I
        0.84222       NPR                    0.84222      NPR
      0.8516275       C-P                  0.8516275      C-P
        50.6408       D-F                    50.6408      D-F
       1.077324       D-G                   1.077324      D-G
    0.000011515      MU-G                0.000011515     MU-G
     24523.6979         W                669298.6016        W
    1571.187319         H                2529.051983        H

          Bi= 5.                              Bi= 40.
          Bo= 1.4                         Bo=1.45890411

   W, H, VS BIOT NO.                  W, H, VS BIOT NO.

          2.448       RAD                      9.125      RAD
            25.         K                        25.        K
             5.       B-I                        40.      B-I
        0.84222       NPR                    0.84222      NPR
      0.8516275       C-P                  0.8516275      C-P
        50.6408       D-F                    50.6408      D-F
       1.077324       D-G                   1.077324      D-G
    0.000011515      MU-G                0.000011515     MU-G
    11352.93587         W                426543.1414        W
    785.5936597         H                1686.034655        H
```

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TUBE WEIGHT FLOW & HEAT TRANSFER COEF [illegible]

SHEET 2 OF 2

β_L=10.

β_o=1.45890411

```
W, H, VS BIOT NO.

       9.125      RAD
         25.        K
         10.      B-I
     0.84222      NPR
   0.8516275      C-P
     50.6408      D-F
    1.077324      D-G
 0.000011515     MU-G
 91412.88537        W
 421.5086639        H
```

β_L=20.

β_o=1.45890411

```
W, H, VS BIOT NO.

       9.125      RAD
         25.        K
         20.      B-I
     0.84222      NPR
   0.8516275      C-P
     50.6408      D-F
    1.077324      D-G
 0.000011515     MU-G
 197462.7542        W
 843.0173278        H
```

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TABLE III C[illegible] OF EQ[illegible] TI[illegible]

F[illegible] NUMBERS, (FO)

WHERE R-1 = INSIDE RADIUS OF [illegible] -IN
R-2 = INSIDE RADIUS OF [illegible] -IN
T-1 = TIME FROM INITIAL [illegible] -SEC
T-2 = EQUIVALENT TIME FROM INITIAL [illegible] IN SEC

```
   .0736794965      FD
         9.125      R-1
          300.      T-1
         2.448      R-2
   21.59127731      T-2

   0.147358993      FD
         9.125      R-1
          600.      T-1
         2.448      R-2
   43.18255463      T-2

   .2210384895      FD
         9.125      R-1
          900.      T-1
         2.448      R-2
   64.77383194      T-2

   0.294717986      FD
         9.125      R-1
         1200.      T-1
         2.448      R-2
   86.36510925      T-2

   .3683974825      FD
         9.125      R-1
         1500.      T-1
         2.448      R-2
   107.9563866      T-2

   0.442076979      FD
         9.125      R-1
         1800.      T-1
         2.448      R-2
   129.5476639      T-2
```

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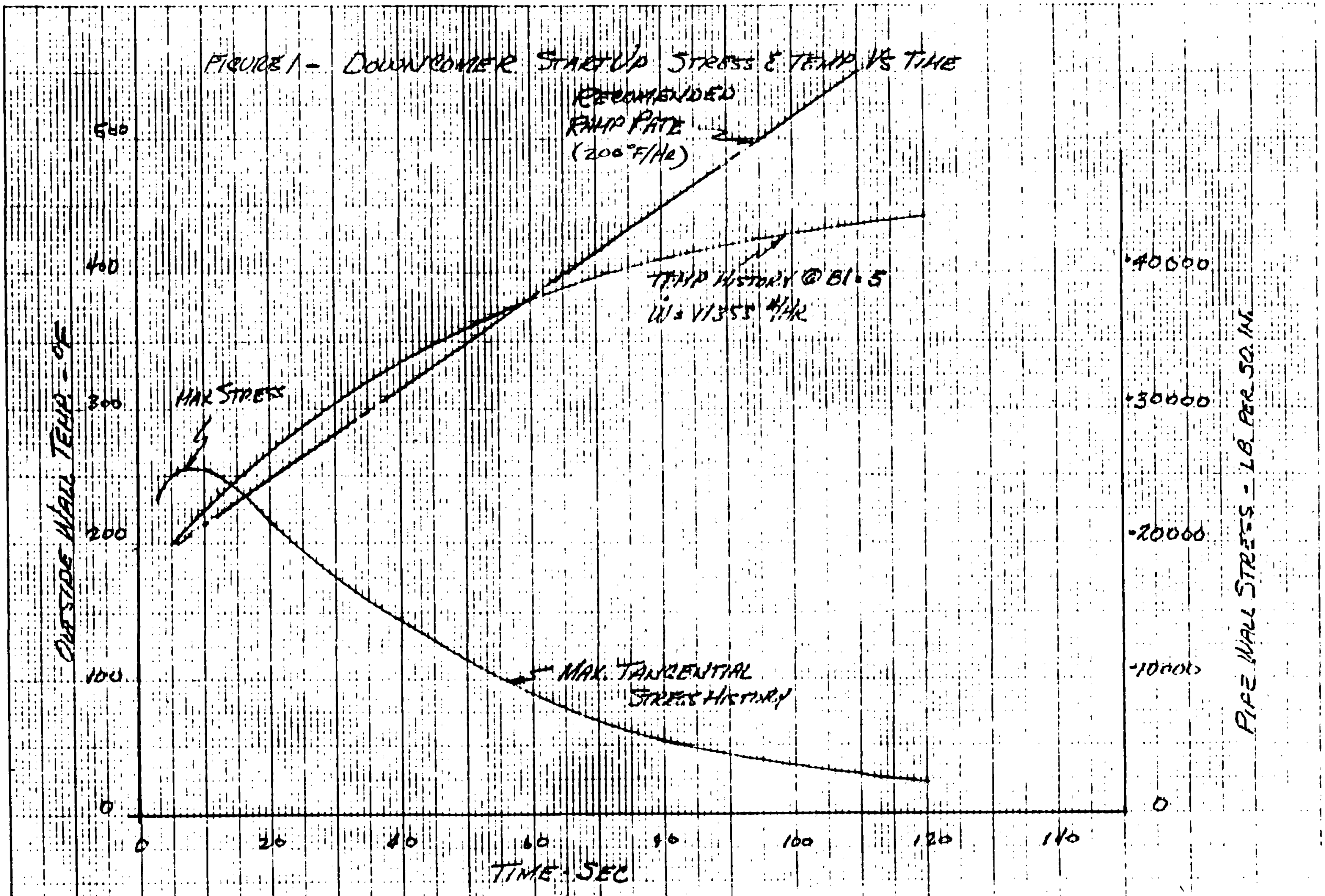

FIGURE 1 - DOWNCOMER STARTUP STRESS & TEMP VS TIME

FIGURE 2-STANDARD 660 MW MAIN STEAMLINE START UP STRESS & TEMP VS. TIME

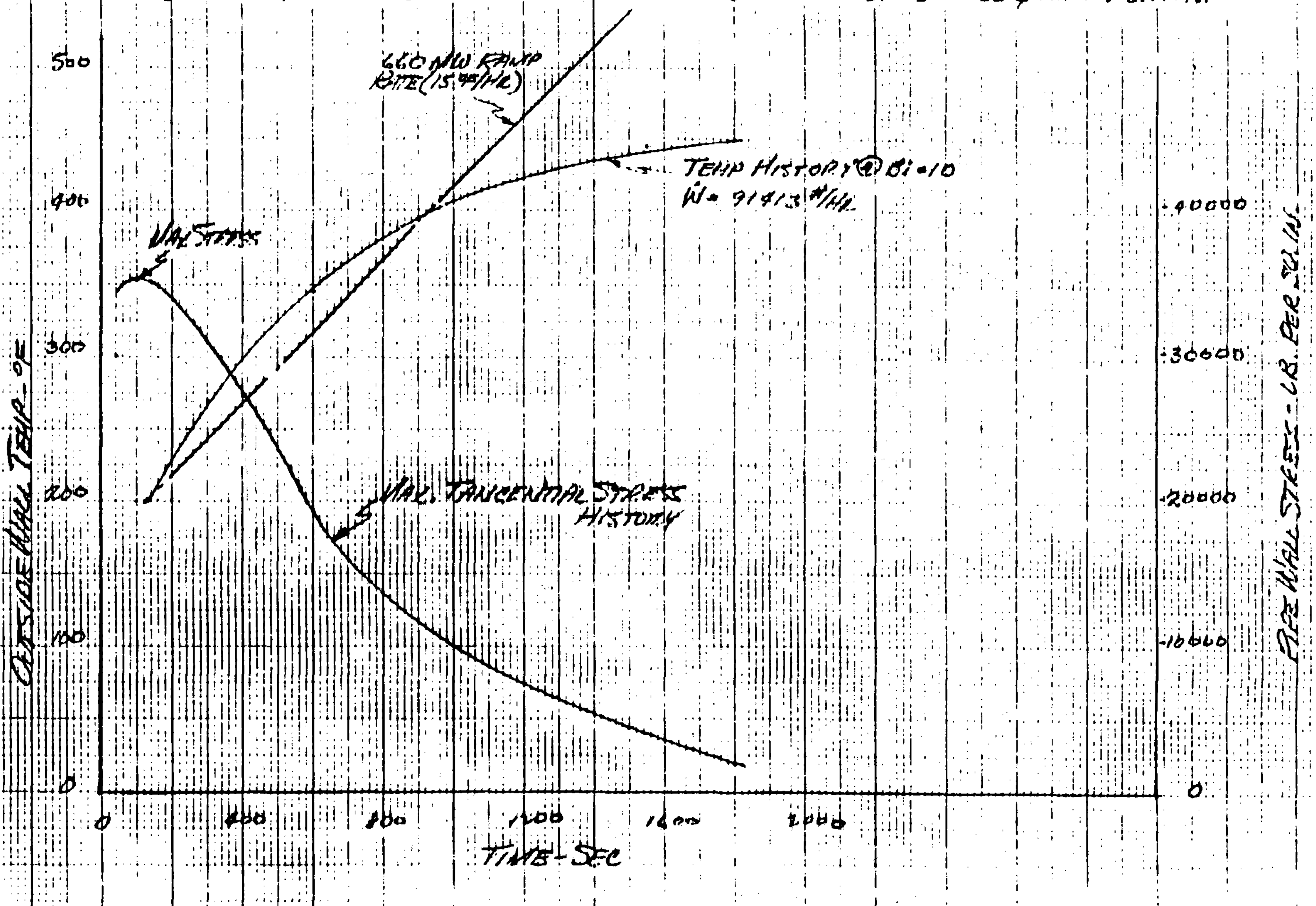

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FIG. 3
NON DIMENTIONAL TANGENTIAL STRESS

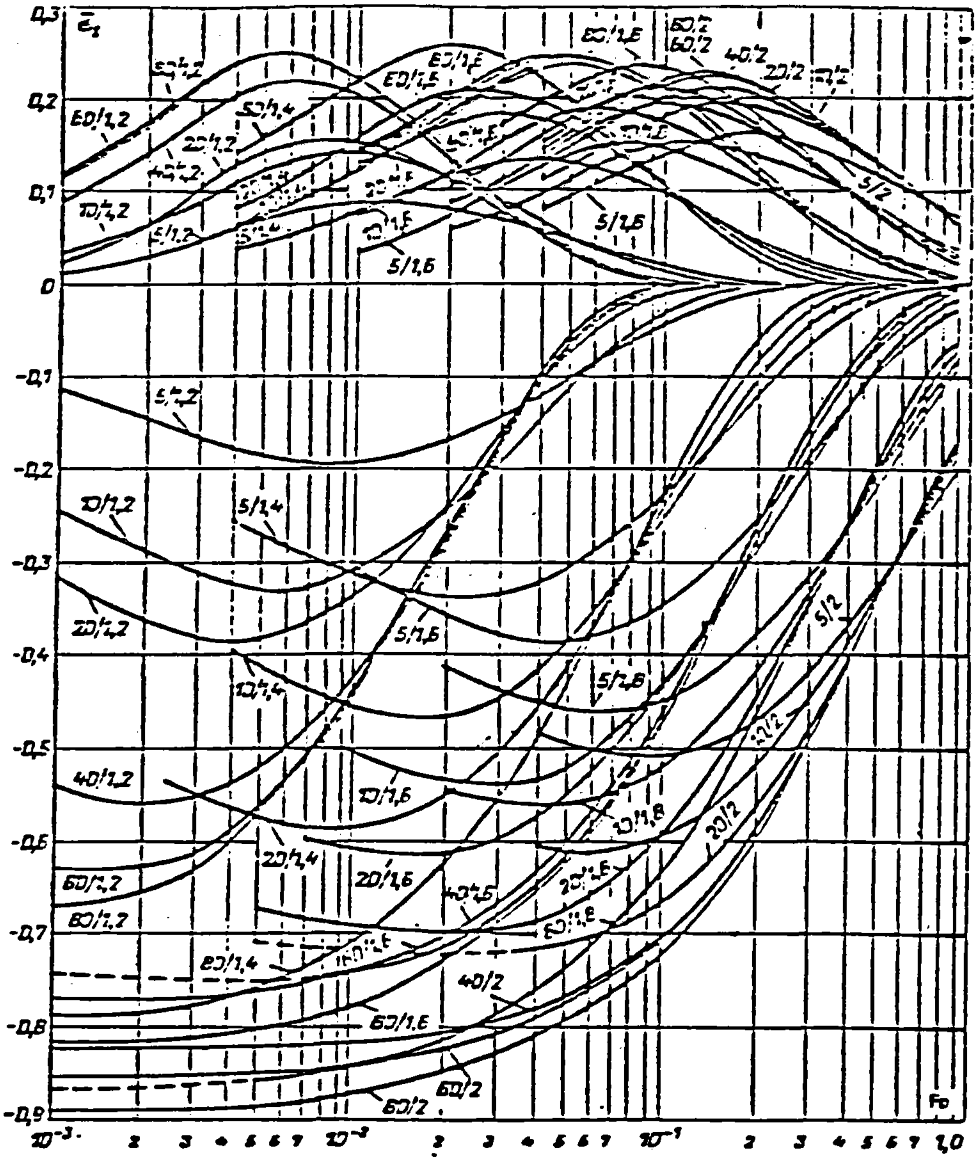

FIG. 5. Diagram for determination of dimensionless tangential stress due to thermal shock $\bar{\sigma}_t$.
a — stresses at the external surface of the pipe wall; b — stresses at the internal surface of the pipe wall. The numbers at each curve give Biot number (first) and the ratio of pipe radii β_e (second). Fo — dimensionless time from the beginning of the thermal shock, in logarithmic scale.

REF N°1

1 OF 74

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY

5301 Bolsa Avenue, Huntington Beach, CA 92647 (714) 896-3311

A3-228-EP-MLJ-1057
[redacted]

Mr. R. N. Schweinberg, Director
Solar Ten Megawatt Project Office
Department of Energy
9550 Flair Drive, Suite 210
El Monte, California 91731

Subject: Contract No. DE-AC03-79SF10499
Solar Facilities Design Integration
[redacted]

References:

(1) MDAC Letter A3-226-EP-MLJ-1027, dated 14 November 1979, R. W. Hallet, to R. N. Schweinberg, "Conference Record Report, Receiver Stress Analysis Meeting, 7 November 1979"

(2) Code Case N-47-14, Cases of ASME Boiler and Pressure Vessel Code, Meeting of 5 May 1978, Approved by Council 10 July 1978

(3) Ten Megawatt Solar Thermal Central Receiver Pilot Plant, Solar Facilities Design Integration, System Data Book, MDC G8211, initial issue - September 1979

Dear Dick:

In response to Action Item (1), assigned at the subject Receiver Stress Analysis Meeting of 7 November 1979, a copy of the MDAC Downcomer/Valve Stress Analysis Report is being forwarded for review.

It is noted that the report has been updated since the Stress Analysis Meeting to incorporate a conservative but realistic "cloud transient" analysis. As suggested by Mr. A. Ludwig of ETEC, at the meeting, the creep-fatigue analysis procedure was also revised to properly reflect the boiler and pressure vessel code procedure delineated in Reference (2). The conclusions of the analysis presented at the meeting will remain valid when the results of the enclosed, updated, analysis are considered.

In response to Action Item (2) from the meeting, a "Typical-day" Pilot Plant Receiver Steam Downcomer load histogram was constructed based on the best data currently available, and is also enclosed, together with a copy of the Receiver operational sequence extracted from the System Data Book (Reference 3).

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A3-228-EP-MLJ-1057
27 November 1979

Please feel free to contact G. C. Coleman at (714) 896-4097 for any further information.

Very truly yours,

ORIGINAL SIGNED BY

R. W. Hallet, Jr.
Program Manager
Solar Facilities Design Integration

MLJ:bj

Attachments: (1) "Downcomer Pipe and Inlet Valve, 10 MWe Solar Pilot Plant, Structural Analysis," draft MDAC Report, dated 2 October 1979

(2) Steam Downcomer Load History (Histogram)

(3) Pilot Plant Receiver Operational Sequence

Cy: K. L. Adler, ETEC/STMPO
A. Ludwig, ETEC
I. Berman, Foster-Wheeler
A. C. Skinrood, Sandia, Livermore
J. Jones, Sandia, Livermore

ic: G. C. Coleman
M. L. Joy
J. E. Raetz

Approval Initials Required

Section	DATE	
MLJ	11-26	
GCC	11-27	
RLQ	11/27	

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Attachment 1

MCDONNELL DOUGLAS CORPORATION

Gillis

10-2-79

PAGE i

DOWNCOMER PIPE AND INLET VALVE

10 MW SOLAR POWER PLANT

STRUCTURAL ANALYSIS

TABLE OF CONTENTS

PAGE

DOWNCOMER PIPE AND INLET VALVE
10 MW SOLAR POWER PLANT

STRUCTURAL ANALYSIS

INTRODUCTION:

IT IS REQUIRED TO ESTABLISH LOAD CRITERIA (ACCEPTABLE LOAD ENVIRONMENT) WITH RESPECT TO STEAM FLOW RATES, PRESSURES, AND TEMPERATURES FOR ALL TRANSIENT AND OPERATING CONDITIONS WHICH WILL RESULT IN STRUCTURAL ADEQUACY OF THE PROPOSED DOWNCOMER PIPE AND DOWNCOMER INLET VALVE. STATIC AND CREEP-FATIGUE ANALYSES WERE PERFORMED FOR A NUMBER OF DIFFERENT LOAD ENVIRONMENTS FOR CONDITIONS OF START-UP AND CLOUD TRANSIENTS. THE DESIGN CRITERIA UPON WHICH ALL ANALYSES WERE BASED ARE THOSE GIVEN IN ASME BOILER AND PRESSURE VESSEL CODES, REFERENCES 1, 2, AND 3. THE LOAD ENVIRONMENT WHICH RESULTED IN STRUCTURAL ADEQUACY WITH RESPECT TO BOTH STATIC STRESS AND CREEP-FATIGUE DAMAGE WAS SELECTED AS THE LOAD CRITERIA, AND THE ANALYSES FOR THESE LOAD CRTERIA ARE PRESENTED HERE. A SUMMARY OF THE LOAD CRITERIA AND RESULTING MARGINS OF SAFETY AND CREEP-FATIGUE DAMAGE IS GIVEN IN THE CONCLUSIONS SECTION, PAGE 5-1.

STATIC ANALYSIS

~

DOWNCOMER PIPE

&

INLET VALVE

STATIC ANALYSIS

DOWNCOMER PIPE

STRUCTURE

THE DOWNCOMER PIPE (FIGURE 1) IS 6.625 INCH DIAMETER SCHEDULE 160 (.718 INCH THICK) MADE OF LOW ALLOY STEEL, 2 1/4 Cr 1 Mo, ASTM A335, GRADE P-22.

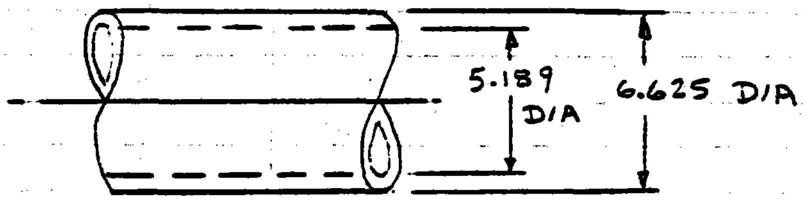

FIGURE 1. DOWNCOMER PIPE

START-UP LOAD CONDITION

PRESSURE; p = 500 PSIA

TEMPERATURE: THE INITIAL TEMPERATURE AND TEMPERATURE GRADIENT 1 SECOND AFTER START OF STEAM FLOW FOR 40000 LBS/HR IS GIVEN IN FIGURE A-1, APPENDIX A-1.

E GILLIS 1-2
6-12-79

DOWNCOMER PIPE

MATERIAL PROPERTIES

MAT'L: A335 : LOW ALLOY STEEL, GRADE P-22, (2¼ Cr, 1 Mo)
SEAMLESS PIPE FOR HIGH TEMP SERVICE

TABLE I

TENSILE STRENGTH, MODULUS OF ELASTICITY, AND COEFFICIENT OF EXPANSION, A335 AT ELEVATED TEMPERATURES

TEMP DEG F	S_m ‡ (KSI) (REF PG A-3)	E (LBS/IN^2 x10^{-6}) (REF PG A-4)	α (IN/IN/°F x10^{6}) (REF PG A-5)
RT	15.0 △	29.9	6.07
200°	15.0	29.5	6.38
238 □	15.0	29.31 *	6.46 *
250	15.0	—	—
300	15.0	29.0	6.60
400	15.0	28.6	6.82

△ $F_{TY} = 30$ KSI ; $F_{TU} = 60$ KSI (REF APPENDIX PAGE A-2)

* $E = \left[29.5 - (29.5 - 29.0)\left(\frac{238-200}{300-200}\right)\right] \times 10^6 = 29.31 \times 10^6$ LBS/IN^2

$\alpha = \left[6.38 + (6.60 - 6.38)\left(\frac{238-200}{300-200}\right)\right] \times 10^{-6} = 6.46 \times 10^{-6}$ IN/IN/°F

‡ S_m IS THE ALLOWABLE TENSILE STRESS EQUAL TO HALF THE YIELD STRESS, F_{TY}.

□ $T_{AVG} = 238$°F (REF PAGE 1-4)

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DOWNCOMER PIPE

PRIMARY AND SECONDARY STRESS ANALYSIS (START UP CONDITION)

PRIMARY STRESS (FROM PRESSURE)

MAX PRESSURE $p = 500$ PSI

$R_o = 3.3125$ IN.

$R_i = 2.5945$ IN.

REF APPENDIX PAGE A-6 FOR REFERENCE SOURCES AND DERIVATION OF STRESS AT INSIDE AND OUTSIDE OF PIPE

HOOP STRESS

$$\sigma_{1p_i} = p \frac{R_o^2 + R_i^2}{R_o^2 - R_i^2} \quad ✓$$

$$= 500 \frac{(3.3125^2 + 2.5945^2)}{(3.3125^2 - 2.5945^2)} = \underline{2087} \ \frac{\text{LBS}}{\text{IN}^2} \quad ✓$$

$$\sigma_{1p_o} = 2pR_i^2 / (R_o^2 - R_i^2)$$

$$= 2(500)\frac{(2.5945^2)}{(3.3125^2 - 2.5945^2)} = \underline{1587} \ \frac{\text{LBS}}{\text{IN}^2} \quad ✓$$

LONGITUDINAL STRESS

$$\sigma_{2p_o} = \sigma_{2p_i} = p/(R_o^2/R_i^2 - 1)$$

$$= 500 / [(3.3125^2/2.5945^2) - 1] = \underline{794} \ \frac{\text{LBS}}{\text{IN}^2} \quad ✓$$

RADIAL STRESS

$$\sigma_{3p_i} = -p = \underline{-500 \ \text{LBS/IN}^2} \quad ✓$$

$$\sigma_{3p_o} = \underline{0.0}$$

DOWNCOMER PIPE

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SECONDARY STRESS ANALYSIS (START UP COND) (REF APPEND PAGE

SINCE IT WILL BE NECESSARY IN CALCULATING THERMAL STRESS (PAGE 1-5) TO INTEGRATE $\int_a^b Tr\,dr$, THIS INTEGRATION WILL BE MADE USING SIMPSON'S RULE APPLIED TO TABLE II.

TABLE II

TEMPERATURE GRADIENT IN PIPE WALL (REF FIG A-1)

r', RADIAL DIST FROM INSIDE (IN.)	r RADIUS (IN)	T TEMP °F (REF FIG A-1)	T×r
0.0	2.5945	400	1038
.0513	2.6458	340	900
.1026	2.6971	306	825
.1539	2.7484	275	756
.2051	2.7996	248	694
.2564	2.8509	230	656
.3077	2.9022	217	630
.3590	2.9535	208	614
.4130	3.0048	204	613
.4616	3.0561	202	617
.5129	3.1074	201	625
.5641	3.1586	200.5	633
.6154	3.2099	200	641
.6667	3.2612	200	652
.7180	3.3125	200	662

$T_{AVE} = 238^*$

THE VALUES OF T×r IN TABLE II ARE NOW INTEGRATED BY SIMPSON'S RULE

$$\int_{2.5945}^{3.3125} Tr\,dr = \frac{h}{2}\left(y_1 + 2y_2 + 2y_3 + \cdots + 2y_{14} + y_{15}\right)$$

WHERE $h/2 = .0513/2 = .02565$ IN

$$\int_{2.5945}^{3.3125} Tr\,dr = .02565\left(1038 + 17712 + 662\right) = .02565(19412) = 497.9$$

°F i

---

* $T_{AVE} = 238°F$. IS DETERMINED BY SIMPSON'S RULE AND USED AS THE TEMPERATURE AT WHICH α & E ARE EVALUATED (REF PAGE 1-2).

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DOWNCOMER PIPE

SECONDARY (THERMAL) STRESSES: (START UP CONDITION)

THE FOLLOWING PARAMETERS WILL BE USED IN THE THERMAL STRESSES CALCULATED BELOW:

$$\left.\begin{array}{l} T_i = 400°F \\ T_o = 200°F \\ T_{AVG} = 238°F \end{array}\right\} \text{(REF PAGE 1-2)}$$

$$\int_a^b Tr\,dr = \int_{2.5945}^{3.3125} Tr\,dr = 497.9 \quad (\text{DEGREES F·INCHES}^2) \quad \text{(REF PAGE 1-4)}$$

$$\left.\begin{array}{ll} \alpha = 6.46 \times 10^{-6} & ((\text{IN/IN})/°F) \\ E = 29.31 \times 10^{6} & (\text{LBS/IN}^2) \end{array}\right\} @\ T = 238°F \quad \left(\begin{array}{c}\text{REF TABLE I} \\ \text{PAGE 1-2}\end{array}\right)$$

$$\mu = .30$$

$$\frac{\alpha E}{1-\mu} = \frac{6.46 \times 29.31}{1-.30} = 270.5 \quad ((\text{LBS/IN}^2)/°F)$$

$$\left.\begin{array}{lll} a = 2.5945 & \text{IN} & (\text{INSIDE RADIUS}) \\ b = 3.3125 & \text{IN} & (\text{OUTSIDE RADIUS}) \end{array}\right\} \text{(REF FIGURE 1, PAGE 1-1)}$$

$$b^2 - a^2 = 3.3125^2 - 2.5945^2 = 4.24123 \ \text{IN}^2$$

THERMAL HOOP STRESSES (REF APPENDIX, PAGE A-10)

$$\sigma_{1T_i} = \frac{\alpha E}{1-\mu}\left[\frac{2}{(b^2-a^2)}\int_a^b Tr\,dr - T\right] = 270.5\left[\frac{2}{4.2412} \times 497.9 - 400\right] = \underline{-44.69} \ (\text{KSI})$$

$$\sigma_{1T_o} = \frac{\alpha E}{1-\mu}\left[\left(\frac{-2}{(b^2-a^2)}\right) \times \int_a^b Tr\,dr - T\right] = 270.5\left[\frac{2}{4.2412} \times 497.9 - 200\right]$$

$$= \underline{9.41 \ (\text{KSI})}$$

LONGITUDINAL THERMAL STRESSES

$$\sigma_{2T_i} = \frac{\alpha E}{1-\mu}\left(\frac{2}{b^2-a^2}\int_a^b Tr\,dr - T\right) = \underline{-44.69} \ (\text{KSI}) \quad (\text{SAME AS } \sigma_{1T_i} \text{ ABOVE})$$

$$\sigma_{2T_o} = \frac{\alpha E}{1-\mu}\left(\frac{2}{b^2-a^2}\int_a^b Tr\,dr - T\right) = \underline{9.41} \ (\text{KSI}) \quad (\text{SAME AS } \sigma_{1T_o} \text{ ABOVE})$$

RADIAL STRESS

$$\sigma_{3T_i} = \sigma_{3T_o} = \frac{0.0}{(\text{KSI})} \quad (\text{BY INSPECTION})$$

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TABLE III

PRIMARY AND SECONDARY STRESSES AND STRESS DIFFERENCES

(T_o = 400°F ; T_i = 200°F)

DOWNCOMER PIPE - STARTUP CONDITION

TYPE LOAD	STRESS TYPE	STRESS (KSI)	
		INSIDE	OUTSIDE
PRESSURE (PRIMARY) (500 PSI) (REF PG 1-3)	σ_{1p}	2.09	1.59
	σ_{2p}	.79	.79
	σ_{3p}	-.50	0.0
THERMAL (SECONDARY) (REF PG 1-5)	σ_{1T}	-44.69	9.41
	σ_{2T}	-44.69	9.41
	σ_{3T}	0.0	0.0
PRESSURE (PRIMARY) (500 PSI)	$S_{12_p} = \sigma_{1p} - \sigma_{2p}$	1.30	-.80
	$S_{23_p} = \sigma_{2p} - \sigma_{3p}$	1.29	.79
	$S_{31_p} = \sigma_{3p} - \sigma_{1p}$	-2.59	-1.59
THERMAL (SECONDARY)	$S_{12_T} = \sigma_{1T} - \sigma_{2T}$	0.0	0.0
	$S_{23_T} = \sigma_{2T} - \sigma_{3T}$	-44.69	9.41
	$S_{31_T} = \sigma_{3T} - \sigma_{1T}$	44.69	-9.41
COMBINED PRESSURE + THERMAL (PRIMARY + SECONDARY)	$S_{12_{PT}} = S_{12_p} + S_{12_T}$	1.30	.80
	$S_{23_{PT}} = S_{23_p} + S_{23_T}$	-43.40	10.20
	$S_{31_{PT}} = S_{31_p} + S_{31_T}$	42.10	-11.00

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TABLE IV

MARGINS OF SAFETY
FOR
PRIMARY AND PRIMARY PLUS SECONDARY LOADS
DOWN COMER PIPE - START UP CONDITION

ITEM	INSIDE	OUTSIDE
S_P, PRIMARY STRESS INTENSITY+ (KSI) (REF TABLE III)	2.59	1.59
S_{PT}, PRIMARY PLUS SECONDARY STRESS INTENSITY (KSI) (REF TABLE III	43.40	11.00
S_m, ALLOWABLE STRESS INTENSITY (KSI)	15.0	15.0
ALLOWABLE PRIMARY STRESS, KS_m (KSI), WHERE K=1 *	15.0	15.0
ALLOWABLE PRIMARY PLUS SECONDARY STRESS, KS_m (KSI) WHERE K=3*	45.0	45.0
MARGIN OF SAFETY FOR PRIMARY STRESS $M.S.=\left(\frac{\text{ALLOWABLE}}{\text{MAX STRESS}}\right)_P-1$	4.79 (HIGH)	8.43 (HIGH)
MARGIN OF SAFETY FOR SECONDARY STRESS $M.S.=\left(\frac{\text{ALLOWABLE}}{\text{MAX STRESS}}\right)_{P+S}-1$	.04	3.09

← (REF PAGE A-3)

CONCLUSION: PIPE IS ADEQUATE (MINIMUM MS = .04 ABOVE) FOR THE PRIMARY AND PRIMARY PLUS SECONDARY LOADS ON THE DOWNCOMER PIPE FOR THE START UP CONDITION

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* REF APPENDIX PAGE A-7 FOR ALLOWABLE STRESS CRITERIA FOR PRIMARY AND SECONDARY STRESSES, AND PAGE A-8 FOR VALUE OF STRESS INTENSITY K.

\+ THE STRESS INTENSITY S IS THE LARGEST ABSOLUTE VALUE OF S_{12}, S_{23} AND S_{31}.

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DOWNCOMER PIPE

CLOUD PASSAGE CONDITION

GENERAL: THE DOWNCOMER PIPE WAS INITIALLY ANALYZED FOR THE CLOUD PASSAGE CONDITION UNDER THE VERY CONSERVATIVE ASSUMPTION THAT THE STEAM TEMPERATURE CHANGED INSTANTANEOUSLY FROM 960°F TO 660°F RESULTING IN A VERY HIGH TEMPERATURE GRADIENT THROUGH THE PIPE WALL AND STRESSES WHICH, WHEN COMBINED WITH STRESS FROM STEAM PRESSURE, RESULTED IN HIGH CREEP DAMAGE. THIS INITIAL ANALYSIS IS GIVEN FOR REFERENCE IN APPENDIX B.

A REVISED MAXIMUM TEMPERATURE GRADIENT, BASED UPON A REALISTIC STEAM TEMPERATURE CHANGE RATE OF 30°F/MIN, HAS BEEN GENERATED (APPENDIX, FIGURE A-2, PAGE A-11).

THE THERMAL STRESS FROM THIS REVISED THERMAL GRADIENT IS NOW CALCULATED.

DOWNCOMER PIPE

CLOUD PASSAGE CONDITION

SECONDARY STRESS (FROM TEMPERATURE)

THERMAL HOOP AND LONGITUDINAL STRESS (INSIDE)

$$\sigma_{1_{T_i}} = \sigma_{2_{T_i}} = \frac{\alpha E}{1-\mu}\left[\frac{2}{b^2-a^2}\int_a^b Tr\,dr - T\right]$$ (REF APPENDIX, PAGE A-10)

WHERE $\int_a^b Tr\,dr$ IS OBTAINED FROM TABLE V FOR THE TEMPERATURE GRADIENT OF FIGURE A-2 APPENDIX PAGE A-11. THE VALUES FROM TABLE V WILL BE SUBSTITUTED INTO SIMPSON'S RULE TO NUMERICALLY INTEGRATE $\int_a^b Tr\,dr$

TABLE V

TEMP GRADIENT AND VALUES OF T×r

r RADIUS (IN)	T TEMP (°F)	T×r (°F·IN)
2.5945	924,0	2397
2,7740	927,0	2571
2,9535	928.5	2742
3.1330	929.5	2912
3,3125	930,0	3081

DOWNCOMER PIPE

CLOUD PASSAGE CONDITION (CONT)

SECONDARY STRESS (CONT)

$$\int_{r_i}^{r_o} Tr\,dr = \frac{\Delta r}{2}\left[(Tr)_1 + 2(Tr)_2 + 2(Tr)_3 + 2(Tr)_4 + (Tr)_5\right]$$ (SIMPSONS RULE) (REF TABLE V)

$$= \frac{.1795}{2}\left[2397 + 2\times2571 + 2\times2742 + 2\times2912 + 3081\right]$$

$$= \frac{.1795}{2}\times 21928 = 1968$$

ALSO THE AVERAGE TEMPERATURE (REQUIRED FOR MATERIAL PROPERTIES) FROM TABLE V BY SIMPSON'S RULE IS

$$T_{AVE} = \int_{r_i}^{r_o} T\,dr \Big/ (r_o - r_i)$$

$$= \frac{\Delta r}{2}\left[T_1 + 2T_2 + 2T_3 + 2T_4 + T_5\right] \Big/ (r_o - r_i)$$

$$= \frac{.1795}{2}\left[924 + 2\times927 + 2\times928.5 + 2\times929.5 + 930\right] \Big/ .718$$

$$= \frac{.1795}{2}\times 7424 / .718 = 928\ ^\circ F$$

THE VALUES OF E AND α AT $T_{AVE} = 928^\circ F$ ARE NOW OBTAINED

$$E = \left[24.5 - (24.5 - 23.0)\left(\frac{928-900}{1000-900}\right)\right]\times10^{6} = 24.08\times10^{6}\ (LBS/IN^2)$$

$$\alpha = \left[7.84 + (7.97 - 7.84)\left(\frac{928-900}{1000-900}\right)\right]\times10^{-6} = 7.88\times10^{-6}\ (IN/IN/^\circ F)$$

REF APPENDIX PAGE B-3

$a = 2.5945$ (IN)

$b = 3.3125$ (IN)

$T = 924^\circ F$ (TABLE V)

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DOWNCOMER PIPE

CLOUD PASSAGE CONDITION (CONT)

SECONDARY STRESS (CONT)

THERMAL HOOP AND LONGITUDINAL STRESS (INSIDE)

$$\sigma_{1_{Ti}} = \sigma_{2_{Ti}} = \frac{7.88 \times 24.05}{1-.3}\left[\frac{2}{3.3125^2 - 2.5945^2} \times 1968 - 924\right]$$

$$= 271.07 \times 4.03 = \underline{\underline{1093}} \ (\text{LBS}/\text{IN}^2)$$

THERMAL HOOP AND LONGITUDINAL STRESS (OUTSIDE)

$$\sigma_{1_{To}} = \frac{\alpha E}{1-m}\left[\frac{2}{(b^2-a^2)}\int_a^b T\,dr - T\right]$$

WHERE $T = 930^\circ F$ (TABLE V)

$$\sigma_{1_{To}} = \sigma_{2_{To}} = \frac{7.88 \times 24.05}{1-.3}\left[\frac{2}{3.3125^2 - 2.5945^2} \times 1968 - 930\right]$$

$$= 271.07 \times (928.03 - 930) = \underline{\underline{-533}} \ (\text{LBS}/\text{IN}^2)$$

ALLOWABLE STRESS INTENSITIES AT ELEVATED TEMPS.

$$\sigma_{924} = 11.0 + (13.1 - 11.0)\left(\frac{950-924}{950-900}\right) = 12.09 \ \left(\begin{matrix}\text{KSI}\\ \text{INSIDE}\end{matrix}\right)$$

$$\sigma_{930} = 11.0 + (13.1 - 11.0)\left(\frac{950-930}{950-900}\right) = 11.84 \ \left(\begin{matrix}\text{KSI}\\ \text{OUTSIDE}\end{matrix}\right)$$

REF APPENDIX B PAGE B-2

DOWNCOMER PIPE - CLOUD PASSAGE (CONT)

PRIMARY AND SECONDARY STRESS ANALYSIS

PRIMARY STRESS (FROM PRESSURE)

HOOP STRESS - INSIDE SURFACE

$$\sigma_{1p_i} = p\,\frac{(R_o^2+R_i^2)}{(R_o^2-R_i^2)}$$ (REF APPENDIX PAGE A-6)

WHERE $p = 1515$ (PSI)
$R_o = 3.3125$ (IN)
$R_i = 2.5945$ (IN)

$$\sigma_{1p_i} = 1515\,\frac{(3.3125^2+2.5945^2)}{(3.3125^2-2.5945^2)} = \underline{\underline{6324.0}}\left(\frac{LBS}{IN^2}\right)$$

HOOP STRESS - OUTSIDE SURFACE

$$\sigma_{1p_o} = 2pR_i^2/(R_o^2-R_i^2)$$

$$= 2\times1515\times2.5945^2/(3.3125^2-2.5945^2) = \underline{\underline{4809.0}}\left(\frac{LBS}{IN^2}\right)$$

LONGITUDINAL STRESS - INSIDE & OUTSIDE

$$\sigma_{2p_i} = \sigma_{2p_o} = p/(R_o^2/R_i^2-1)$$

$$= 1515/(3.3125^2/2.5945^2-1) = \underline{\underline{2406}}\ (LBS/IN^2)$$

RADIAL STRESS

$\sigma_{3p_i} = -p = \underline{-1515}$ (LBS/IN^2) (INSIDE) } BY INSPECTION
$\sigma_{3p_o} = 0.0$ (LBS/IN^2) (OUTSIDE) }

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TABLE VI

PRIMARY AND SECONDARY STRESS AND STRESS DIFFERENCE SUMMARY

DOWNCOMER PIPE - CLOUD PASSAGE

TYPE LOAD	STRESS TYPE	STRESS (KSI)	
		INSIDE	OUTSIDE
PRESSURE (1515 PSI)	σ_{1P}	6.32	4.81
	σ_{2P}	2.41	2.41
	σ_{3P}	-1.52	0.0
THERMAL	σ_{1T}	1.09	-.53
	σ_{2T}	1.09	-.53
	σ_{3T}	0.0	0.0
PRESSURE (1515 PSI)	$S_{12_P} = \sigma_{1P} - \sigma_{2P}$	3.91	2.40
	$S_{23_P} = \sigma_{2P} - \sigma_{3P}$	3.93	2.41
	$S_{31_P} = \sigma_{3P} - \sigma_{1P}$	-7.84	-4.81
THERMAL	$S_{12_T} = \sigma_{1T} - \sigma_{2T}$	0.0	0.0
	$S_{23_T} = \sigma_{2T} - \sigma_{3T}$	1.09	-.53
	$S_{31_T} = \sigma_{3T} - \sigma_{1T}$	-1.09	+.53
COMBINED PRESSURE + THERMAL	$S_{12} = \sigma_{12P} + \sigma_{12T}$	3.91	2.40
	$S_{23} = \sigma_{23P} + \sigma_{23T}$	5.02	1.88
	$S_{31} = \sigma_{31P} + \sigma_{31T}$	-8.93	-4.28

DOWNCOMER PIPE - CLOUD PASSAGE (CONT)

MARGINS OF SAFETY

PRIMARY STRESS CASE

$MS = S_m / S - 1$

WHERE $S_m = 12.09$ KSI (INSIDE) } REF PAGE 1-11
$= 11.84$ KSI (OUTSIDE)

$S = 7.84$ KSI (INSIDE) } REF TABLE VI
$= 4.81$ KSI (OUTSIDE)

INSIDE

$MS = 12.09 / 7.84 - 1 = +.54$

OUTSIDE

$MS = 11.84 / 4.81 - 1 = +1.46$

COMBINED PRIMARY AND SECONDARY STRESS CASE

$MS = 3 \times S_m / S - 1$

WHERE $S_m = 12.09 \times 3 = 36.27$ KSI (INSIDE)
$= 11.84 \times 3 = 35.52$ KSI (OUTSIDE)

AND $S = 8.93$ KSI (INSIDE)
$= 4.28$ KSI (OUTSIDE) (REF TABLE VI)

$MS = 36.27/8.93 - 1 = 3.06$ (INSIDE)

$MS = 35.52/4.28 - 1 =$ HIGH (OUTSIDE)

DOWNCOMER INLET VALVE

GENERAL: THE DOWNCOMER INLET VALVE (FIGURE 2) WAS ANALYZED FOR A NUMBER OF TRIAL LOAD ENVIRONMENTS USING THE NASTRAN FINITE ELEMENT COMPUTER PROGRAM. ANALYSIS FOR THE CASE WHICH RESULTED IN STRUCTURAL ADEQUACY FOR BOTH STATIC STRESS AND CREEP FATIGUE DAMAGE IS PRESENTED HERE.

START-UP LOAD CONDITION

STEAM FLOW RATE, $\dot{w}$ = 20,000 LBS/HR
STEAM PRESSURE, p = 500 PSI
STEAM TEMPERATURE, T = 960° F
INITIAL WALL TEMP, T = 280° F
TIME STEP, t = 4.8 SEC'S

THE TEMPERATURE OF THE CRITICAL ELEMENT (REF FIGURE , ELEMENT NO 179), AT TIME STEP $t = 4.8$ SEC'S, FROM THE NASTRAN ANALYSIS IS

$T = 435°$ F

MATERIAL PROPERTIES: THE MATERIAL PROPERTIES ASSUMED FOR THE VALVE ARE THE SAME AS THOSE USED FOR THE DOWNCOMER PIPE (THAT IS, FOR THE SA335 P22 MATERIAL, REF APPENDIX PAGES A-2, A-3, A-4, & A-5).

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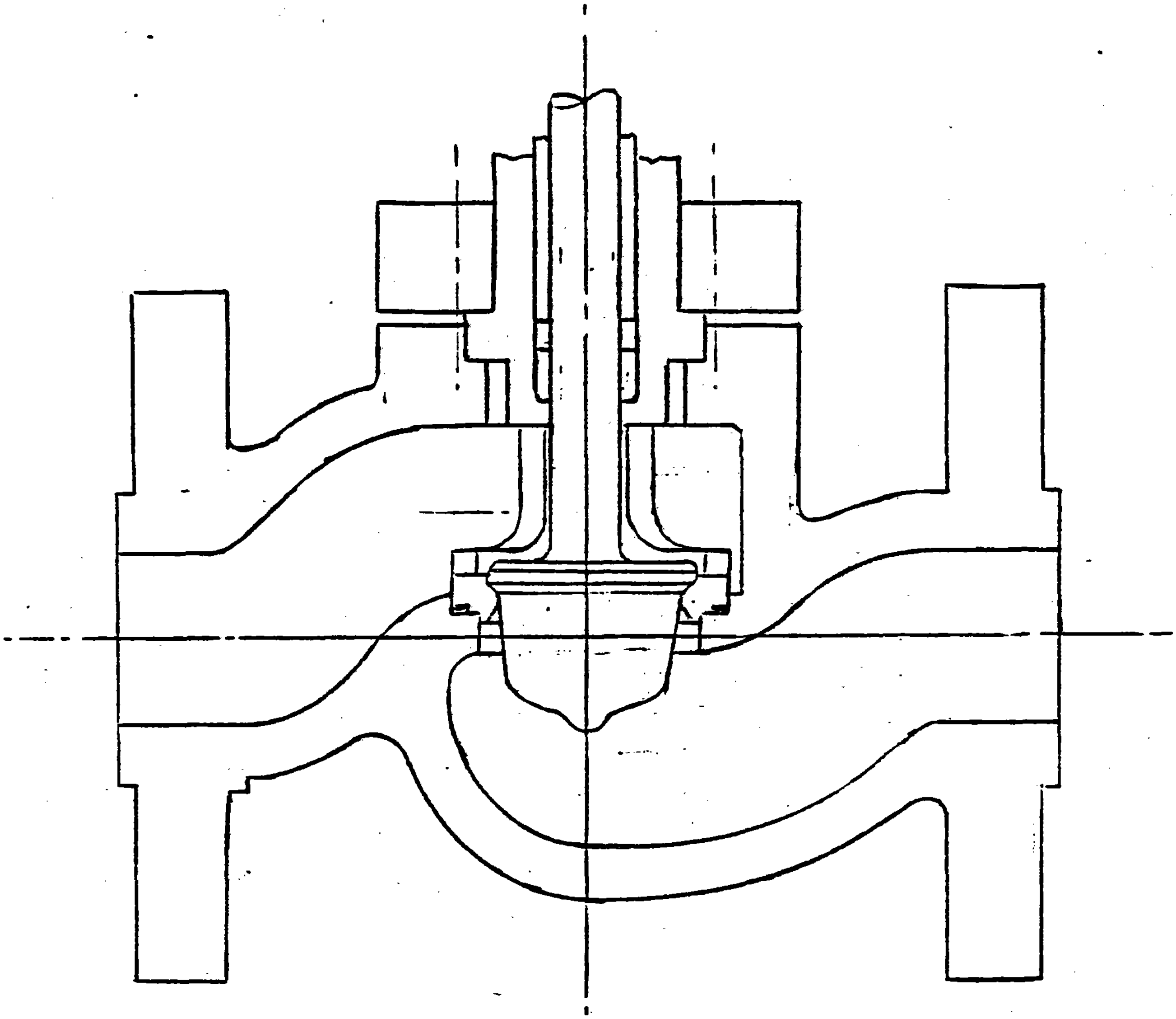
PREPARED BY: E Gillis
CHECKED BY:
DATE:
TITLE:

PAGE: 2-2
MODEL:
REPORT BY:

DOWNCOMER INLET VALVE



SCALE = 2/5

FIGURE 2. PROPOSED VALVE

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DOWNCOMER INLET VALVE

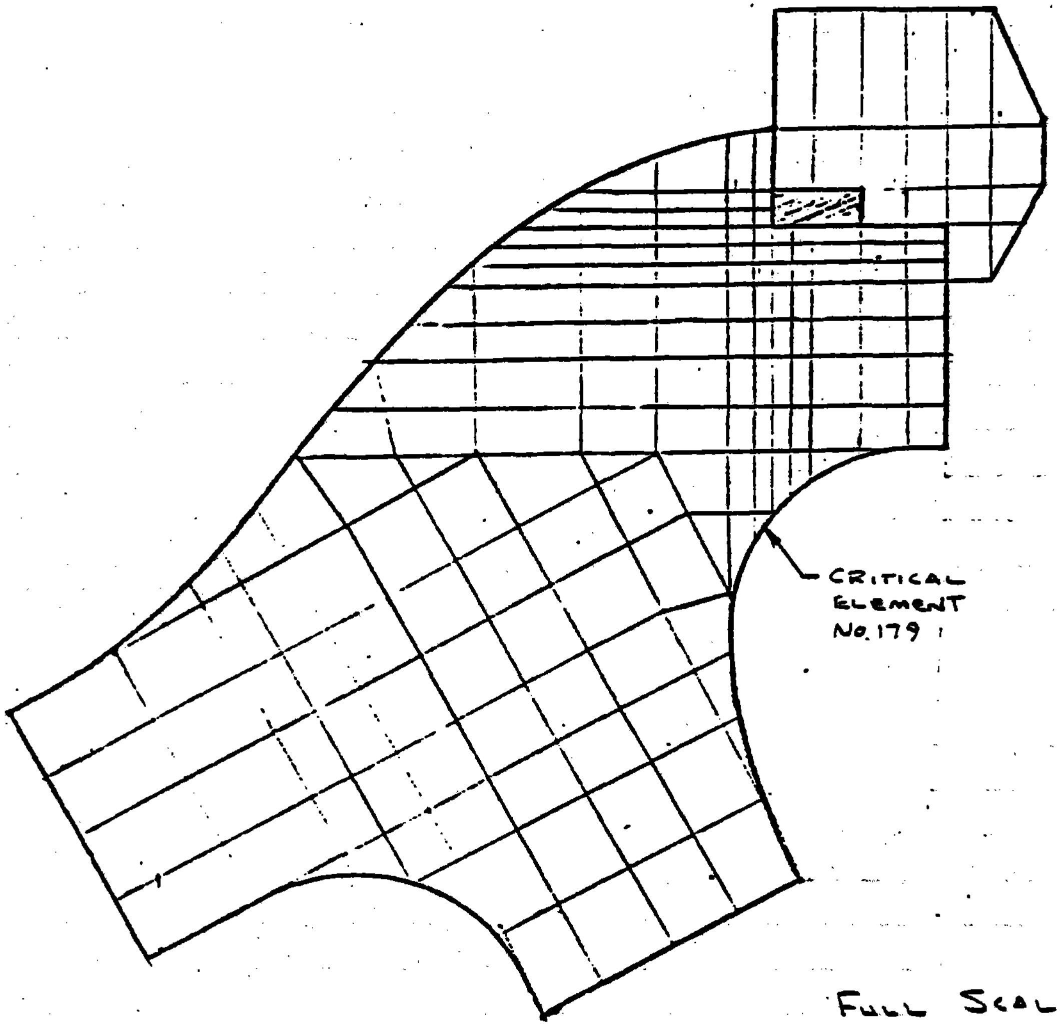

FIGURE 3. DOWNCOMER VALVE, NASTRAN IDEALIZATION AT CRITICAL SECTION SHOWING CRITICAL ELEMENT LOCATION.

DOWNCOMER INLET VALVE (START UP CONDITION) (CONT)

ANALYSIS: THE CRITICAL PORT OF THE INLET VALVE (FIGURE 2) FOR THE START-UP LOADS (PAGE 2-1) IS IDEALIZED (FIGURE 3) FOR THE NASTRAN FINITE ELEMENT PROGRAM. THE ELEMENT HAVING THE HIGHEST STRESSES IS ELEMENT NO 179.

THE DESIGN CRITERIA USED FOR THE ANALYSIS ARE THAT OF REFERENCE 2 (ASME B&PVC SECTION III, PAGE 88, SUBSECTION NB-3200)

PRIMARY (PRESSURE) STRESS: THE PRIMARY (PRESSURE) STRESSES FOR THE VALVE, WHICH ARE VERY LOW COMPARED TO THE THERMAL STRESSES, ARE ASSUMED CONSERVATIVELY TO BE THE SAME AS THOSE OBTAINED FOR THE DOWNCOMER PIPE FOR THE START-UP LOAD CONDITION.

$$\left.\begin{array}{lll} \sigma_{1_p} = .79 & \text{KSI} & \text{(LONGITUDINAL)} \\ \sigma_{2_p} = -.50 & \text{KSI} & \text{(RADIAL)} \\ \sigma_{3_p} = 2.09 & \text{KSI} & \text{(HOOP)} \end{array}\right\} \begin{array}{l} \text{REF PAGE 1-3} \\ \text{INSIDE STRESS} \end{array}$$

SECONDARY (THERMAL) STRESS: THE SECONDARY (THERMAL) STRESS ARE OBTAINED FROM THE NASTRAN FINITE ELEMENT PROGRAM (REF FILE NO S930, USER NO. = M64770)

$\sigma_{1_T} = -43.8$ KSS

$\sigma_{2_T} = 0.0$ KSI

$\sigma_{3_T} = -37.8$ KSI

DOWNCOMER INLET VALVE (START-UP CONDITION) (CONT)

ANALYSIS (CONT)

THE STRESS INTENSITIES S FOR PRIMARY, SECONDARY, AND COMBINED PRIMARY PLUS SECONDARY STRESSES ARE OBTAINED AS FOLLOWS:

PRIMARY STRESS INTENSITIES (KSI)

$S_{12p} = \sigma_{1p} - \sigma_{2p} = .79 + .50 = 1.29$

$S_{23p} = \sigma_{2p} - \sigma_{3p} = -.50 - 2.09 = -2.59$

$S_{31p} = \sigma_{3p} - \sigma_{1p} = 2.09 - .79 = 1.30$

SECONDARY STRESS INTENSITIES (KSI)

$S_{12T} = \sigma_{1T} - \sigma_{2T} = -43.8 - 0.0 = -43.8$

$S_{23T} = \sigma_{2T} - \sigma_{3T} = 0.0 + 37.8 = 37.8$

$S_{31T} = \sigma_{3T} - \sigma_{1T} = -37.8 + 43.8 \quad 6.0$

COMBINED PRIMARY PLUS SECONDARY STRESS INTENSITIES

$S_{12ps} = S_{12p} + S_{12s} = 1.29 - 43.8 = -42.5$ KSI

$S_{23ps} = S_{23p} + S_{23s} = -2.59 + 37.8 = 35.2$ KSI

$S_{31ps} = S_{31p} + S_{31s} = 1.30 + 6.0 = 7.3$ KSI

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DOWNCOMER INLET VALVE (START-UP CONDITION) (CONT)

ANALYSIS (CONT)

ALLOWABLE STRESS INTENSITIES

PRIMARY ALLOWABLE STRESS

$S_m = 15.0$ KSI (REF APPENDIX, PAGES A-12 AND A-3)

COMBINED PRIMARY PLUS SECONDARY ALLOWABLE STRESS

$3 \times S_m = 3 \times 15.0 = 45.0$ KSI (REF APPENDIX, PAGES A-12, A-13, & A-3)

MARGINS OF SAFETY

PRIMARY STRESS CONDITION

$MS_p = S_m / S - 1$

WHERE S IS THE LARGEST ABSOLUTE VALUE OF $S_{12_p}, S_{23_p}, S_{31_p}$; IE. $S = 2.59$ KSI (REF PAGE 2-5)

$MS_p = 15 / 2.59 - 1 = \underline{\underline{4.8}}$

DOWNCOMER INLET VALVE (START-UP CONDITION) (CONT)

ANALYSIS (CONT)

MARGINS OF SAFETY (CONT)

PRIMARY + SECONDARY STRESS CONDITION

$$MS_{ps} = \frac{3 \times S_m}{S} - 1$$

WHERE $3 \times S_m = 45.0$ KSI (REF PAGE 2-6)

AND $S = 42.5$ KSI. (THE LARGEST
ABSOLUTE VALUE OF S_{12ps}, S_{23ps}, S_{31ps},
REF PAGE 2-5)

$$MS_{ps} = \frac{45.0}{42.5} - 1 = \boxed{+.06}$$

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CREEP-FATIGUE ANALYSIS

~

DOWNCOMER PIPE

&

INLET VALVE

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CREEP FATIGUE ANALYSIS - DOWNCOMER PIPE

DESIGN CRITERIA

THE CRITERIA FOR CREEP FATIGUE AND THERMOL RATCHETING FOR THE DOWNCOMER PIPING ARE DEFINED IN THE PROPER STEP BY STEP SEQUENCE AS FOLLOWS:

- "CREEP FATIGUE AND THERMOL RATCHETING CRITERIA AS GUIDLINES FROM ASME B&PVC SECTIONS III AND CODE CASE N-47 (1592)". (REF DEFINITION OF DESIGN CRITERIA, (B) COTOGORY A, STEAM PIPING)
- THE FOLLOWING CRITERIA ARE OBTAINED FROM REF 3, ASME BOILER AND PRESSURE VESSEL CODE CASE N-47-14

-3251 GENERAL REQUIREMENTS (REF 3, N-47, PAGE 126)

"THE STRAINS AND DEFORMATIONS RESULTING FROM THE SPECIFIED OPERATING CONDITIONS SHALL BE EVALUATED. THIS EVALUATION SHALL INCLUDE THE EFFECT OF RATCHETING, THE INTERACTION OF CREEP AND FATIGUE ....."

3252. CRITERIA (REF 3, PAGE 126)

"IT IS THE RESPONSIBILITY OF THE OWNER TO DEFINE THE ACCEPTIBILITY CRITERIA TO BE APPLIED AS STRAIN, DEFORMATION AND FATIGUE LIMITS IN THE DESIGN SPECIFICATIONS (NCA-3250). THE ACCEPTIBILITY CRITERIA AND MATERIAL PROPERTIES CONTAINED IN APPENDIX T MAY BE USED."

CREEP FATIGUE ANALYSIS - DOWNCOMER PIPE (CONT)

DESIGN CRITERIA (CONT)

THE FOLLOWING CRITERIA ARE OBTAINED FROM APPENDIX T (REF 3)

T-1430 LIMITS USING ELASTIC ANALYSIS
T-1431 GENERAL REQUIREMENTS } (REF 3, APPENDIX T PAGE 168)

"(a) THE ELASTIC ANALYSIS RULES IN THIS PARAGRAPH MAY BE USED ONLY WHEN THE ELASTIC RATCHETING RULES OF T-1320 HAVE BEEN SATISFIED"

T-1320 SATISFACTION OF STRAIN LIMITS USING ELASTIC ANALYSIS
T-1321 GENERAL REQUIREMENTS } REF 3, APPENDIX T PAGE 165

"WHEN ELASTIC ANALYSES ARE USED, THE STRAIN LIMITS OF T1310 (STRAIN LIMITS FOR INELASTIC ANALYSIS) ARE CONSIDERED TO HAVE BEEN SATISFIED IF THE LIMITS OF ANY ONE OF T-1322, T-1323, OR T-1324 IS SATISFIED"

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CREEP-FATIGUE ANALYSIS - DOWNCOMER PIPE (CONT)

THERMAL ROTCHETING ANALYSIS (REF 3, T-1321, PAGE 165)

EVALUATION OF PARAMETERS

$X = (P_L + P_b/K_T)/S_y$ (REF 3, PAGE 165)

WHERE $P_L = 6.32$ KSI (MAX PRIMORY DIRECT STRESS FROM P=1515 PSI, REF PAGE 1-12)

$P_b = 0$ (PRIMORY BENDING STRESS)

$S_y = 24.7 - (24.7-23.6)\frac{(960-950)}{(1000-950)} = 24.48$ KSI (REF 3, PG 151)

$X = 6.32/24.48 = .26$

$Y = (Q_R)_{MAX}/S_y$

WHERE $(Q_R)_{MAX} = 1.09$ KSI (MAX RANGE OF SECONDARY STRESS FOR CLOUD PASSAGE, TABLE VI PAGE 1-13)

$\therefore Y = 1.09/24.48 = .04$

IN ORDER FOR THE THERMAL ROTCHETING NOT TO BE A FACTOR, TEST NOS 1, 2, OR 3, UNDER T-1322, T-1323, AND T-1324 CAN BE SATISFIED (REF 3, N-47, PAGE 165)

$X+Y = .26+.04 = .30$

TEST NO 2.

$X+Y = .3 < 1$

CONCLUSIONS: TEST NO 2 IS SATISFIED. THEREFORE ROTCHETING IS NOT A PROBLEM AND CREEP-FATIGUE FAILURE CAN BE ANALYZED USING ELASTIC ANALYSIS.

DOWNCOMER PIPE

CREEP-FATIGUE ANALYSIS -

"WHEN ELASTIC ANALYSIS IS USED TO SATISFY THE REQUIREMENTS OF T-1411, THE FATIGUE AND CREEP-RUPTURE DAMAGE SHALL BE SUMMED LINEARLY AND THE TOTAL CREEP-FATIGUE DAMAGE, D, SHALL NOT EXCEED UNITY."
(REF 3, N-47, T-1431, PAGE 169)

"..... FOR A DESIGN TO BE ACCEPTABLE, THE CREEP AND FATIGUE DAMAGE SHALL SATISFY THE FOLLOWING RELATION:" (REF 3, N-47, T 1411, PAGE 167)

$$\sum_{j=1}^{p}\left(\frac{n}{N_d}\right)_j + \sum_{k=1}^{q}\left(\frac{t}{T_d}\right)_k \le D \quad \ldots\ldots\ldots \quad (1)$$

WHERE THE FIRST TERM REPRESENTS THE FATIGUE DAMAGE AND THE SECOND TERM REPRESENTS THE CREEP RUPTURE DAMAGE, AND $D \le 1$

THE FATIGUE DAMAGE TERM IS EVALUATED ON THE NEXT PAGE WHILE FOR THE DOWNCOMER PIPE THERE ARE TWO CONDITIONS CONTRIBUTING TO FATIGUE DAMAGE (IE, $P = 2$, ABOVE):

(1) TRANSIENT CONDITION CONSISTING OF THE DAILY START-UP CASE REPRESENTED BY FIG A-1, APPENDIX, PAGE A-1; $n = 365 \times 30 = 10950$ CYCLES.

(2) TRANSIENT CONDITION CONSISTING OF CLOUD PASSAGE REPRESENTED BY THE CURVE FIGURE A-2, APPENDIX, PAGE A-11. ASSUME CONSERVATIVELY APPROXIMATELY ONE CLOUD PER DAY; $n \approx 10^4$ CYCLES.

DOWNCOMER PIPE

FATIGUE DAMAGE -

CASE 1 (j=1, CURVE No. 4, FIGURE A-1, START UP CONDITION)

$n = 10950$ CYCLES (PREVIOUS PAGE)

$N_j = 100,000$ CYCLES
FOR $S_{ALT} = \frac{44.7}{2} = 22.35$ KSI

{ REF TABLE II, PAGE 1-6 AND FIG A-3, PAGE A-14

CASE 2. (j=2, CURVE FIGURE A-2, CLOUD PASSAGE, PAGE A-11

$n = 10000$ CYCLES (PREVIOUS PAGE)

$N \approx \infty$ CYCLES FOR $S_{ALT} = \frac{1.09}{2} = .55$ (KSI)

{ REF TABLE VI PAGE 1-16 AND FIG A-3, PG A-14

THE FATIGUE DAMAGE IS

$$\sum_{j=1}^{p} \left(\frac{n}{N_j} \right)_j = \underset{\text{(START-UP)}}{\frac{10950}{100,000}} + \underset{\text{(CLOUD PASSAGE)}}{\frac{10,000}{\infty}} = .110 + 0.0 = \underline{\underline{.110}}$$

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DOWNCOMER PIPE

CREEP DAMAGE

THE CREEP DAMAGE CONSISTS OF ONE CASE (IE, $q=1$, EQUATION 1, PAGE 3-4) OBTAINED FROM THE HISTOGRAM, FIG 4 (PAGE 3-7). INSPECTION OF FIGURE 4 AND THE STRESS TO RUPTURE CURVES, FIGURE A-4, APPENDIX A-15, SHOWS THAT ONLY THE COMBINED OPERATING AND CLOUD PASSAGE CONDITION, AT TEMPERATURE $T = 960°F$, ARE SIGNIFICANT WITH RESPECT TO CREEP DAMAGE.

COMBINED OPERATING AND CLOUD PASSAGE CONDITION

$T = 960°F$, $p = 1515$ PSI (REF FIGURE 4)

TIME $\tau = .25 \times 24 \times 365 \times 30 = 6.6 \times 10^4$ HOURS

MAX STRESS INTENSITY

$S = 8.93$ KSI (~~REF TABLE VI, PAGE 1-13~~ CLOUD PASSAGE)

$T_d = 3.0 \times 10^5$ HRS (REF FIG A-4, APPENDIX, PAGE A-15)

TOTAL CREEP DAMAGE

$$\sum_{K=1}^{1} \left(\frac{\tau}{T_d}\right) = \frac{6.6 \times 10^4}{3 \times 10^5} = \underline{\underline{.22}}$$

TOTAL CREEP-FATIGUE DAMAGE

$$\sum_{j=1}^{p} \left(\frac{n}{N_d}\right)_j + \sum_{k=1}^{q} \left(\frac{\tau}{T_d}\right)_k = \underset{\substack{(\text{FATIGUE}) \\ (\text{PAGE } 3.5)}}{.11} + \underset{\substack{(\text{CREEP}) \\ (\text{ABOVE})}}{.22} = .33 < 1.0$$

CONCLUSIONS: SINCE THE CREEP-FATIGUE DAMAGE $D = .33 < 1.0$ (ABOVE), THE DOWNCOMER PIPE HAS SUFFICIENT RESISTANCE TO CREEP FATIGUE FOR THE 30 YEAR LIFE.

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CORPORATION

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DOWNCOMER PIPE

HISTOGRAM

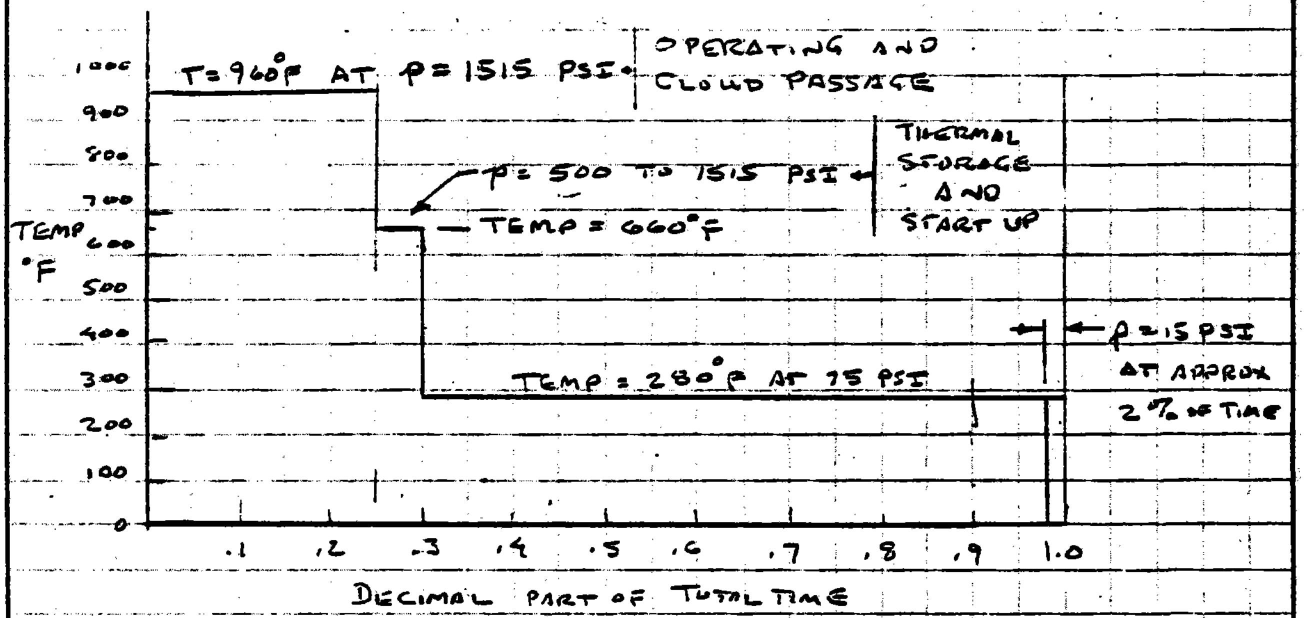

FIGURE 4. HISTOGRAM OF TEMP VS. TIME FOR DOWNCOMER PIPE.

FATIGUE DAMAGE - INLET VALVE

START-UP CASE

$n = 10950$ CYCLES (REF BOTTOM OF PAGE 3-4)

$N_1 = 8 \times 10^4$ CYCLES
FOR $S_{ALT} = \frac{42.5}{2} = 21.3$ KSI

REF PAGE 2-5
AND FIGURE A-3, PAGE A-14

THE FATIGUE DAMAGE IS

$$\frac{n}{N_1} = \frac{10950}{80000} = .137$$

TOTAL FATIGUE DAMAGE - INLET VALVE

$$D = \sum_{j=1}^{p} \left(\frac{n}{N_1}\right)_j = .137 < 1.0$$

CONCLUSION: THE PROPOSED DOWNCOMER INLET VALVE IS ACCEPTABLE WITH RESPECT TO FATIGUE DAMAGE (IE D = .137 < 1.0, ABOVE).

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INLET VALVE

CREEP DAMAGE

ALTHOUGH THE CLOUD PASSAGE CASE AND THE MAXIMUM 1515 PSI PRESSURE CASE WERE NOT ANALYZED USING THE NASTRAN MODEL, IT WILL BE ASSUMED THAT THE MAXIMUM STRESS INTENSITY FOR THESE CONDITIONS IS THE SAME AS THAT OF THE DOWNCOMER PIPE, $\underline{S} = 8.93$ KSI, RESULTING IN $T_d = 3.0 \times 10^5$ HRS AT $T = 960°F$ (REF PAGE 3.6). THE TOTAL ACTUAL TIME IS $t = 6.6 \times 10^4$ HRS, AND THE CREEP DAMAGE IS

$$D = \sum_{K=1}^{1} \left(\frac{t}{T_d}\right) = \frac{6.6 \times 10^4}{3 \times 10^5} = \underline{\underline{.22}}$$

CONCLUSIONS:

THE LOAD CRITERIA (ACCEPTABLE LOAD ENVIRONMENT) FOR BOTH THE DOWNCOMER PIPE AND DOWNCOMER INLET VALVE ARE SUMMARIZED IN TABLE VII. CORRESPONDING MARGINS OF SAFETY FOR STATIC LOADS ARE SUMMARIZED IN TABLE VIII.. CREEP-FATIGUE DAMAGE AND CORRESPONDING NUMBERS OF PREDICTED LIFE CYCLES ARE SUMMARIZED IN TABLE IX

INSPECTION OF TABLE VIII AND IX SHOWS STRUCTURAL ADEQUACY OF BOTH THE DOWNCOMER PIPE AND DOWNCOMER VALVE WITH RESPECT TO MAXIMUM STATIC STRESSES (i.e. PRIMARY AND SECONDARY SRESSES) AND CREEP-FATIGUE RESISTANCE FOR THE LOAD CRITERIA GIVEN IN TABLE VII.

THE LOAD CRITERIA FOR THE START-UP CONDITION FOR THE INLET VALVE (M.S. = +.06, TABLE VIII) GOVERN OVER THOSE OF FOR THE DOWNCOMER PIPE (MS = +.04), SINCE THE FORMER CRITERIA ARE CONSIDERABLY LESS SEVERE WITH RESPECT TO STEAM FLOW RATES ($\dot{W}$ = 20,000 LBS/HR VS. 40,000 LBS/HR) AND INITIAL WALL TEMPERATURE (T_W = 280°F VS 200°F), (REF TABLE VII).

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TABLE VII
LOAD CRITERIA
DOWNCOMER PIPE AND VALVE - 10 MW SOLAR POWER PLANT

PART	DOWN COMER PIPE		DOWN-COMER VALVE	PIPE & VALVE
CONDITION	START-UP	CLOUD PASSING	START UP	OPER-ATING
$\dot{w}$ STEAM FLOW RATE (LBS/HR)	40000	DESIGN	20000	DESIGN
P STEAM PRESSURE (PSI)	500	1515	500	1515
T_s STEAM TEMP (°F)	960	960 TO 660	960	960
T_w INITIAL WALL TEMP (°F)	200	960	280	—

TABLE VIII

MAX STRESS AND MARGINS OF SAFETY SUMMARY

DOWNCOMER PIPE AND DOWNCOMER INLET VALVE

PART	DOWNCOMER PIPE		INLET VALVE
LOAD CONDITION	START UP (REF PG 1-7)	CLOUD PASSAGE (REF PG 1-14)	START-UP (PAGES 2-6 & 2-7)
S_p MAXIMUM PRIMARY STRESS INTENSITY (KSI)	2.59	7.84	2.6
S MAXIMUM PRIMARY PLUS SECONDARY STRESS INTENSITY (KSI)	43.4	8.93	42.5
S_m ALLOWABLE PRIMARY STRESS INTENSITY (KSI)	15.0	12.09	15.0
$3S_m$ ALLOWABLE PRIMARY PLUS SECONDARY STRESS INTENSITY (KSI)	45.0	36.27	45.0
$MS_p = S_m/S_p - 1$	4.79	.54	4.77
$MS_{ps} = 3S_m/S - 1$	.04	3.06	.06

TABLE IX

CREEP-FATIGUE DAMAGE AND PREDICTED LIFE CYCLES

DOWNCOMER PIPE AND DOWNCOMER INLET VALVE

PART	DOWNCOMER PIPE (REF PG 3-6)	DOWNCOMER INLET VALVE (SEE PG 4-1 & 4-2)
CREEP DAMAGE $D_c = \sum_{K=1}^{6} \left(\frac{t}{T_d}\right)_K$	.22	.22
FATIGUE DAMAGE $D_F = \sum_{j=1}^{p} \left(\frac{n}{N_d}\right)_j$	.11	.14
TOTAL CREEP-FATIGUE DAMAGE $D = D_c + D_F$	.33	.36
PREDICTED NUMBER OF LIFE CYCLES $N' = 1/D$	3.03	2.78

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PAGE 6-1

REFERENCES

1. ANSI B31.1 POWER PIPING, 1977 EDITION ASME, 345 EAST 47TH ST, NEW YORK, N.Y. 10017

2. ASME BOILER AND PRESSURE VESSEL CODE, SECTION III, ASME, 345 EAST 47TH ST. NEW YORK, N.Y. 10017

3. N-47-14, CASES OF ASME BOILER AND PRESSURE VESSEL CODE, MEETING OF MAY 5, 1978, APPROVED BY COUNCIL JULY 10, 1978.

APPENDIX A

REFERENCE INFORMATION

TEMPERATURE GRADIENT THROUGH PIPE WALL

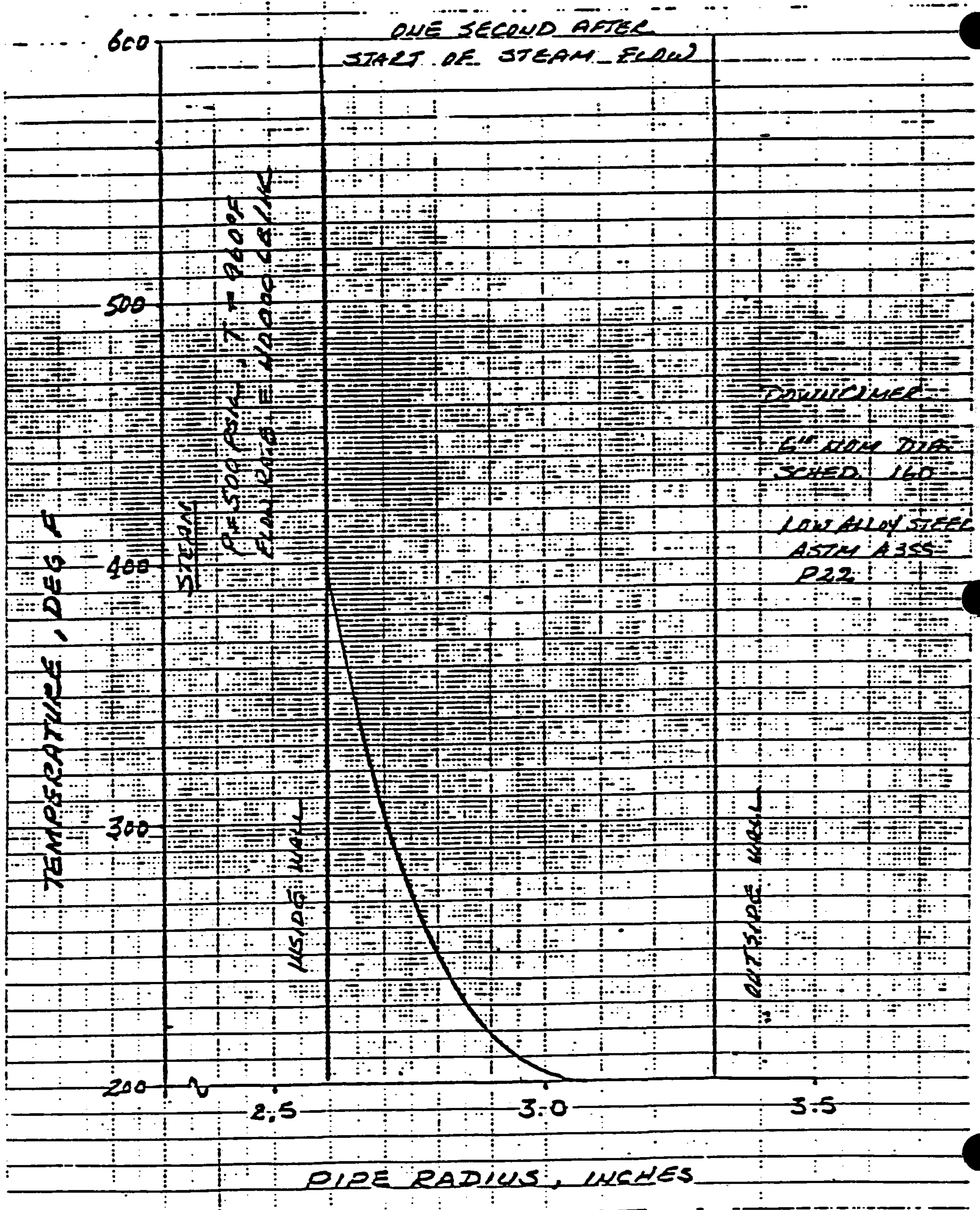

FIGURE A-1 TEMP GRADIENT - DOWNCOMER PIPE
START UP CONDITION

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A-2

(REF 1)

TABLE ACS-1 (CONT'D)
DESIGN STRESS INTENSITY VALUES, S_m IN TENSION FOR CARBON AND LOW-ALLOY STEELS, IN KIPS/SQ IN.
(Multiply by 1000 to Obtain psi)

Nominal Composition	P-No.	Gr.-No.	Product Form	Specification Number	Grade	Notes	Specified Minimum Yield	Specified Minimum Tensile
Low Alloy Steel (Cont'd)								
2¼ Cr-1 Mo	5	1	Plate	SA-387	22, Cl.1	(7)	30.0	60.0
2¼ Cr-1 Mo	5	1	Smls. Tb.	SA-213	T22	. . .		
2¼ Cr-1 Mo	5	1	Smls. Pp.	SA-335	P22	. . .		
2¼ Cr-1 Mo	5	1	FB Pp.	SA-369	FP22	. . .		
2¼ Cr-1 Mo	5	1	Forg.	SA-336	F22a	. . .		
2¼ Cr-1 Mo	5	1	Cast.	SA-217	WC9	(2)	40.0	70.0
2¼ Cr-1 Mo	5	1	Plate	SA-387	22, Cl.2	(2)	45.0	75.0
2¼ Cr-1 Mo	5	1	Forg.	SA-336	F22	. . .		
2¼ Cr-1 Mo	5	1	Forg.	SA-182	F22	. . .	40.0	70.0
2¼ Cr-1 Mo	5	2	Cast.	SA-487	8N	(2)	55.0	85.0
3 Cr-1 Mo	5	1	Smls. Tb.	SA-199	T21	. . .	25.0	60.0
3 Cr-1 Mo	5	1	Plate	SA-387	21, Cl.1	(7)	30.0	60.0
3 Cr-1 Mo	5	1	Smls. Tb.	SA-213	T21	. . .		
3 Cr-1 Mo	5	1	Smls. Pp.	SA-335	P21	. . .		
3 Cr-1 Mo	5	1	Forg.	SA-336	F21a	. . .		
3 Cr-1 Mo	5	1	FB Pp.	SA-369	FP21	. . .		
3 Cr-1 Mo	5	1	Forg.	SA-182	F21	. . .	45.0	75.0
3 Cr-1 Mo	5	1	Forg.	SA-336	F21N	. . .		
3 Cr-1 Mo	5	1	Plate	SA-387	21, Cl.2	(2)		
5 Cr-½ Mo	5	2	Smls. Tb.	SA-199	T5	. . .	25.0	60.0
5 Cr-½ Mo	5	2	Plate	SA-387	5 Cl.1	. . .	30.0	60.0
5 Cr-½ Mo	5	2	Smls. Tb.	SA-213	T5	. . .		
5 Cr-½ Mo	5	2	Smls. Pp.	SA-335	P5	. . .		
5 Cr-½ Mo	5	2	Smls. Pp.	SA-369	FP5	. . .		
5 Cr-½ Mo-Si	5	2	Smls. Tb.	SA-213	T5b	. . .		
5 Cr-½ Mo-Si	5	2	Smls. Pp.	SA-335	P5b	. . .		
5 Cr-½ Mo-Ti	5	2	Smls. Tb.	SA-213	T5c	. . .		
5 Cr-½ Mo-Ti	5	2	Smls. Pp.	SA-335	P5c	. . .		
5 Cr-½ Mo	5	2	Forg.	SA-182	F5	. . .	40.0	70.0
5 Cr-½ Mo	5	2	Forg.	SA-336	F5	. . .	36.0	60.0
5 Cr-½ Mo	5	2	Plate	SA-387	5 Cl.2	. . .	45.0	75.0
5 Cr-½ Mo	5	2	Forg.	SA-336	F5a	. . .	50.0	80.0
5 Cr-½ Mo	5	2	Cast.	SA-217	C5	(2)	60.0	90.0
5 Cr-½ Mo	5	2	Forg.	SA-182	F5a	. . .	65.0	
7 Cr-½ Mo	5	2	Smls.Tb.	SA-199	T7	. . .	25.0	60.0

(REF 2)

APPENDIX A

Maximum Allowable Stress Values In Tension In Thousands of Pounds Per Square Inch
For Metal Temperature Not Exceeding Deg. F (b) (2)

LOW AND INTERMEDIATE ALLOY STEEL

Seamless Pipe and Tubes

20 to 400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Specification (a)	Grade
15.0	15.0	15.0	15.0	15.0	15.0	14.7	14.0	12.5	10.0	6.2	4.2	2.7	1.7	1.2	A199	T3b
15.0	14.5	14.0	13.7	13.4	13.1	12.8	12.0	10.3	7.6	5.6	4.1	3.0	2.0	1.3	A199	T5
15.0	14.5	14.0	13.7	13.4	13.1	12.5	11.5	9.5	7.0	5.0	3.5	2.5	1.8	1.2	A199	T7
15.0	14.5	14.0	13.7	13.4	13.1	12.8	12.5	12.0	10.8	8.5	5.5	3.3	2.2	1.5	A199	T9
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.1	11.0	7.8	5.5	4.0	2.5	1.2	A199	T11
15.0	15.0	15.0	15.0	14.8	14.5	13.9	13.2	12.0	9.0	7.0	5.5	4.0	2.7	1.5	A199	T21
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.1	11.0	7.8	5.8	4.2	3.0	1.6	A199	T22
15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.7	12.5	10.0	6.2	...	...	...	...	A213	T2
15.0	15.0	15.0	15.0	15.0	15.0	14.7	14.0	12.5	10.0	6.2	4.2	2.7	...	...	A213	T3b
15.0	14.5	14.0	13.7	13.4	13.1	12.8	12.0	10.3	7.6	5.6	4.1	3.0	2.0	1.3	A213	T5
15.0	14.5	14.0	13.7	13.4	13.1	12.8	12.0	10.3	7.6	5.6	4.1	3.0	2.0	1.3	A213	T5b
15.0	14.5	14.0	13.7	13.4	13.1	12.8	12.0	10.3	7.6	5.6	4.1	3.0	2.0	1.3	A213	T5c
15.0	14.5	14.0	13.7	13.4	13.1	12.5	11.5	9.5	7.0	5.0	3.5	2.5	1.8	1.2	A213	T7
15.0	14.5	14.0	13.7	13.4	13.1	12.8	12.5	12.0	10.8	8.5	5.5	3.3	2.2	1.5	A213	T9
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.1	11.0	6.5	4.0	3.0	...	...	A213	T11
15.0	15.0	15.0	15.0	15.0	15.0	14.7	14.2	13.1	11.0	6.5	4.0	2.8	...	...	A213	T12
15.0	15.0	15.0	15.0	14.8	14.5	13.9	13.2	12.0	9.0	7.0	5.5	4.0	...	...	A213	T21
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.1	11.0	7.8	5.8	4.2	...	...	A213	T22
16.2	16.2	16.2	16.2	...	...	...	...	...	...	...	...	...	...	...	A333	3
15.0	15.0	15.0	15.0	...	...	...	...	...	...	...	...	...	...	...	A333	4
16.2	16.2	16.2	16.2	...	...	...	...	...	...	...	...	...	...	...	A333	7
[illegible]	...	...	...	...	...	...	...	...	...	...	...	...	...	...	A333	9
13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.4	...	...	...	...	...	...	...	A335	P1
13.7	13.7	13.7	13.7	13.7	13.7	13.4	13.1	12.5	10.0	6.2	...	...	...	...	A335	P2
15.0	14.5	14.0	13.7	13.4	13.1	12.8	12.0	10.3	7.6	5.6	4.1	3.0	2.0	1.3	A335	P5
15.0	14.5	14.0	13.7	13.4	13.1	12.8	12.0	10.3	7.6	5.6	4.1	3.0	2.0	1.3	A335	P5b
15.0	14.5	14.0	13.7	13.4	13.1	12.8	12.0	10.3	7.6	5.6	4.1	3.0	2.0	1.3	A335	P5c
15.0	14.5	14.0	13.7	13.4	13.1	12.5	11.5	9.5	7.0	5.0	3.5	2.5	1.8	1.2	A335	P7
15.0	14.5	14.0	13.7	13.4	13.1	12.8	12.5	12.0	10.8	8.5	5.5	3.3	2.2	1.5	A335	P9
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.1	11.0	6.5	4.0	3.0	...	...	A335	P11
15.0	15.0	15.0	15.0	15.0	15.0	14.7	14.2	13.1	11.0	6.5	4.0	2.8	...	...	A335	P12
15.0	15.0	15.0	15.0	14.8	14.5	13.9	13.2	12.0	9.0	7.0	5.5	4.0	...	...	A335	P21
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.1	11.0	7.8	5.8	4.2	...	...	A335	P22
13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.4	...	...	...	...	...	...	...	A369	FP1
13.7	13.7	13.7	13.7	13.7	13.7	13.4	13.1	12.5	10.0	6.2	...	...	...	...	A369	FP2
15.0	15.0	15.0	15.0	15.0	15.0	14.7	14.0	12.5	10.0	6.2	4.2	2.7	...	...	A369	FP3b
15.0	14.5	14.0	13.7	13.4	13.1	12.8	12.0	10.3	7.6	5.6	4.1	3.0	2.0	1.3	A369	FP5
15.0	14.5	14.0	13.7	13.4	13.1	12.5	11.5	9.5	7.0	5.0	3.5	2.5	1.8	1.2	A369	FP7
15.0	14.5	14.0	13.7	13.4	13.1	12.8	12.5	12.0	10.8	8.5	5.5	3.3	2.2	1.5	A369	FP9
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.1	11.0	6.5	4.0	3.0	...	...	A369	FP11
15.0	15.0	15.0	15.0	15.0	15.0	14.7	14.2	13.1	11.0	6.5	4.0	2.8	...	...	A369	FP12
15.0	15.0	15.0	15.0	14.8	14.5	13.9	13.2	12.0	9.0	7.0	5.5	4.0	...	...	A369	FP21
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.1	11.0	7.8	5.8	4.2	...	...	A369	FP22

APPENDIX C

MODULI OF ELASTICITY FOR FERROUS MATERIAL[1]

Table C-1

Material	E = Modulus of Elasticity, psi (Multiply tabulated Values by 10^6)														
	Temperature, Deg F														
	−325	−200	−100	70[2]	200	300	400	500	600	700	800	900	1000	1100	1200
Carbon Steels with Carbon Content 0.30% or less	...	...	29.0	27.9	27.7	27.4	27.0	26.4	25.7	24.8	23.4	...	...	...	...
Carbon Steels with Carbon Content Above 0.30%	...	...	30.4	29.9	29.5	29.0	28.3	27.4	26.7	25.4	23.8	...	...	...	...
Carbon-Moly Steels	...	...	30.4	29.9	29.5	29.0	28.6	28.0	27.4	26.6	25.7	24.5	...	...	...
Low Cr-Moly Steels—Through 3 Cr	...	...	30.4	29.9	29.5	29.0	28.6	28.0	27.4	26.6	25.7	24.5	23.0	20.4	15.6
Intermediate Cr-Moly Steels (5 Cr-9 Cr)	...	...	28.1	27.4	27.1	26.8	26.4	26.0	25.4	24.9	24.2	23.5	22.8	21.9	20.8
Austenitic Stainless Steels:															
Type 304—18 Cr-8 Ni	...	...	...	28.3	27.9	27.1	26.6	26.0	25.6	24.7	24.1	23.2	22.5	21.8	21.1
Type 309—23 Cr-12 Ni	...	...	...	28.1	...	...	...	...	...	...	23.1	...	22.6	...	21.8
Type 310—25 Cr-20 Ni	...	...	...	29.0	28.2	27.5	26.8	26.2	25.5	24.9	24.2	23.6	23.0	22.4	21.8
Type 316—16 Cr-12 Ni-2 Mo	...	...	...	28.3	28.1	27.5	26.9	26.3	25.6	24.9	24.2	23.5	22.8	22.2	21.5
Type 321—18 Cr-10 Ni-Ti	...	...	...	28.9	28.0	27.3	26.5	25.8	25.3	24.5	23.8	23.2	22.5	21.9	21.2
Type 347—18 Cr-10 Ni-Cb	...	...	...	28.9	28.2	27.5	26.8	26.1	25.4	24.8	24.1	23.4	22.8	22.0	21.4
Straight Chromium Stainless Steels (12 Cr, 17Cr, 27 Cr)	...	...	29.8	29.2	28.7	28.3	27.7	27.0	26.0	24.8	23.1	21.1	18.6	15.6	12.2
Gray Cast Iron	...	...	...	13.4	13.2	12.9	12.6	12.2	11.7	11.0	10.2	...	...	...	...

1. These data are for information and it is not to be implied that materials are suitable for all the temperature ranges shown.
2. Values shown for austenitic stainless steels in this column are at 75 F.

(REF 2)

APPENDIX B

THERMAL EXPANSION DATA

Mean Coefficient of Thermal Expansion = $\frac{A}{10^6}$ (in./in./F)
Linear Thermal Expansion = B (in./100 ft)
} in Going from 70 F to Indicated Temperature

Material	Coefficient	Temperature Range 70 F to −325	−150	−50	70	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
Carbon steel; Carbon-moly steel low-chrome steels (through 3 Cr)	A	5.00	5.50	5.80	6.07	6.38	6.60	6.82	7.02	7.23	7.44	7.65	7.84	7.97	8.12	8.19	8.28	8.36
	B	2.37	1.45	0.84	0	0.99	1.82	2.70	3.62	4.60	5.63	6.70	7.81	8.89	10.04	11.10	12.22	13.34
Intermediate alloy steels; (5 Cr-Mo through 9 Cr-Mo)	A	4.70	5.20	5.45	5.73	6.04	6.19	6.34	6.50	6.66	6.80	6.96	7.10	7.22	7.32	7.41	7.49	7.55
	B	2.22	1.37	0.79	0	0.94	1.71	2.50	3.35	4.24	5.14	6.10	7.07	8.06	9.05	10.00	11.06	12.05
Austenitic stainless steels	A	8.15	8.60	8.90	9.11	9.34	9.47	9.59	9.70	9.82	9.92	10.05	10.16	10.29	10.39	10.48	10.54	10.60
	B	3.85	2.27	...	0	1.46	2.61	3.80	5.01	6.24	7.50	8.80	10.12	11.48	12.84	14.20	15.56	16.92
Straight chromium stainless steels; (12 Cr, 17 Cr, and 27 Cr)	A	4.30	4.70	5.00	5.24	5.50	5.66	5.81	5.96	6.13	6.26	6.39	6.52	6.63	6.72	6.78	6.85	6.90
	B	2.04	1.24	0.72	0	0.86	1.56	2.30	3.08	3.90	4.73	5.60	6.49	7.40	8.31	9.20	10.11	11.01
25 Cr – 20 Ni	A	6.35	6.85	7.20	7.48	7.76	7.92	8.08	8.22	8.38	8.52	8.68	8.81	8.92	9.00	9.08	9.12	9.18
	B	3.00	1.81	0.98	0	1.21	2.18	3.20	4.24	5.33	6.44	7.60	8.78	9.95	11.12	12.31	13.46	14.65
Monel (67 Ni – 30 Cu)	A	5.55	6.75	7.15	7.48	7.84	8.02	8.20	8.40	8.58	8.78	8.96	9.16	9.34	9.52	9.70	9.88	10.04
	B	2.62	1.79	...	0	1.22	2.21	3.25	4.33	5.46	6.64	7.85	9.12	10.42	11.77	13.15	14.58	16.02
Monel (66 Ni – 29 Cu-Al)	A	5.35	6.45	6.80	7.12	7.48	7.68	7.90	8.09	8.30	8.50	8.70	8.90	9.10	9.30	9.50	9.70	9.89
	B	2.53	1.70	0.98	0	1.17	2.12	3.13	4.17	5.28	6.43	7.62	8.86	10.16	11.50	13.00	14.32	15.78
Aluminum	A	9.90	10.90	11.60	12.25	12.95	13.28	13.60	13.90	14.20								
	B	4.68	2.88	1.67	0	2.00	3.66	5.39	7.17	9.03								
Gray cast iron	A					5.75	5.93	6.10	6.28	6.47	6.65	6.83	7.00	7.19				
	B				0	0.90	1.64	2.42	3.24	4.11	5.03	5.98	6.97	8.02				
Bronze	A	8.40	8.75	9.15	9.57	10.03	10.12	10.23	10.32	10.44	10.52	10.62	10.72	10.80	10.90	11.00		
	B	3.98	2.31	1.32	0	1.56	2.79	4.05	5.33	6.64	7.95	9.30	10.68	12.05	13.47	14.92		
Brass	A	8.20	8.50	8.95	9.34	9.76	10.00	10.23	10.47	10.69	10.92	11.16	11.40	11.63	11.85	12.09		
	B	3.88	2.24	1.29	0	1.52	2.76	4.05	5.40	6.80	8.26	9.78	11.35	12.98	14.65	16.39		
Wrought iron	A	5.70	6.30	6.65	6.97	7.32	7.48	7.61	7.73	7.88	8.01	8.13	8.29	8.39				
	B	2.70	1.67	0.96	0	1.14	2.06	3.01	3.99	5.01	6.06	7.12	8.26	9.36				
Copper-Nickel (70 Cu – 30 Ni)	A	6.65	7.40	7.80	8.16	8.54	8.71	8.90										
	B	3.15	1.95	1.13	0	1.33	2.40	3.52										

These data are for information and it is not to be implied that materials are suitable for all the temperature ranges shown.

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APPENDIX A
(REF 2)

STRESSES IN PIPE FROM PRESSURE

HOOP (TANGENTIAL)

PRIMARY STRESS ON OUTSIDE FROM PRESSURE

$$\sigma_{t_o} = \frac{P_i r_i^2 + \left(r_i^2 r_o^2 / \rho^2\right) P_i}{r_o^2 - r_i^2}$$

(REF ADVANCED MECHANICS OF MATERIALS
SEELY & SMITH, 2ND EDITION, JOHN WILEY & SONS
N.Y., PAGE 299, EQ 346)

WHERE $\rho = r_o$

$$\boxed{\sigma_{t_o} = \frac{P_i\left(r_i^2 + r_i^2\right)}{r_o^2 - r_i^2} = \frac{2 P_i r_i^2}{r_o^2 - r_i^2}}$$

✓

HOOP (TANGENTIAL)

PRIMARY STRESS ON INSIDE FROM PRESSURE

$$\boxed{\sigma_{t_i} = \frac{P\left(r_i^2 + r_o^2\right)}{\left(r_o^2 - r_i^2\right)}}$$

(REF 3, PAGE 300)
(EQ 352)

✓

PRIMARY LONGITUDINAL STRESS ON INSIDE AND OUTSIDE FROM PRESSURE

$$\sigma_{l_o} = \sigma_{l_i} = \frac{-P \pi r_i^2}{\pi\left(r_o^2 - r_i^2\right)}$$

$$\boxed{\sigma_{l_o} = \sigma_{l_i} = \frac{-P}{\left(\frac{r_o^2}{r_i^2} - 1\right)}}$$

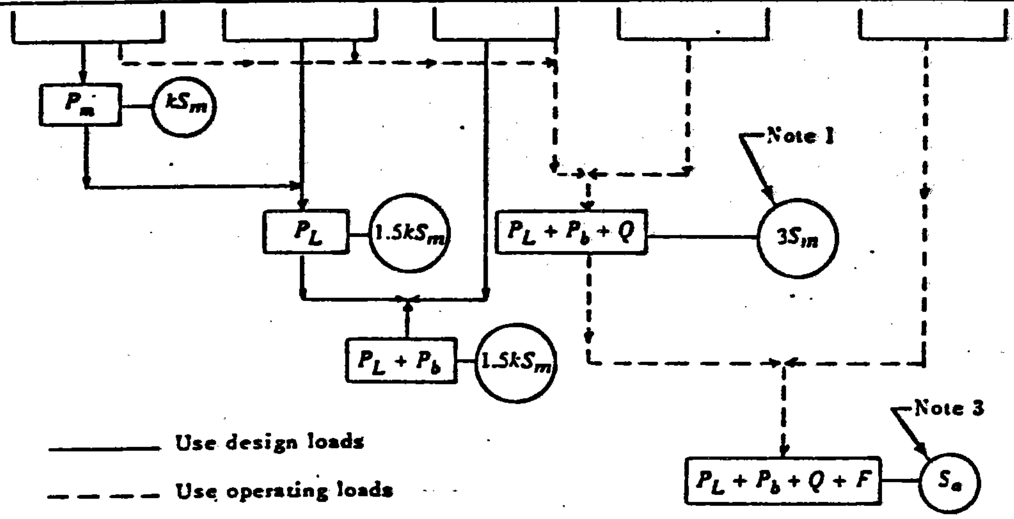
✓

PRIMARY RADIAL STRESS ON INSIDE & OUTSIDE FROM PRESSURE

$$\left.\begin{aligned} \sigma_{r_i} &= -P \\ \sigma_{r_o} &= 0.0 \end{aligned}\right\} \text{FROM INSPECTION}$$

Stress Category	Primary			Secondary Membrane plus Bending	Peak
	General Membrane	Local Membrane	Bending		
Description (For examples, see Table 4-120.1)	Average primary stress across solid section. Excludes discontinuities and concentrations. Produced only by mechanical loads.	Average stress across any solid section. Considers discontinuities but not concentrations. Produced only by mechanical loads.	Component of primary stress proportional to distance from centroid of solid section. Excludes discontinuities and concentrations. Produced only by mechanical loads.	Self-equilibrating stress necessary to satisfy continuity of structure. Occurs at structural discontinuities. Can be caused by mechanical load or by differential thermal expansion. Excludes local stress concentrations.	(1) Increment added to primary or secondary stress by a concentration (notch). (2) Certain thermal stresses which may cause fatigue but not distortion of vessel shape.
Symbol (Note 4)	P_m	P_L	P_b	Q	F

Combination of stress components and allowable limits of stress intensities.



NOTE 1 – This limitation applies to the range of stress intensity. When the secondary stress is due to a temperature excursion at the point at which the stresses are being analyzed, the value of S_m shall be taken as the average of the S_m values tabulated in Part AM for the highest and the lowest temperature of the metal during the transient. When part or all of the secondary stress is due to mechanical load, the value of S_m shall be taken as the S_m value for the highest temperature of the metal during the transient.

NOTE 2 – The stresses in Category Q are those parts of the total stress which are produced by thermal gradients, structural discontinuities, etc., and do not include primary stresses which may also exist at the same point. It should be noted, however, that a detailed stress analysis frequently gives the combination of primary and secondary stresses directly and, when appropriate, this calculated value represents the total of P_m (or P_L) + P_b + Q and not Q alone. Similarly, if the stress in Category F is produced by a stress concentration, the quantity F is the additional stress produced by the notch, over and above the nominal stress. For example, if a plate has a nominal stress intensity, S, and has a notch with a stress concentration factor, K, then $P_m = S$, $P_b = 0$, $Q = 0$, $F = P_m (K-1)$ and the peak stress intensity equals $P_m + P_m (K-1) = KP_m$.

NOTE 3 – S_a is obtained from the fatigue curves, Figs. 5-110.1, 5-110.2 and 5-110.3. The allowable stress intensity for the full range of fluctuation is $2 S_a$.

NOTE 4 – The symbols P_m, P_L, P_b, Q, and F do not represent single quantities, but rather sets of six quantities representing the six stress components σ_t, σ_l, σ_r, τ_{tb} τ_{lr}, and τ_{rt}.

NOTE 5 – The k factors are given in Table AD-150.1.

FIG. 4-130.1 STRESS CATEGORIES AND LIMITS OF STRESS INTENSITY

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APPENDIX A-8

(REF 1)

TABLE AD-150.1
STRESS INTENSITY *k* FACTORS FOR VARIOUS LOAD COMBINATIONS

Condition	Load Combination (See AD-110)	*k* Factors	Calculated Stress Limit Basis
Design	A The design pressure, the dead load of the vessel, the contents of the vessel, the imposed load of the mechanical equipment, and external attachment loads	1.0	Based on the corroded thickness at design metal temperature
	B Condition A above plus wind load	1.2	Based on the corroded thickness at design metal temperature
	C Condition A above plus earthquake load	1.2	Based on the corroded thickness at design metal temperature
	(NOTE: The condition of structural instability or buckling must be considered)		
Operation	A The actual operating loading conditions. This is the basis of fatigue life evaluation	See AD-160 and Appendix 5	Based on corroded thickness at operating pressure and metal operating temperature
Test	A The required test pressure, the dead load of the vessel, the contents of the vessel, the imposed load of the mechanical equipment, and external attachment loads	1.25 for hydrostatic test and 1.15 for pneumatic test. See AD-151 for special limits.	Based on actual design values at test temperature

TABLE AD-155.1
MINIMUM PERMISSIBLE VESSEL METAL TEMPERATURES FOR FERROUS METALS OTHER THAN AUSTENITIC IN RELATION TO IMPACT TEST TEMPERATURE[1]

Type of Vessel	Service Temperature	Pressure Test Temperature	Startup Temperature
Base Vessel			
As-welded	Same	30 F higher	(Note 2)
PWHT	Same	Same	(Note 2)
Lethal			
As-welded		Not permitted	
PWHT	(Note 5)	(Note 5)	(Note 2)
Refrigerated Service (Note 4)			
As-welded	Same (Note 3)	30 F higher	(Note 2)
PWHT	Same	Same	(Note 2)

NOTES:
(1) When impact tests are not performed because Fig. AM-218.1 is used, the minimum permissible temperature from Fig. AM-218.1 shall be considered the impact test temperature for applying this table.
(2) If pressure is applied at a metal temperature below the minimum permissible temperature, it shall not exceed 20% of the required test pressure.
(3) Only when nozzle welds and other areas of high localized stress are postweld heat treated, except in the case of 9% nickel steel up to and including 2 in. thickness; otherwise, 30 F higher.
(4) Refrigerated service for purposes of this table is defined as service below 32 F where the temperature is controlled in the process rather than being caused by atmospheric conditions.
(5) 20 F higher for each additional inch of nominal thickness or fraction thereof for thickness over 1 in. but not to exceed 60 F higher.

E. Gillis
(S. Scotti)

10-3-77

THERMAL STRESS EQUATIONS

THE FOLLOWING EQUATIONS FOR THERMAL STRESSES IN A LONG CIRCULAR CYLINDER ARE OBTAINED FROM PAGE 412 OF THEORY OF ELASTICITY BY TIMOSHENKO AND GOODIER.

THERMAL STRAINS

$$\epsilon_r - \alpha T = \frac{1}{E}\left[\sigma_r - \nu(\sigma_\theta + \sigma_z)\right]$$

$$\epsilon_\theta - \alpha T = \frac{1}{E}\left[\sigma_\theta - \nu(\sigma_z + \sigma_r)\right]$$

$$\epsilon_z - \alpha T = \frac{1}{E}\left[\sigma_z - \nu(\sigma_r + \sigma_\theta)\right]$$

THERMAL STRESSES

$$\sigma_r = \frac{\alpha E}{1-\nu}\,\frac{1}{r^2}\left(\frac{r^2-a^2}{b^2-a^2}\int_a^b Tr\,dr - \int_a^r Tr\,dr\right) \qquad (244)$$

$$\sigma_\theta = \frac{\alpha E}{1-\nu}\,\frac{1}{r^2}\left(\frac{r^2+a^2}{b^2-a^2}\int_a^b Tr\,dr + \int_a^r Tr\,dr - Tr^2\right) \qquad (245)$$

$$\sigma_z = \frac{\alpha E}{1-\nu}\left(\frac{2}{b^2-a^2}\int_a^b Tr\,dr - T\right) \qquad (246)$$

THE STRESS EQUATIONS ON THE PREVIOUS PAGE REDUCE TO THE FOLLOWING EQUATIONS FOR THE SPECIAL CASES OF $r = a$ AND $r = b$.

HOOP STRESS (REF EQUATION 295, PAGE A-9)

INSIDE $r = a$

$$\sigma_{1T_i} = \frac{\alpha E}{1-\nu}\,\frac{1}{a^2}\left[\left(\frac{a^2+a^2}{b^2-a^2}\right)\int_a^b Tr\,dr + \int_a^a Tr\,dr - Ta^2\right]$$

$$= \frac{\alpha E}{1-\nu}\,\frac{1}{a^2}\left[\left(\frac{2a^2}{b^2-a^2}\right)\int_a^b Tr\,dr - Ta^2\right]$$

$$= \frac{\alpha E}{1-\nu}\left[\frac{2}{(b^2-a^2)}\int_a^b Tr\,dr - T\right]$$

OUTSIDE; $r = b$

$$\sigma_{1T_o} = \frac{\alpha E}{1-\nu}\,\frac{1}{b^2}\left[\left(\frac{b^2+a^2}{b^2-a^2}\right)\int_a^b Tr\,dr + \int_a^b Tr\,dr - Tb^2\right]$$

$$= \frac{\alpha E}{1-\nu}\,\frac{1}{b^2}\left[\left(\frac{b^2+a^2}{b^2-a^2}+1\right)\int_a^b Tr\,dr - Tb^2\right]$$

$$= \frac{\alpha E}{1-\nu}\left[\frac{2}{(b^2-a^2)}\int_a^b Tr\,dr - T\right]$$

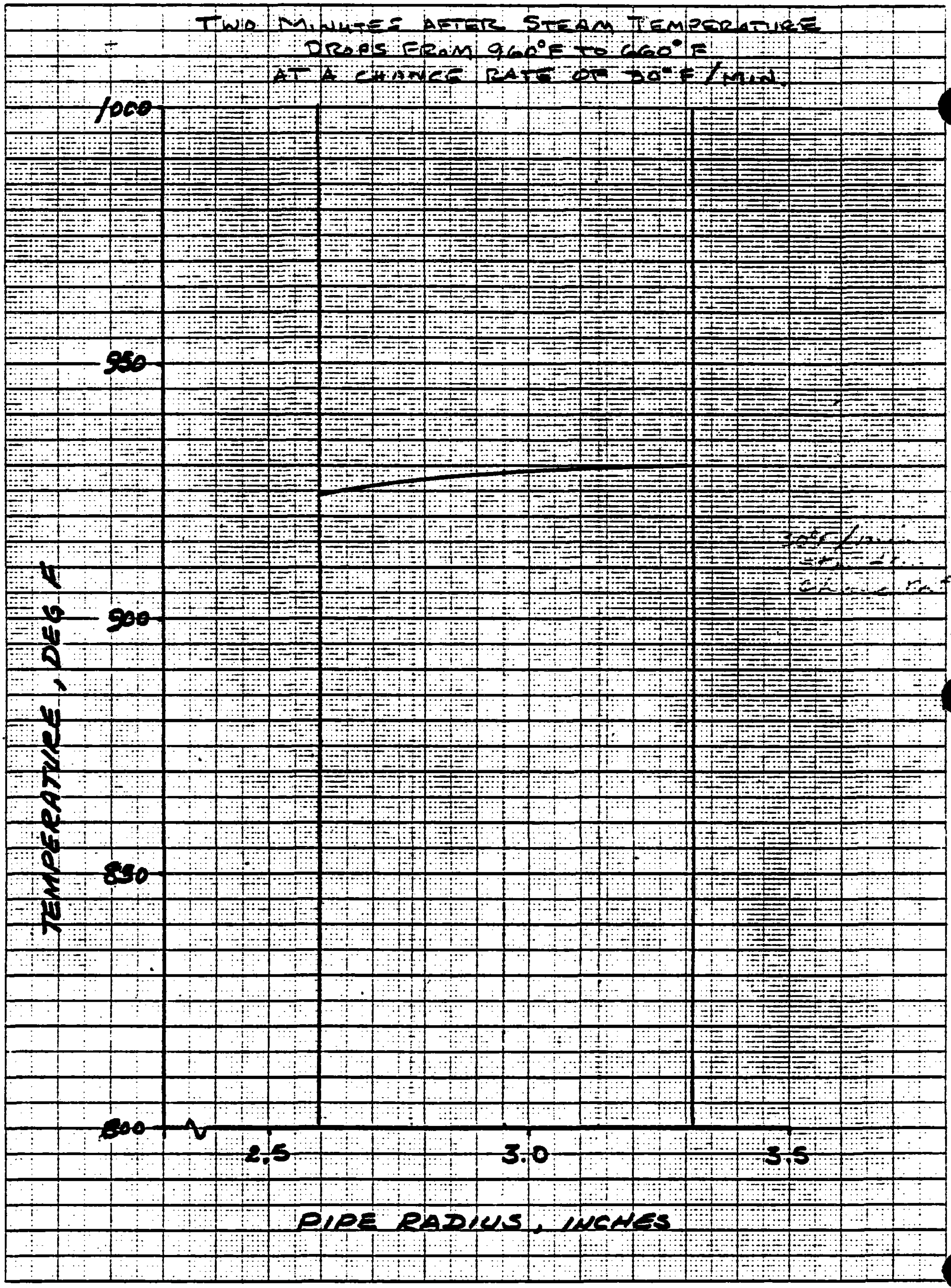

FIGURE A-2. MAX TEMP GRADIENT THRU PIPE WALL
CLOUD PASSAGE

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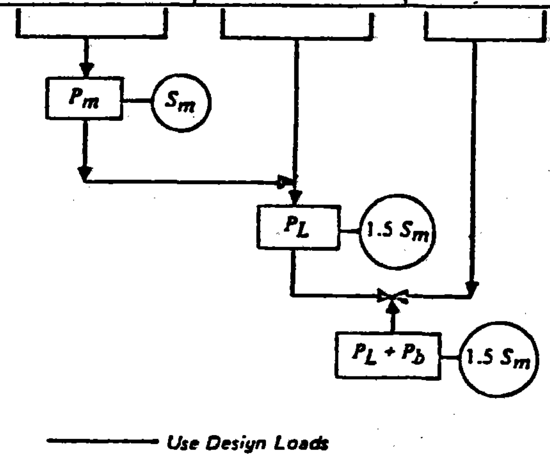
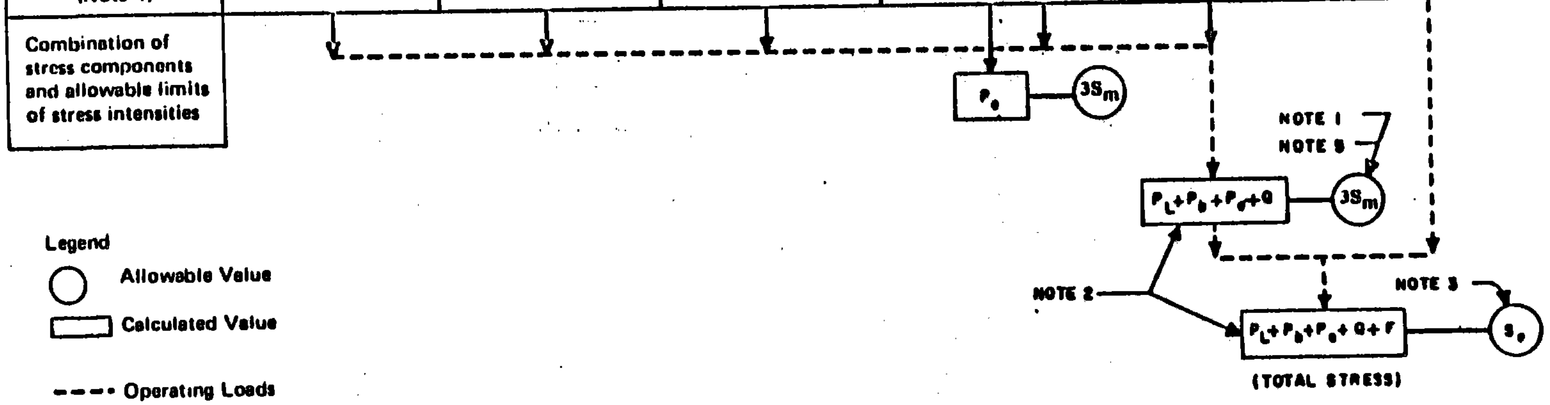
Stress Category	Primary		
	General Membrane	Local Membrane	Bending
Description (For examples, see Table NB-3217-1	Average primary stress across solid section. Excludes discontinuities and concentrations. Produced only by mechanical loads.	Average stress across any solid section. Considers discontinuities but not concentrations. Produced only by mechanical loads.	Component of primary stress proportional to distance from centroid of solid section. Excludes discontinuities and concentrations. Produced only by mechanical loads. (Note 2)
Symbol (Note 1)	P_m	P_L	P_b
Combination of stress Components and Allowable Limits of Stress Intensities.			

NOTE 1: The symbols P_m, P_L, and P_b do not represent single quantities, but rather sets of six quantities representing the six stress components σ_t, σ_l, σ_r, τ_{lt}, τ_{lr}, and τ_{rt}.

NOTE 2: Bending component of primary stress for piping shall be the stress proportional to the distance from centroid of pipe cross-section.

FIG. NB-3221-1 STRESS CATEGORIES AND LIMITS OF STRESS INTENSITY FOR DESIGN CONDITIONS

Stress Category	Primary			Secondary		Peak
	General Membrane	Local Membrane	Bending	Expansion	Membrane Plus Bending	
Description (for examples see Table NB-3217-2)	Average primary stress across solid section. Excludes effects of discontinuities and concentrations. Produced by pressure and mechanical loads.	Average stress across any solid section. Considers effects of discontinuities but not concentrations. Produced by pressure and mechanical loads, including inertia earthquake effects.	Component of primary stress proportional to distance from centroid of solid section. Excludes effects of discontinuities and concentrations. Produced by pressure and mechanical loads, including inertia earthquake effects. (Note 6)	Stresses which result from the constraint of "free end displacement" and the effect of anchor point motions resulting from earthquakes. Considers effects of discontinuities but not local stress concentration. (not applicable to vessels)	Self-equilibrating stress necessary to satisfy continuity of structure. Occurs at structural discontinuities. Can be caused by pressure, mechanical loads, or by differential thermal expansion. Excludes local stress concentrations.	(1) Increment added to primary or secondary stress by a concentration (notch). (2) Certain thermal stresses which may cause fatigue but not distortion.
Symbol (Note 4)	P_m	P_L	P_b	P_e	Q	F
Combination of stress components and allowable limits of stress intensities						



Note 1. When the secondary stress is due to a temperature transient at the point at which the stresses are being analyzed or to restraint of free end deflection, the value of S_m shall be taken as the average of the tabulated Sm values for the highest and the lowest temperatures of the metal during the transient. When part or all of the secondary stress is due to mechanical load, the value of S_m shall not exceed the value for the highest temperature of metal during the transient.

Note 2. The stresses in category Q are those parts of the total stress that are produced by thermal gradients, structural discontinuities, etc., and they do not include primary stresses that may also exist at the same point. However, it should be noted that a detailed stress analysis frequently gives the combination of primary and secondary stresses directly and, when appropriate, the calculated value represents the total of $P_m + P_b + Q$ and not Q alone. Similarly, if the stress in category F is produced by a stress concentration, the quantity F is the additional stress produced by the notch over and above the nominal stress. For example, if a point has a nominal stress intensity, P_m, and has a notch with a stress concentration factor, K, then $P_m < S_m$, $P_b = 0$, $Q = 0$, $F = P_m(K - 1)$, and the peak stress intensity equals $P_m + P_m(K - 1) = KP_m$. However, P_L is the total membrane stress that results from mechanical loads, including discontinuity effects, rather than a stress increment. Therefore, the P_L value always includes the P_m contribution.

Note 3. S_a is obtained from the fatigue curves, Figs. I-9.0. The allowable stress intensity for the full range of fluctuations is $2S_a$.

Note 4. The symbols P_m, P_L, P_b, P_e, Q, and F do not represent single quantities but sets of six quantities representing the six stress components σ_t, σ_l, σ_r, τ_{lt}, τ_{lr}, and τ_{rt}.

Note 5. Special rules for exceeding $3S_m$ are provided in NB-3228.3.

Note 6. Bending component of primary stress for piping shall be the stress proportional to the distance from centroid of pipe cross-section.

FIG. NB-3222-1
STRESS CATEGORIES AND LIMITS OF STRESS INTENSITY FOR NORMAL AND UPSET OPERATING CONDITIONS

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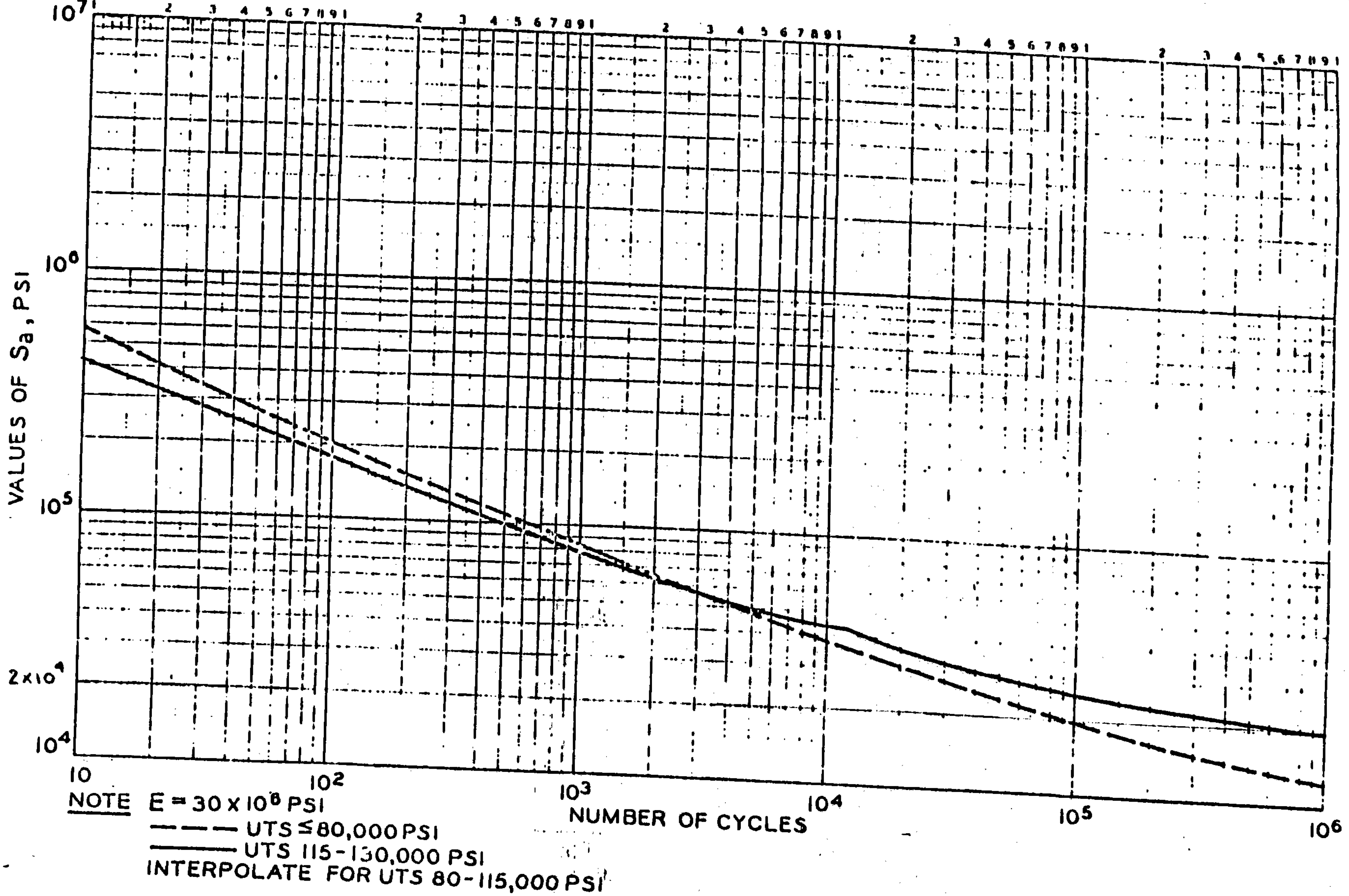

FIG. I-9-1 DESIGN FATIGUE CURVES FOR CARBON, LOW ALLOY, AND HIGH TENSILE STEELS
(For Metal Temperatures Not Exceeding 700 F)

FIG A-3

Table I-14.6D

2¼ Cr-1 Mo — Expected Minimum Stress-to-Rupture Values, ksi

Temp., °F	10 hr	30 hr	10^2 hr	3×10^2 hr	10^3 hr	3×10^3 hr	10^4 hr	3×10^4 hr	10^5 hr	3×10^5 hr
700	59.0	59.0	59.0	59.0	59.0	59.0	59.0	59.0	54.0	49.0
750	58.0	57.0	56.0	54.6	53.0	51.2	48.0	43.3	37.5	34.1
800	56.0	55.5	54.0	48.5	43.0	37.5	34.5	30.5	27.0	24.0
850	52.0	50.5	46.0	40.5	35.0	31.0	27.5	24.0	21.0	18.5
900	46.0	41.0	36.0	32.0	28.0	25.0	21.6	19.0	16.4	14.1
950	40.0	35.0	30.0	26.0	22.2	19.5	17.0	14.6	12.6	11.0
1000	31.5	27.5	24.0	21.0	17.9	15.2	13.1	11.0	9.4	7.9
1050	26.0	22.5	19.0	16.5	14.0	12.0	10.0	8.3	7.0	5.8
1100	21.0	18.0	15.1	13.0	10.8	9.1	7.5	6.2	5.0	4.1
1150	17.0	14.1	11.8	9.8	8.0	6.7	5.4	4.4	3.5	2.8
1200	13.5	11.1	9.2	7.6	6.2	5.0	4.0	3.2	2.5	2.0

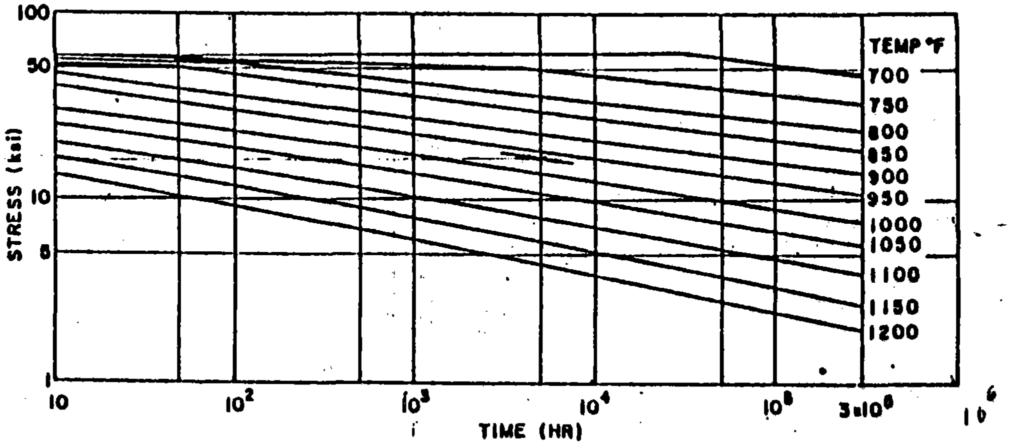

Fig. I-14.6D 2¼ Cr/1 Mo — 100 percent of the minimum stress-to-rupture

FIG A-4

58 of 74
A-15

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Bi

APPENDIX B

DOWNCOMER PIPE ANALYSIS

FOR

CLOUD PASSAGE CONDITION

ASSUMING

STEAM TEMPERATURE CHANGES INSTANTANEOUSLY

(REFERENCE INFORMATIN ONLY)

E GILLIS

6-6-79

DOWNCOMER PIPE

CLOUD PASSAGE CONDITION

LOADS:

PRESSURE $p = 1515$ PSIA

TEMPERATURE: THE TEMPERATURE GRADIENT THRU THE PIPE WALL IS GIVEN IN FIGURE B1, APPENDIX, PAGE B-8, AND IS SUMMARIZED BELOW IN TABLE B1

TABLE B1

TEMPERATURE GRADIENT IN PIPE WALL

CLOUD PASSAGE CONDITION

R (IN)	T (°F)
2.635	914
2.714	925
2.794	934
2.873	942
2.952	947
3.032	951
3.111	954
3.191	955
3.270	956

$T_o = 956$

$T_i = 908$

$T_{AVG} = 942$°F

(REF PAGE B-5)

61 OF 74.

E Gillis B-7
[illegible]

DOWNCOMER PIPE - CLOUD PASSAGE
(CONT)

MATERIAL PROPERTIES

A335 FERRITIC ALLOY STEEL 2¼ Cr - 1 Mo)
SEAMLESS PIPE FOR HIGH TEMP SERVICE

TABLE B-II

ALLOWABLE STRESS INTENSITY - A335 AT ELEVATED TEMPS

TEMP (DEG F)	Sm (KSI)
R.T.	$F_{ty} = 30.0$ $F_{tu} = 60.0$
900°	13.1
950°	11.0
1000°	7.8

← (REF APPENDIX, PAGE A-2) (for R.T.)

} (REF APPENDIX, PAGE A-3) (for 900°, 950°, 1000°)

STRENGTH AT 956°F (OUTSIDE)

$$\sigma_{956} = 11.0 - (11.0 - 7.8)\left(\frac{956 - 950}{1000 - 950}\right) = \underline{10.62 \text{ KSI}}$$

STRENGTH AT 908°F (INSIDE)

$$\sigma_{908} = 11.0 + (13.1 - 11.0)\left(\frac{950 - 908}{950 - 900}\right) = \underline{12.76 \text{ KSI}}$$

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6-6-79

DOWN COMER PIPE - CLOUD PASSAGE (CONT)

MATERIAL PROPERTIES (CONT)

MODULUS OF ELASTICITY & COEFFICIENT OF EXPANSION

TABLE B-III

MODULUS OF ELASTICITY AND COEFFICIENT OF EXPANSION OF A 335 AT ELEVATED TEMPERATURES

TEMP DEG F	E (LBS/IN² x10⁻⁶)	α (IN/IN/°F x10⁶)
RT	29.9	6.07
900°	24.5	7.84
1000°	23.0	7.97

↑ REF APPENDIX PAGE A-4 ↑ REF APPENDIX PAGE A-5

MODULUS OF ELASTICITY AT AVERAGE TEMP T = 942° F

$$E = \left[24.5 - (24.5 - 23.0)\frac{(942-900)}{(1000-900)}\right] \times 10^{6} = \frac{23.87 \times 10^{6}}{\text{LBS/IN}^2}$$

COEFFICIENT OF EXPANSION AT $T_{AVG} = 942°$ F

$$\alpha = \left[7.84 + (7.97 - 7.84)\left(\frac{942-900}{1000-900}\right)\right] \times 10^{-6}$$

$$= \frac{7.89 \times 10^{-6}}{\text{IN/IN/°F}}$$

DOWNCOMER PIPE - CLOUD PASSAGE (CONT)

SECONDARY STRESS (FROM TEMPERATURE)

THE FOLLOWING PARAMATERS ARE REQUIRED FOR USE IN THE THERMAL STRESS CALCULATIONS BELOW:

THE INTEGRAL OF $\int_a^b Tr\,dr$ (FIGURE B-1, APPENDIX B-8) IS OBTAINED (PAGE B-5) USING SIMPSON'S RULE ON DATA FROM TABLE B IV.

TABLE B IV

TEMPERATURE GRADIENT IN PIPE WALL, CLOUD PASSING *

r RADIUS (IN)	T * TEMP (°F)	T×r (°F IN)
2.5945	908.0	2356
2.6971	923.0	2489
2.7996	935.0	2618
2.9022	944.0	2740
3.0048	950.0	2855
3.1074	953.5	2963
3.2099	955.5	3067
3.3125	956.0	3167

---

* REF FIGURE B-1 APPENDIX PAGE B-8

E GILLIS

6-7-79

DOWNCOMER PIPE - CLOUD PASSAGE (CONT)

SECONDARY STRESS (FROM TEMPERATURE) (CONT)

$$\int_{r_i}^{r_o} T r\, dr = \frac{\Delta r}{2}\left[(Tr)_1 + 2\,(Tr)_2 + 2\,(Tr)_3 \cdots + 2\,(Tr)_7 + (Tr)_9\right]$$

(SIMPSON'S RULE)

$$\left.\begin{aligned} \text{WHERE } \frac{\Delta r}{2} &= \frac{.1026}{2} = .0513 \quad (\text{IN}) \\ r_o &= 3.3125 \quad (\text{IN}) \\ r_i &= 2.5945 \quad (\text{IN}) \end{aligned}\right\} \begin{array}{l} \text{REF} \\ \text{TABLE B-IV} \end{array}$$

AND $(Tr)_1$ $(Tr)_2$ ETC. ARE OBTAINED FROM TABLE B-IV.

$$\int_{2.5945}^{3.3125} T r\, dr = .0513\left[2356 + 2 \times 2489 + 2 \times 2618 + 2 \times 2740 + 2 \times 2855 + 2 \times 2963 + 2 \times 3067 + 3167\right]$$

$$= .0513\left[38987\right] = 2000.0 \quad ({}^\circ\text{F IN}^2)$$

AVERAGE TEMP (FOR MAT'L PROPERTIES)

$$T_{AVE} = \int_{r_i}^{r_o} T\, dr \Big/ (r_o - r_i) = \frac{676.4}{.718} = 942\ {}^\circ\text{F}$$

DOWNCOMER PIPE - CLOUD PASSAGE (CONT)

SECONDARY STRESS (FROM TEMPERATURE) (CONT)

THERMAL HOOP STRESS - INSIDE

$$\sigma_{1T_i} = \frac{\alpha E}{1-\mu}\left[\frac{2}{b^2-a^2}\int_a^b Tr\,dr - T\right]$$

WHERE $\alpha = 7.89\times10^{-6}$ (IN/IN/°F) } (REF PAGE B-3)

$E = 23.87\times10^{6}$ (LBS/IN^2)

$b = r_2 = 3.3125$ (IN) } (REF PAGE 1-1)

$a = r_1 = 2.5945$ (IN)

$\int_a^b Tr\,dr = 2000.0$ (°F IN^2) (REF PAGE B-5)

$T = 908$ (°F) ; $\mu = .3$

$$\sigma_{1T_i} = \frac{7.89\times10^{-6}\times23.87\times10^{6}}{1-.3}\left[\frac{2}{3.3125^2-2.5945^2}\times2000.0 - 908\right]$$

$$= 269.05\left[943.12-908\right] \quad = \underline{9450 \text{ (LBS/IN}^2\text{)}}$$

THERMAL HOOP STRESS - OUTSIDE

$$\sigma_{1T_o} = \frac{\alpha E}{1-\mu}\left[\frac{2}{(b^2-a^2)}\int_a^b Tr\,dr - T\right]$$

WHERE α, E, ETC ARE THE SAME AS ABOVE EXCEPT FOR T

$T = 956$ (°F)

$$\sigma_{1T_o} = (7.59\times10^{-6}\times23.57\times10^{6})/(1-.3)\left[\frac{2}{3.3125^2-2.5945^2}\times2000.0-956\right]$$

$$= 269.05\left[943.12-956\right] = \underline{-3464 \text{ (LBS/IN}^2\text{)}}$$

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E GILLIS

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DOWN COMER PIPE - CLOUD PASSAGE (CONT)

SECONDARY STRESS (FROM TEMPERATURE) (CONT)

THERMAL LONGITUDINAL STRESSES - INSIDE & OUTSIDE

INSPECTION OF THE EQUATIONS FOR HOOP STRESS AND LONGITUDINAL STRESS (REF APPENDIX PAGES A-9 AND A-10) SHOWS THAT THE LONGITUDINAL STRESS IS EQUAL TO THE HOOP STRESS ON BOTH THE INNER AND OUTER SURFACES.

$$\sigma_{2T_i} = \sigma_{1T_i} = 9450 \quad (LBS/IN^2)$$

AND $\sigma_{2T_o} = \sigma_{1T_o} = -3464$ (LBS/IN^2)

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B-8

DOUGLAS

REF. JOB PAGE NOS.
PREPARED BY PJK DATE 6-5-9
JOB PAGE NO.
MODEL
REPORT NO.

TEMPERATURE GRADIENT
THROUGH PIPE WALL

4 SECOND AFTER
STEAM TEMPERATURE
DROPS FROM 960°F TO 660°F

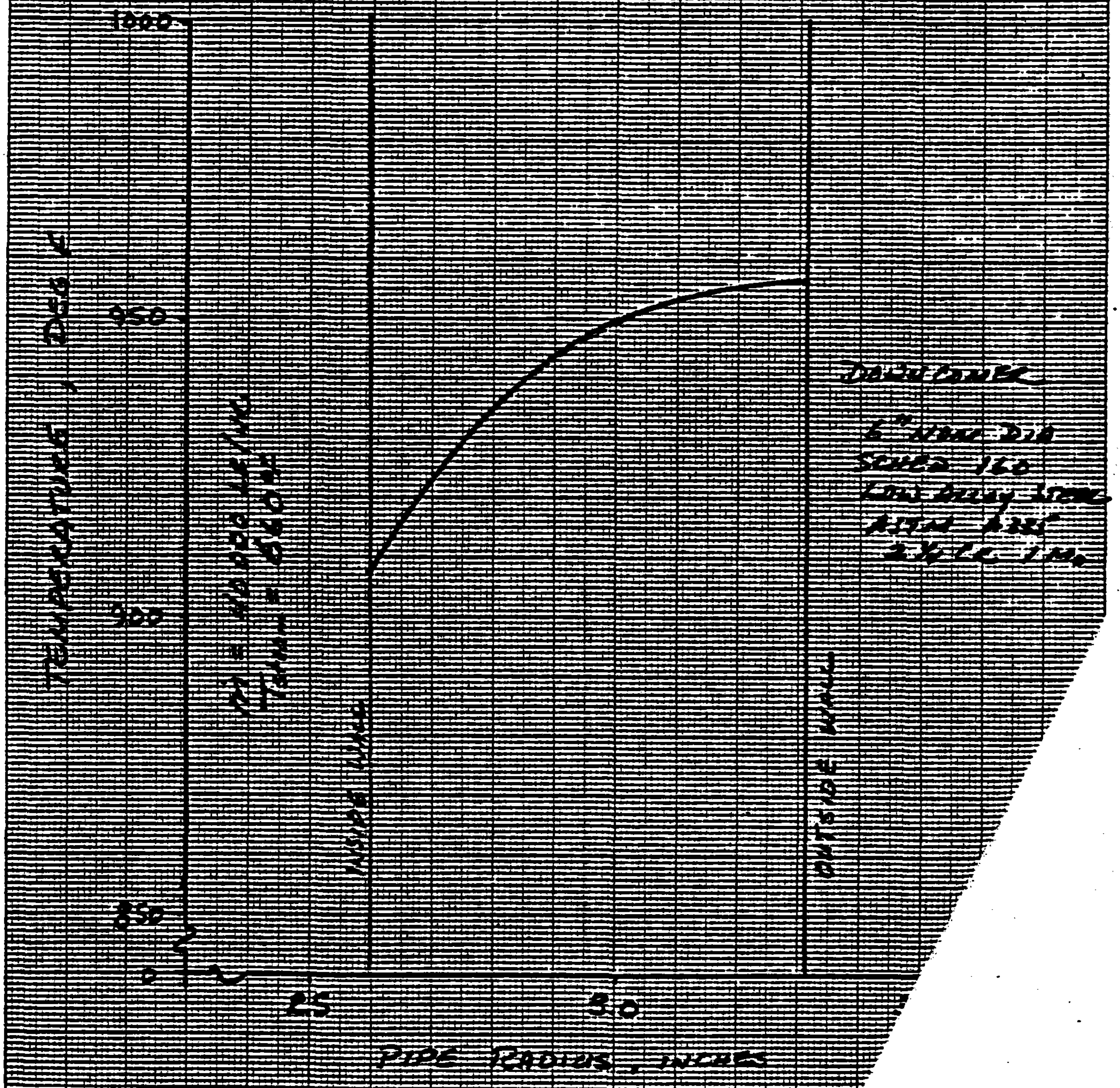

FIGURE B-1 CLOUD PASSAGE

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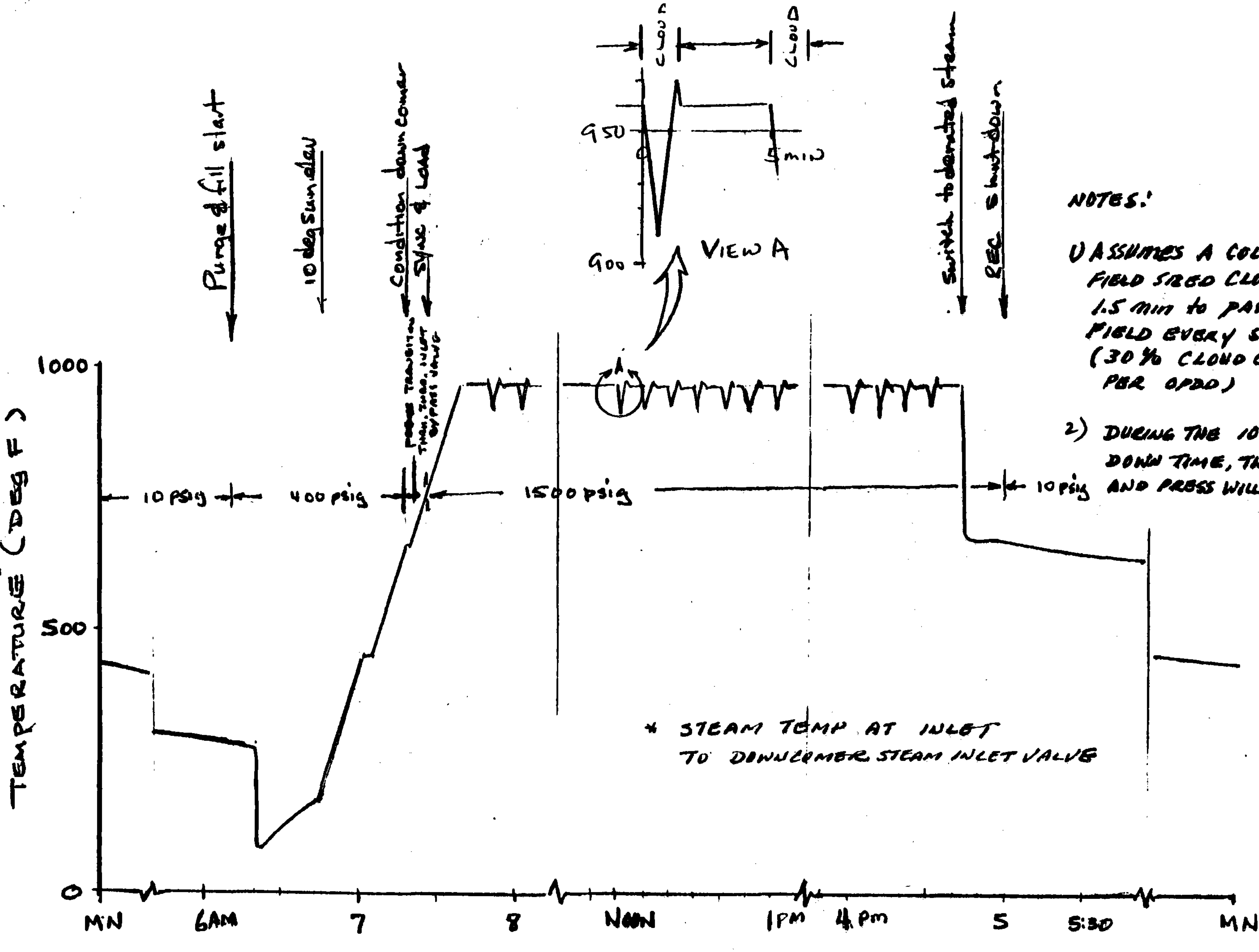
Attachment 2



* STEAM TEMP AT INLET TO DOWNCOMER STEAM INLET VALVE

NOTES:

1) ASSUMES A COLLECTOR FIELD SIZED CLOUD TAKES 1.5 min to PASS OVER THE FIELD EVERY 5 MINUTES (30% CLOUD COVER, PER OPDO)

2) DURING THE 10% SYSTEM DOWN TIME, THE TEMP AND PRESS WILL BE AMBIENT.

TYPICAL DAILY CYCLE

Attachment 3

ASSUMPTIONS FOR PLANT STARTUP

1. Circulating water is available.
2. Cooling tower fan is on (one).
3. Bearing cooling water is available.
4. Air compressors are on (service and instrument).
5. Condensate storage water makeup system is active.
6. #1 train active for seal steam, blanket steam and DA pegging steam (on auxiliary pump).
7. Vacuum is on condenser.
8. Hotwell pump is on-line and recirc to condenser is active.
9. Deaerator pegging steam is (20) psia from TSSG.
10. Deaerator water temperature is (228)°F.
11. Downcomer is "bottled up" and on blanket steam.
12. Receiver has been drained and pressurized with GN_2.
13. TSCH has been on blanket steam overnight with inlet valve (TDSIV) closed.

Drawings used RS P&ID, CO60479, A Change
TSS P&ID, CO61179, A Change
Solar Flow Diagram, S10MW-PP, R4 Revision

RS FEEDPUMP STARTUP

The RS feedpump is started in a recirculating configuration prior to supplying feedwater to the system.

1. Check valve lineup (visual check)
   - (a) RS feedpump discharge valve closed, and bypass closed.
   - (b) Bearing cooling water valve open.
   - (c) Bearing lube oil available.

2. Start pump and ramp speed to minimum flow (TBD #/hr) and verify
   - (a) Recirculate valve open
   - (b) Motor current correct
   - (c) Vibration _(TBD)
   - (d) Bearing cooling water ok
   - (e) Bearing lube oil ok

CONDENSATE CLEANUP

Prior to RS startup the condensate water chemistry must be within certain specifications. This is accomplished by circulating the condensate through the demineralizers and increasingly larger loops of the system until the total system contains clean condensate.

1. Line up valves for inital condensate cleanup from the deaerator to the RS feedwater pump through tower riser bypass loop (TRBL) to condenserand back through the condenser hotwell, demineralizers, low pressure heater (#4) to the deaerator.
   - (a) Preheat panel inlet (RWISK) and receiver panel bypass (RWBV) closed
   - (b) Verify (or set) receiver feedwater pump flow at (28800) lb/hr on recirculation
   - (c) Open TRBL valve into condenser
   - (d) Open TRBL valve at bottom of tower riser
   - (e) Open receiver feedwater pump discharge bypass valve to fill and pressurize line. Monitor downstream pressure.

  (f) Open receiver feedwater pump discharge valve when pressure across valve is (50) psia. Close bypass valve.
  (g) Circulate condensate in this configuration until water chemistry is (10) PPB, etc.

2. Line up valves for condensate cleanup through receiver panel bypass loop.
   (a) Flash tank inlet closed (RFSIV)
   (b) Receiver accumulator outlet closed (RAWDV)
3. Activate Flash Tank drain controllers to maintain a water level which is below the steam outlet to RFSPCV. Flash tank drain to condenser controller - manual closed loop, setpoint = (3) ft. Flash tank drain to #2 heater closed loop - valve closed (0%) controller - manual.
4. Activate flash tank pressure controller, RFSPCV (setpoints, manual closed loop). This valve should remain closed until steam is being generated by the receiver.
   (a) Verify flash tank water level (3) feet (if too high, drain to desired level before activating this controller).
   (b) Verify flash tank pressure (500) psia.
   (c) Make pressure setpoint = 500 psia.
5. Open RWBV valve to receiver flash tank.
6. Ramp TRBL valve into condenser closed.
7. Verify flash tank pressure 500 psia and water level (3) feet. and pump flow is (28800) #/hr. (adjust pump speed to maintain the above).
8. Close TRBL valve at bottom of tower riser.
9. Circulate condensate in this configuration until water chemistry is (10) PPB, etc.

RECEIVER STARTUP

Since it was assumed that the receiver had been drained and pressurized it is necessary to vent the GN_2 out of the receiver panels, as the panels are filled with condensate. After filling the condensate is circulated through the panels until the water chemistry is correct. The receiver is then started through the RS flash tank. When (100)°F of superheat is available the downcomer is conditioned through the turbine inlet bypass loop. Finally pressure control is handed off to the turbine inlet bypass controller, the RS flash tank is shut down and the receiver brought to the desired pressure and temperature for turbine start and/or TS charging.

1. Shutoff GN_2 supply to receiver (if required)
2. Line up valves for startup
   Downcomer stop valve - closed (RDSIV)
   Flash tank inlet valve - closed (RFSIV)
3. Activate the panel temperature controllers in manual - open loop and set the 18 valve positions to (50)% open. Load the closed loop set points - (585)°F.

Note: It may be necessary to have an intermediate boiler outlet temperature setpoint during initial activation of heliostats to prevent thermal shock of the panels, etc. If this is required the above set point would be (400)°F and changed to (585)°F after step 7 below.

4. Open preheat panel inlet valve (RWISK)
5. Close receiver panel bypass valve (RWBV) to (90)% to start condensate flow slowly up into panels (to prevent thermal shock). Open the two main receiver vent valves (to atmosphere) to vent GN_2 (RPWVV, RMSVV). Close each valve as soon as condensate starts flowing. After both vents are closed open the flash tank inlet valve (RFSIV).
6. Monitor all panel temperature (RBSOT-XX). Compare these temperatures with feedwater inlet temperature (RWIT). When all panel temperatures are within 80% of the feedwater temperature, ramp receiver panel bypass valve (RWBV) closed while monitoring flash tank pressure and panel flow. Adjust the pump speed, if required, to maintain the (28,800) #/hr flow and circulate the condensate in this configuration until the water chemistry is

(10) PPB, etc. (during this period the flash tank pressure should be below 500 psia and the condensate level at (3) ft).

7. Activate flash tank drain to #2 heater controller - manual - closed loop, set point = (3) feet. (This controller has a 135 psia limit override, i.e. the valve closes when the pressure ≥ 135 psia.) Close flash tank drain to condenser and reconfigure this controller to manual - closed loop to operate if the RS flash tank high - high level (TBD ft) transducer is activated.
8. Activate the RS panel temperature controllers in manual - closed loop (set point previously loaded at (585)°F). Verify (TBD) #/hr flow (minimum) through each panel.
9. Activate RS feedwater pump controller to manual closed loop, setpoint = 550 psia. This controller maintains preheat panel inlet pressure (RWIP) at this valve.
10. Activate (TBD) segments of heliostats in incremental steps up to an insolation power level of approximately TBD MW (per CS startup procedure).
11. Monitor receiver temperature rise to 585°F (RMSOT) and:
    (a) Verify flash tank pressure (RFSOP) control ok at 500 psia and water level (RFWL) (3) feet.
    (b) Verify all panel temperature are rising (BSOT1-18)
    (c) Add or subtract, CS segments if required
    (d) Verify total flow _ 40000 #/hr
12. Activate receiver accumulator (RA) drain valve (RAWDV) controller in manual - closed loop with level setpoint = (1) foot.
13. Setup turbine inlet bypass line:
    (a) Close main steam line blanket steam valve (steam from/to blanket - seal steam network).
    (b) Open turbine inlet bypass valve to (50)% with controller in manual - open loop.
    (c) Actuate desuperheater temperature controllers - (300)°F setpoint.
    (d) Verify condenser vacuum (2.5) in Hg.
14. Condition downcomer:
    (a) Verify stable receiver operation - (RSOT)°F, (RSOP psia

- (b) Open downcomer valve (RDSIV) (5)% (7) GPM, ([illegible]) ft/sec flow velocity
- (c) Open main steam lines low point drains (if required)
- (d) Monitor turbine inlet bypass line temperature and pressure
- (e) Adjust flow using RDSIV such that temperature is rising at (10)°F/min.

15. Switch from flash tank to bypass control:
    - (a) Verify stable operation of receiver and bypass line temperature is (585)°F.
    - (b) Activate turbine inlet bypass valve controller - manual - closed loop. Put in setpoint of (20 psia less than pressure at this valve) psia - manual - closed loop.
    - (c) Ramp downcomer stop valve (RDSIV) open.
    - (d) Verify RS flash tank pressure control valve (RFSPCV) closed and flash tank pressure _ 500 psia (leave this controller active).
    - (e) Close flash tank inlet stop valve (RFSIV)
    - (f) Close main steam line low point drains, (if they were opened by the operator).
    - (g) Reactivate main steam line blanket and seal steam controller (blanket and seal steam should now be supplied from main steam).
    - (h) Monitor flash tank pressure to assure it is _ 500 psia.

Note: Receiver steam is now available for turbine roll or TS charging.

TURBINE STARTUP

(Receiver Steam)

1. Increase pressure/temperature to turbine roll conditions (if other than a cold start)
    - (a) Ramp temperature setpoint to (TBD)°F at (TBD)°F/min (if required 18 setpoints).

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RECEIVER PANEL POWER GRADIENT ANALYSIS

THIS PACKAGE DEFINES [illegible] PANEL GRADIENTS

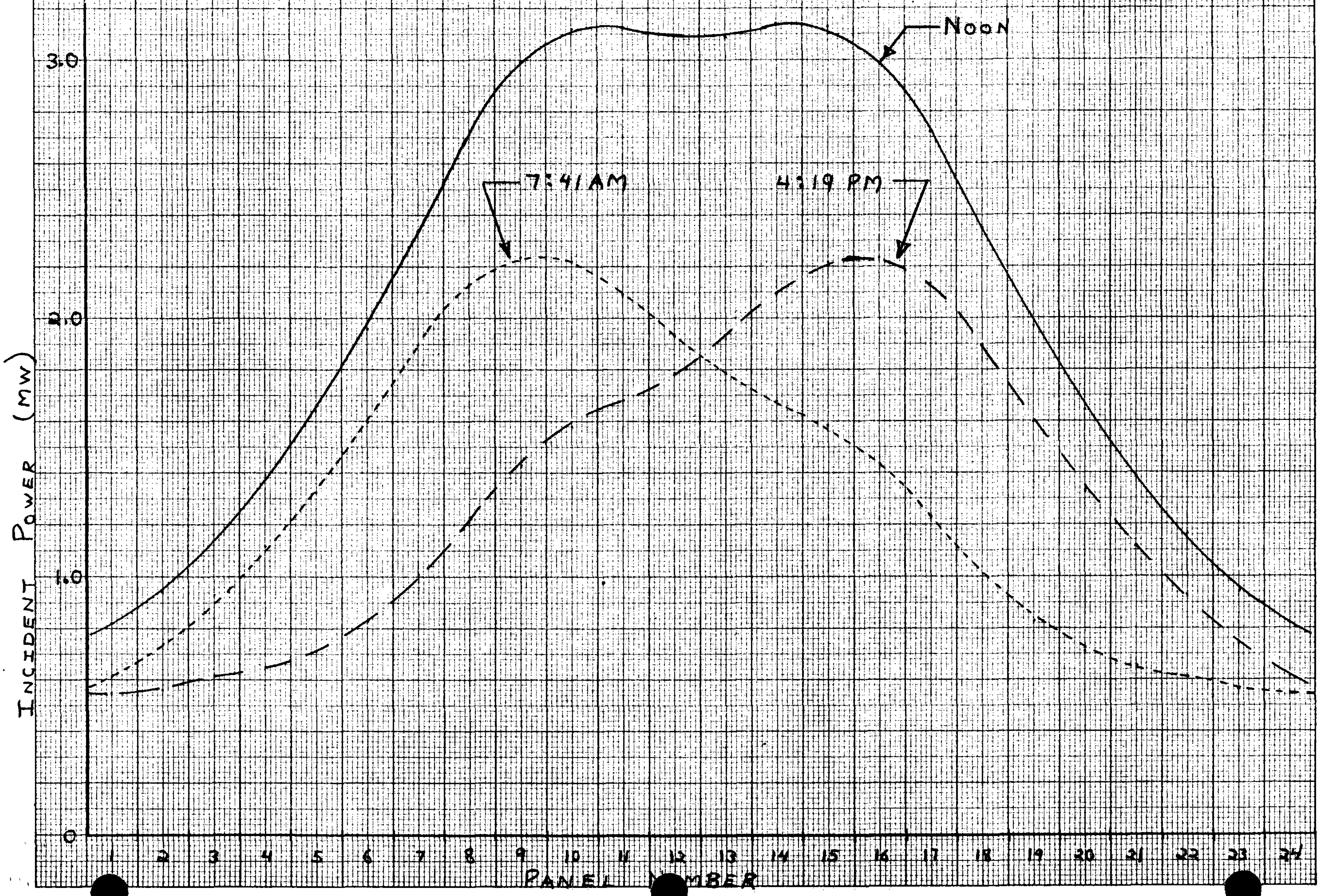
CAUSED BY

1) NORMAL POWER VARIATIONS EXPERIENCED ON SUMMER SOLSTICE, EQUINOX, AND WINTER SOLSTICE

2) CLOUD PASSAGE AS DEFINED BY A SERIES OF "SNAP SHOTS" AS THE CLOUD PASSES OVER THE FIELD

2 OF 14

PANEL POWER VARIATION — EQUINOX



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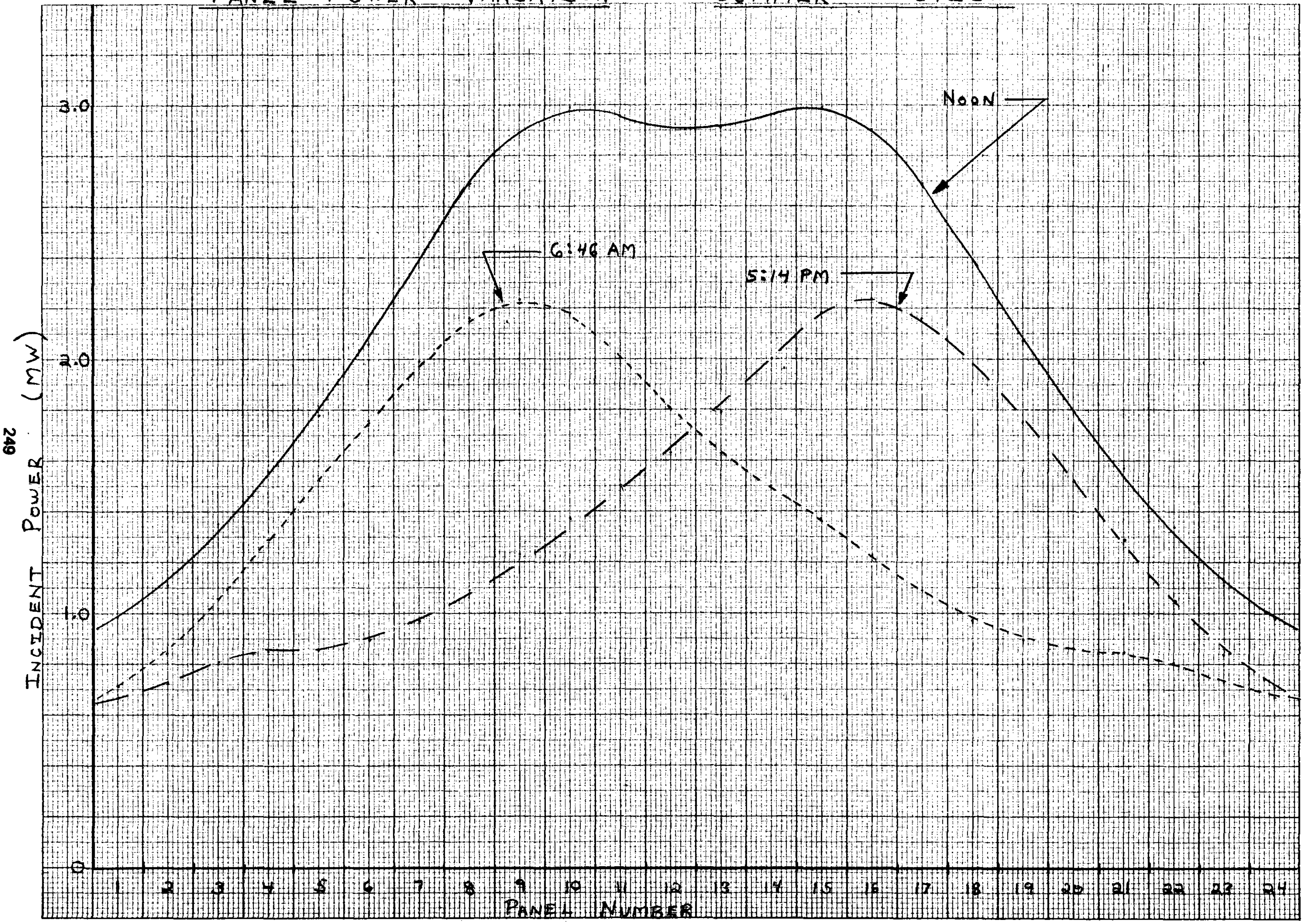
PANEL POWER VARIATION — SUMMER SOLSTICE



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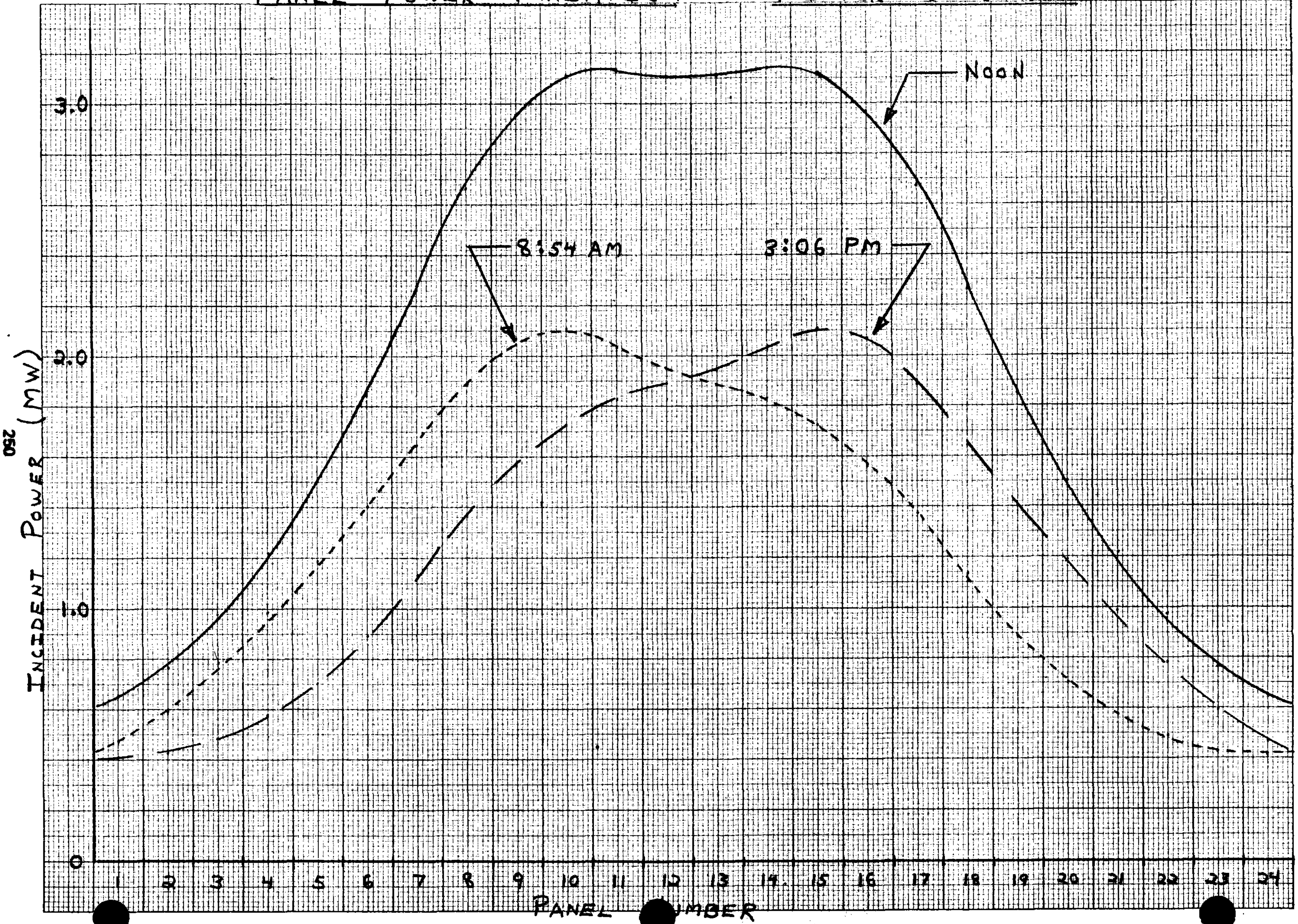
PANEL POWER VARIATION - WINTER SOLSTICE



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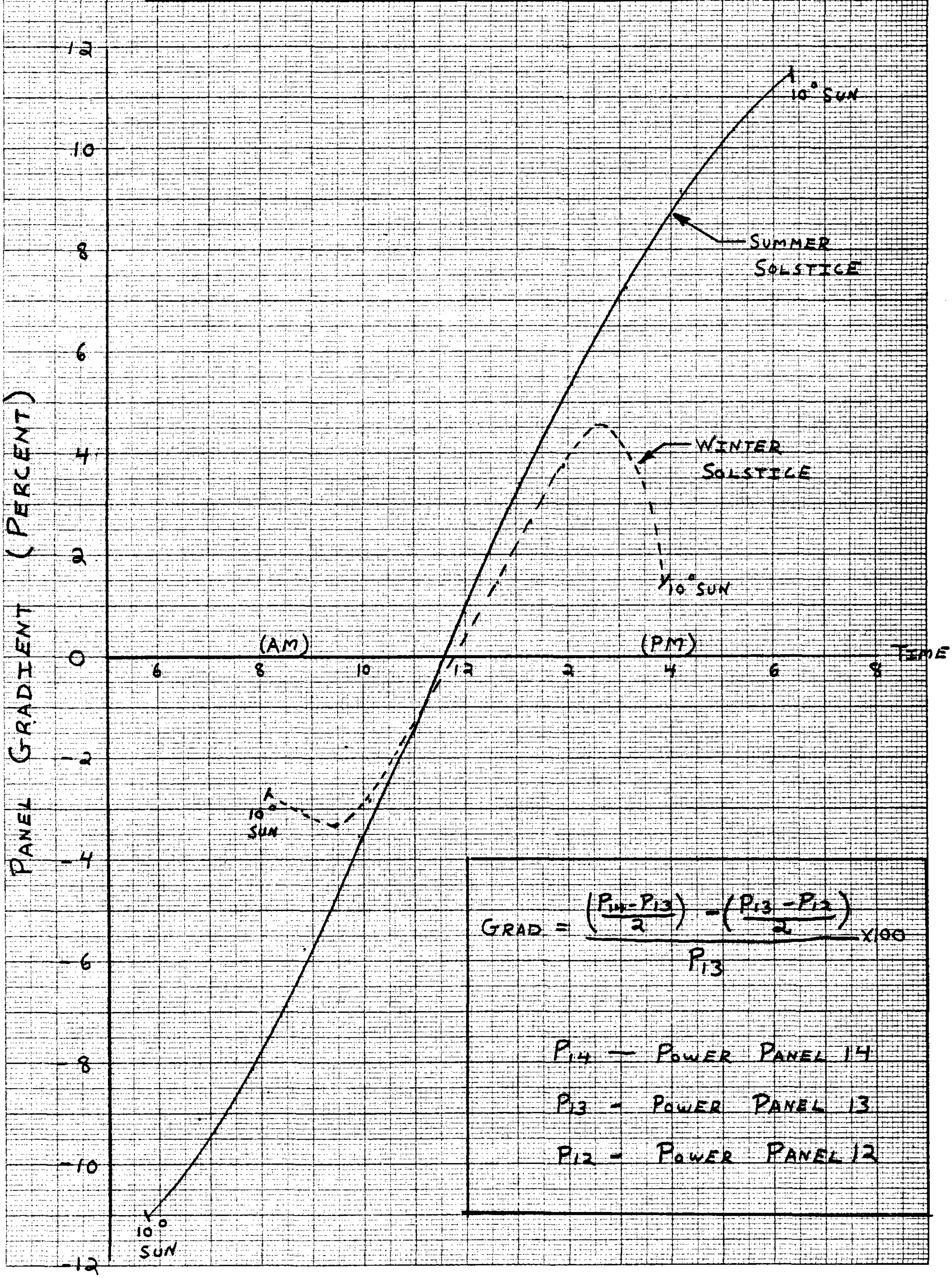
PANEL 13 GRADIENT HISTORY



$$GRAD = \frac{\left(\frac{P_{14}-P_{13}}{2}\right) - \left(\frac{P_{13}-P_{12}}{2}\right)}{P_{13}} \times 100$$

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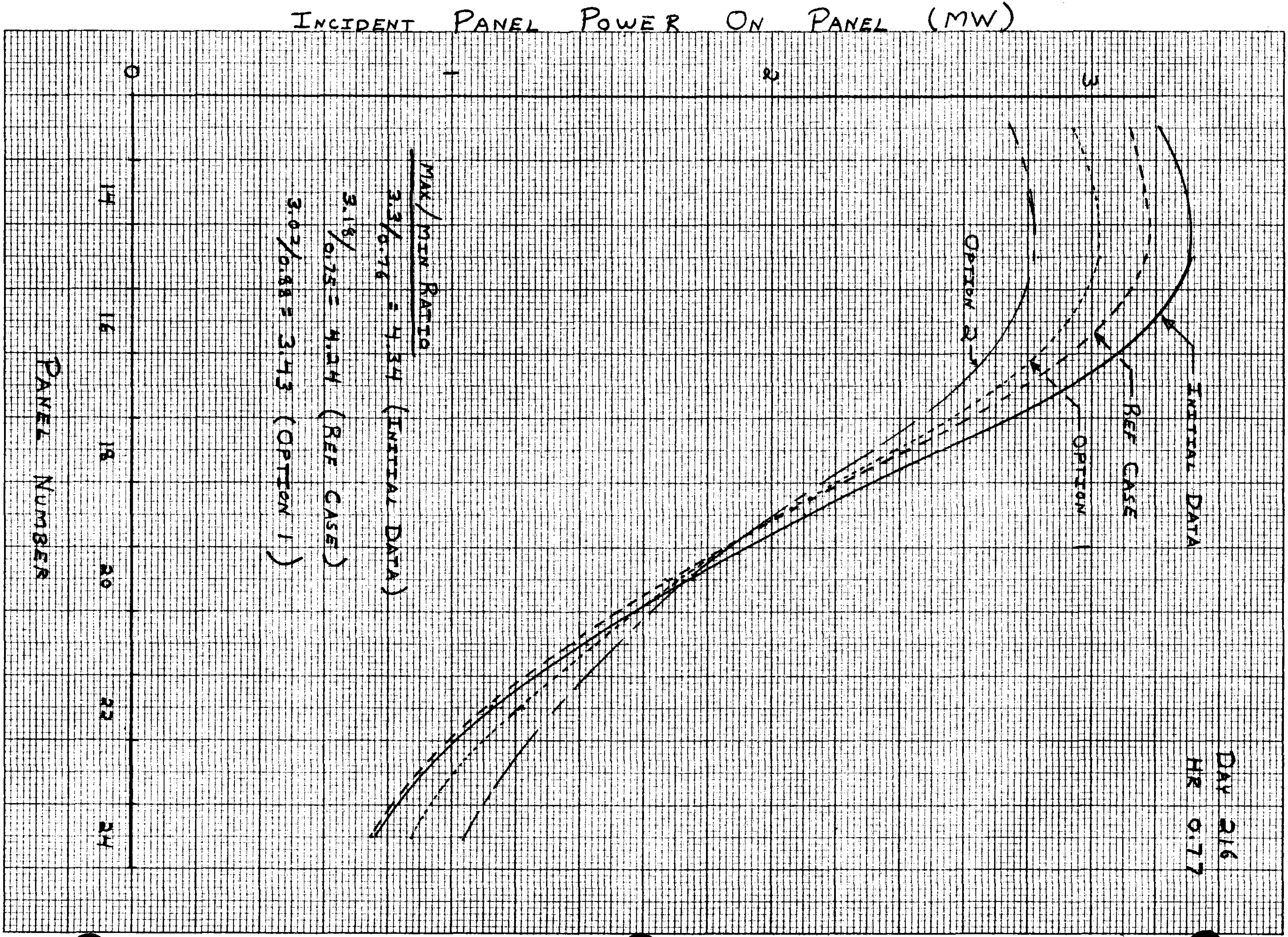

MAX/MIN RATIO
3.3/0.76 = 4.34 (INITIAL DATA)
3.18/0.75 = 4.24 (REF CASE)
3.02/0.88 = 3.43 (OPTION 1)

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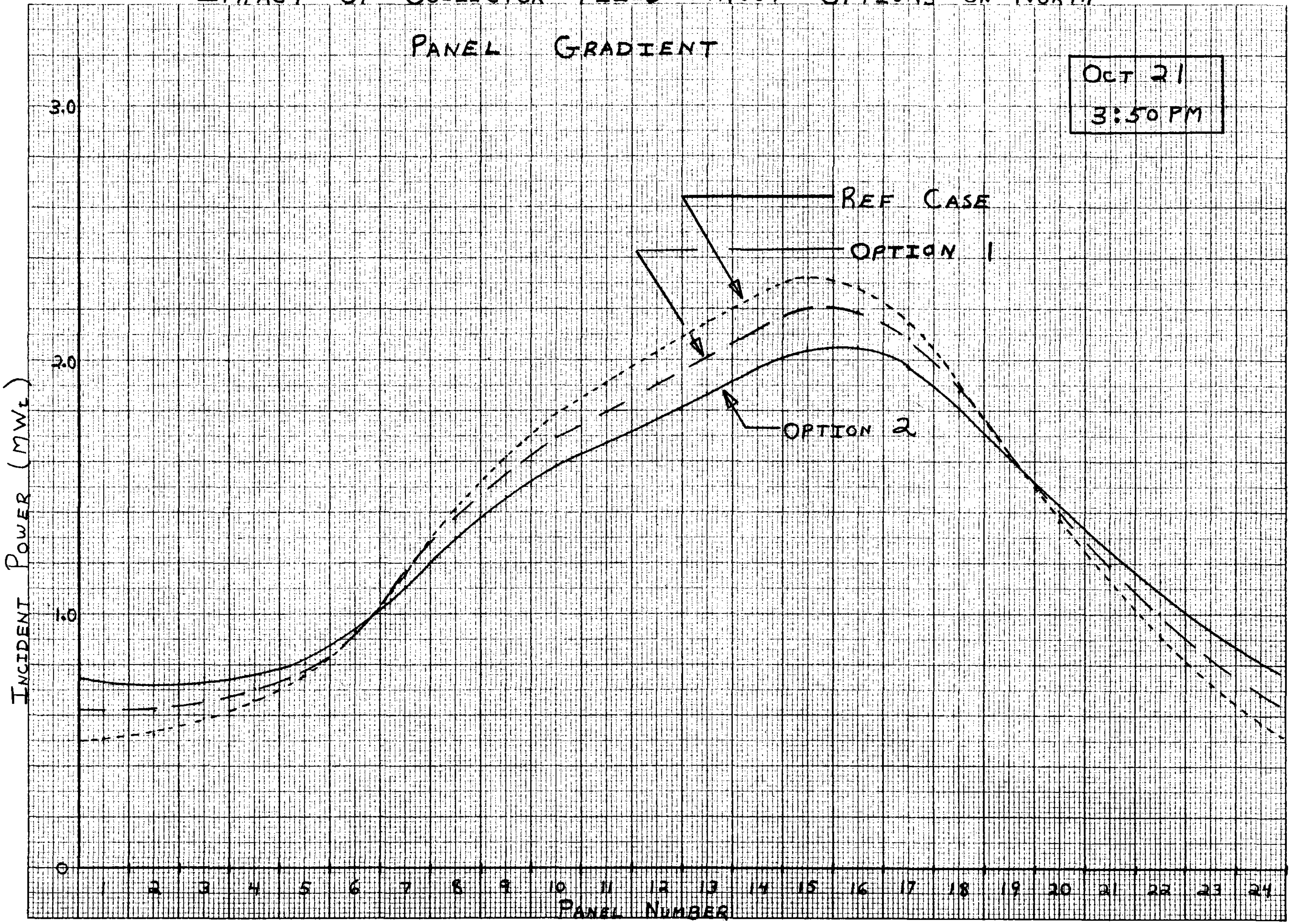
IMPACT OF COLLECTOR FIELD LAYOUT OPTIONS ON NORTH PANEL GRADIENT



OCT 21
3:50 PM

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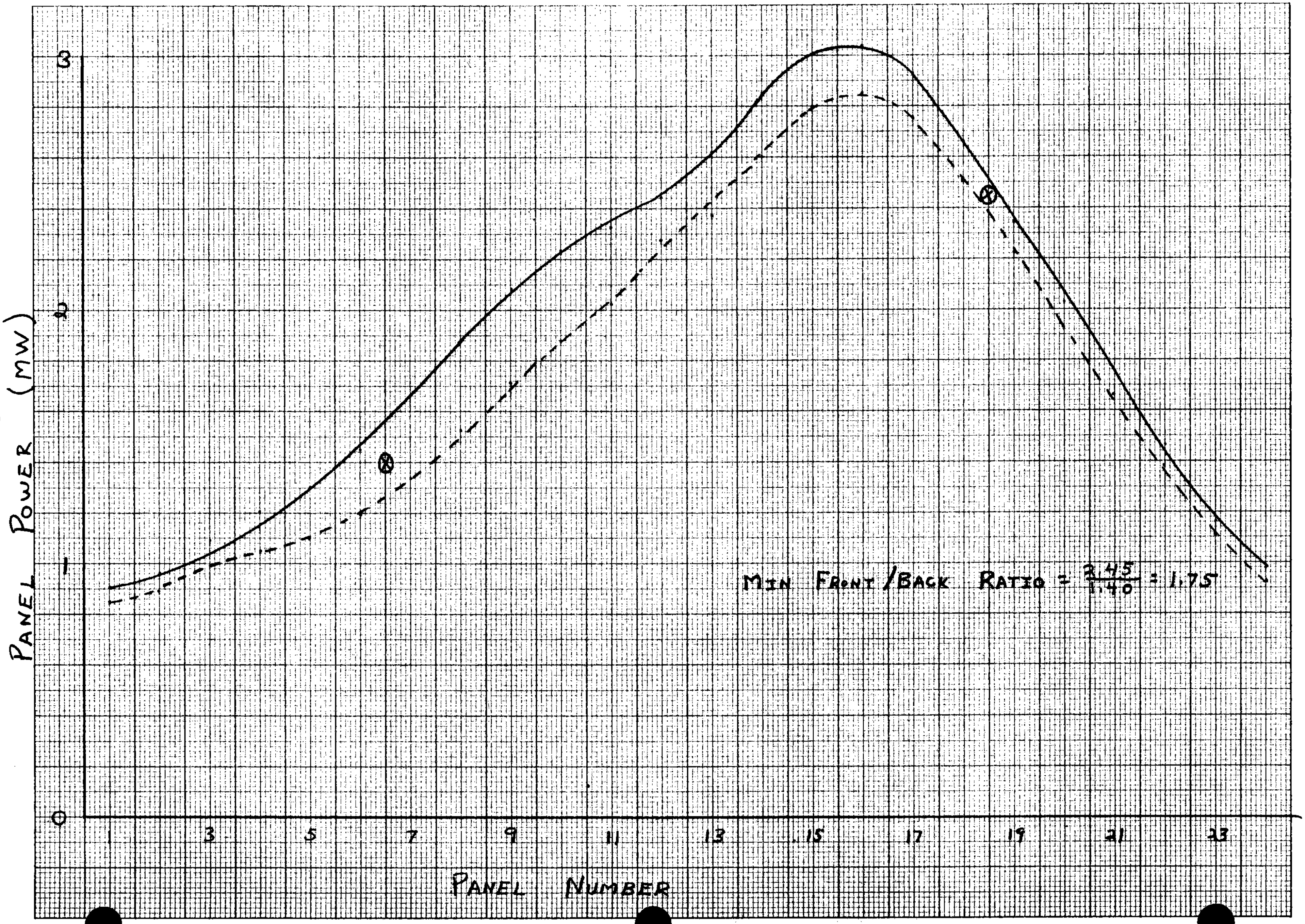

PANEL POWER (MW)
0
1
2
3
1
3
5
7
9
11
13
15
17
19
21
23
PANEL NUMBER
MIN FRONT/BACK RATIO = $\frac{2.45}{1.40}$ = 1.75

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REF CASE

—1907—

ROW 30 OUT

DELETE 20 MORE OFF ENDS

ROW 29 SOME DELETES

TEST CASE 1

—1906—

ROW 29 + 30 OUT

COMPLETE OUT THRU 19

CIRCLE 20 NO DELETE

CIRCLES 21 — 28 SAME AS REF CASE

TEST CASE 2

ROWS 28, 29, + 30 OUT

COMPLELE CIRCLE 20 + 21 COMPLETE

CIRCLES 22-27

6 OFF 27
4 OFF 26

WORKSHEET
FORM 30-103-1 (REV. 10-67)

PANEL 13 GRADIENTS

(SUMMER SOLSTICE)

TIME	PWR	SUN EL	GRAD
-6.28 (5:43)	0.792		-.1105
-5.23 (6:46)	1.630		-.0911
-4.18 (7:49)	2.169		-.0813
-3.14 (8:52)	2.446		-.0574
-2.09 (9:54)	2.638		-.0356
-1.05 (10:57)	2.817		-.0158
0 (12:00)	2.912		.0086
1.05 (1:03)	2.890		.0341
2.09 (2:06)	2.762		.0534
3.14 (3:08)	2.615		.0725
4.18 (4:11)	2.369		.0914
5.23 (5:14)	1.797		.1035
6.28 (6:17)	0.881		.1141

(WINTER SOLSTICE)

TIME	PWR	SUN EL	GRAD
-3.85 (8:09)	1.276		-.0270
-3.20 (8:48)	1.886		-.0305
-2.56 (9:26)	2.365		-.0336
-1.92 (10:05)	2.740		-.0283
-1.28 (10:43)	2.948		-.0176
-0.64 (11:22)	3.060		-.0054
0 (12:00)	3.115		.0043
0.64 (12:38)	3.091		.0144
1.28 (1:17)	3.015		.0265
1.92 (1:55)	2.833		.0378
2.56 (2:34)	2.459		.0455
3.20 (3:12)	1.945		.0388
3.85 (3:51)	1.297		.0142

FIGURE 2

This figure looks at the panel gradients created by 3 alternate collector field designs. The data was developed by the U of H for Oct 21 which is less severe from a gradient standpoint than summer solstice. It shows that the gradients on panels 13 and 14 are essentially identical for the three layouts (identical slopes). The penalties in going with option 1 are

- redo Grading and Concrete construction package
- add ~$300,000 in extra heliostats
- rework preheat panels because of excessive heat loads.

Penalties in going to option 2 are

- redo Grading and Concrete Construction packages
- add ~$720,000 in extra heliostats
- rework or abandon preheat panels because of excessive heat loads.

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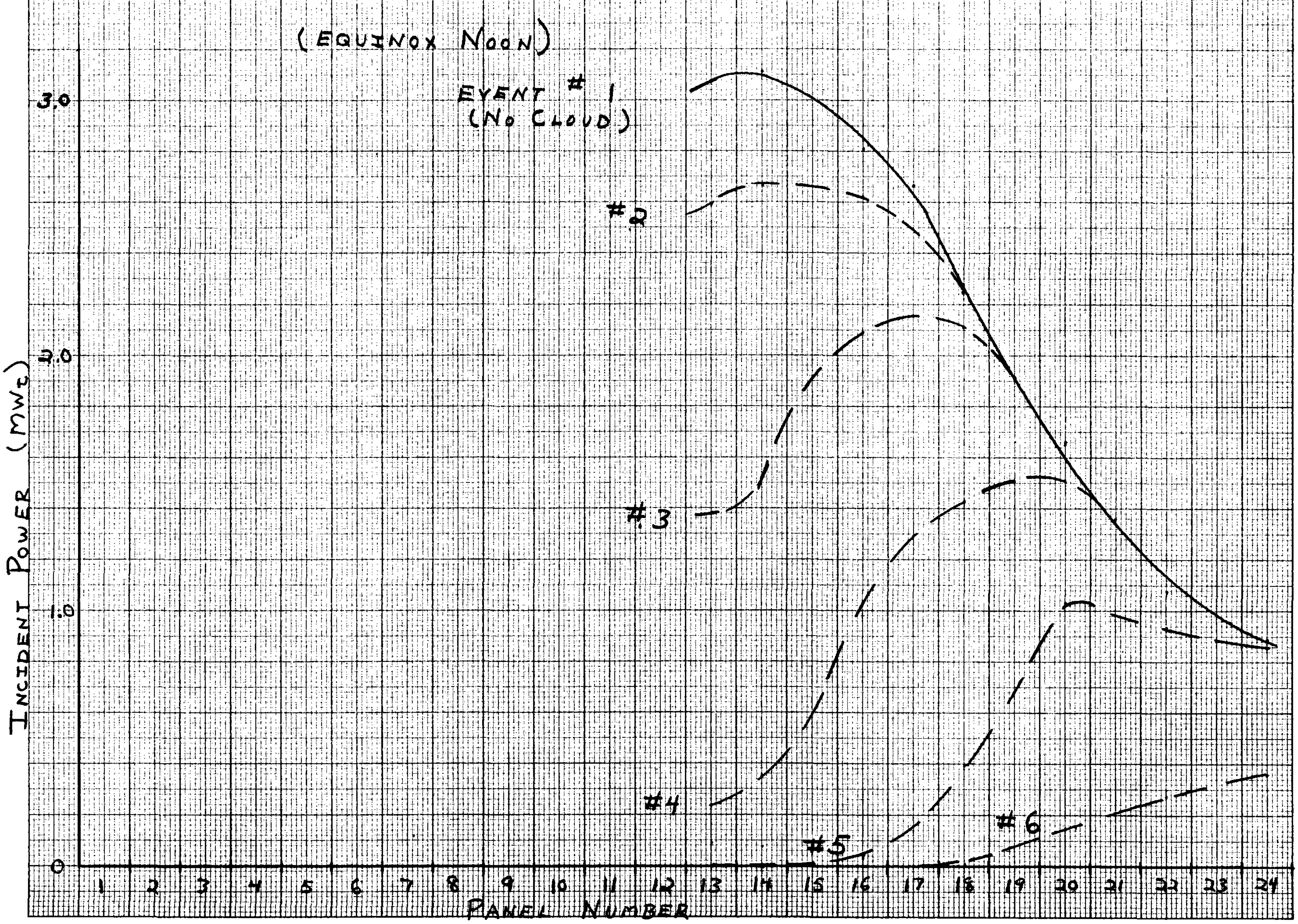
INCIDENT POWER — NORTH/SOUTH CLOUD PASSAGE
(EQUINOX NOON)

EVENT	13	14	15	16	17	18	19	20	21	22	23	24
1	3.08	3.11		2.81	2.665	2.279	1.916	1.66	1.363	1.074		.8701
3	2.59	2.665		2.622		2.249		1.66		1.074		.870
5	1.38	1.516		2.093		2.107		1.64		1.072		.870
7	.236	.354		1.038		1.432		1.508		1.064		.870
9	0	0		.0444		.395		1.037		.936		.857
11	0	0		.0045		~0		.151		.278		.354
13	.087	.079		.035		0		0		0		0
15	1.059	.980		.001 .408	.1739	.064		0		0		0
17	2.309	2.20		1.1162		.419		.0699		.0048		0
19	3.054	3.042		2.447		1.46		.287		.016		0
21	3.08	3.111		2.791		2.111		1.159		.445		.167
23	3.08	3.11		2.81		2.279		1.66		1.074		.870

130F14

NORTH TO SOUTH CLOUD PASSAGE

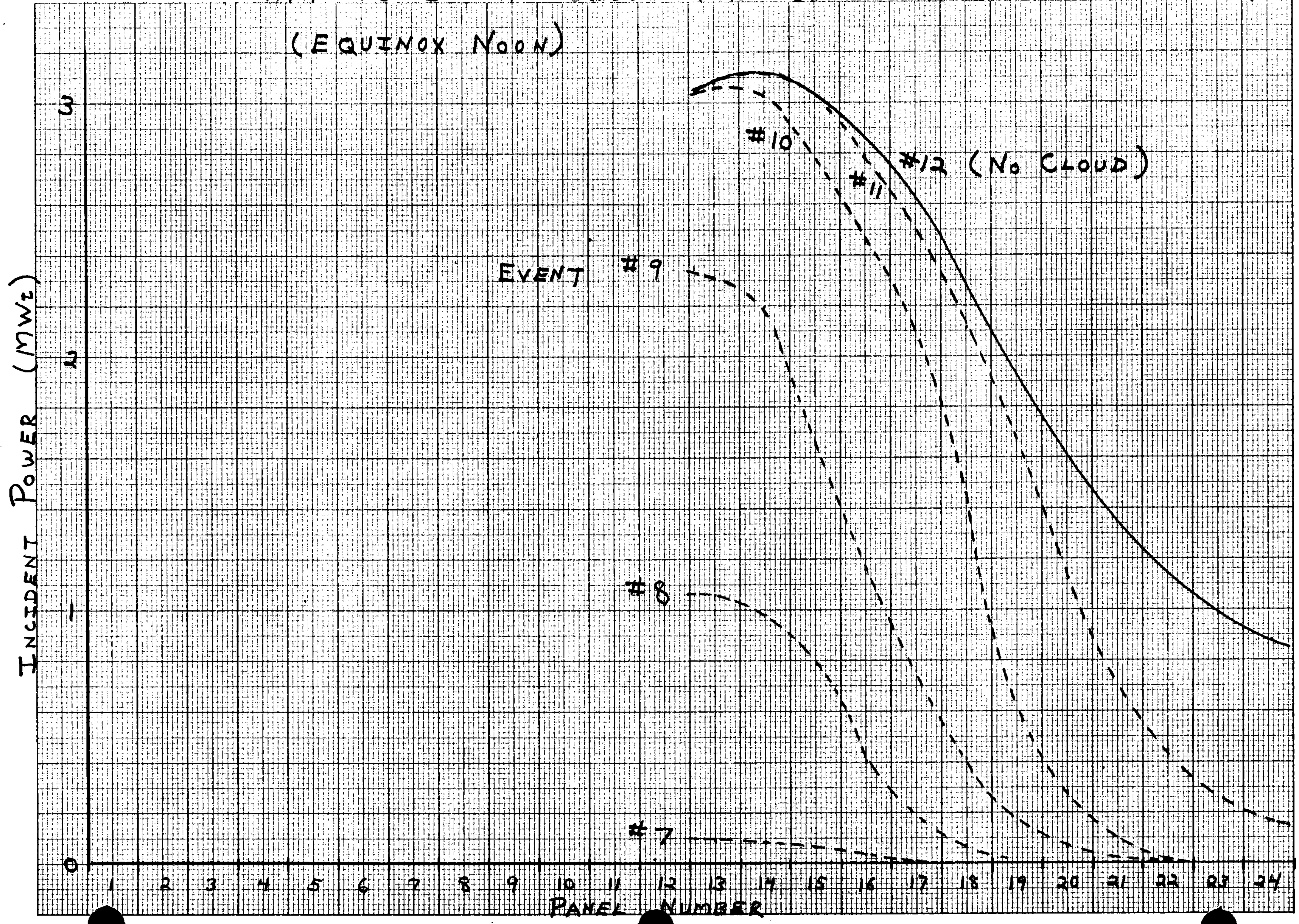
FIGURE 1 OF 2



14 OF 14

NORTH TO SOUTH CLOUD PASSAGE

FIGURE 2 OF 2



3/4/79
1 OF 1

RECEIVER SIZE DEFINITION

BEST DAY 8 AM $\rightarrow (I)(\cos)(B{+}S) = 677.41 = (897.66)(.7605)(.9923)$

PDR WINTER 2 PM $\rightarrow (I)(\cos)(B{+}S) = 715.43 = (950)(.8015)(.9396)$

SINCE BOTH MUST SUPPLY THE SAME POWER,

$$A_1\,(677.41) = A_2\,(715.43)$$

$$A_1 = \left(\frac{715.43}{677.41}\right) A_2 = 1.056\,A_2$$ GLASS AREA SCALING FACTOR

PEAK POWER COMPARISON

BEST DAY NOON $P_1 = A_1\,(989.67)(.8442)(.9974) = 833.31\,A_1$

PDR NOON $P_2 = A_2\,(950)(.8442)(.9974) = 799.90\,A_2$

$P_1 = 833.31\,A_1$ $P_2 = 799.90\,A_2$

$= (833.31)(1.056)\,A_2$

$P_1 = 879.98\,A_2$

$$P_1 = 879.98\left(\frac{P_2}{799.90}\right) = 1.100\,P_2$$

ASSUME SAME RELATIVE CIRCUMFERENTIAL DISTRIB.

$L_1 = 1.100\,L_2$ (RECEIVER LENGTH)
(ASSUME ADDITIONAL POWER IS APPLIED AT AVERAGE FLUX LEVEL)

SEE PEAK TO AVERAGE CALC $\frac{\text{PEAK}}{\text{AVE}} = 1.27$

IF ΔP IS APPLIED AT PEAK LEVEL (SAME END FALL OFF ASSUMED), ΔL CAN BE REDUCED BY FACTOR $P/A = 1.27$

$\Delta L = 10\% \left(\frac{1}{1.27}\right) = 7.87\%$

$L_1 = 1.08\,L_2 \rightarrow L_2$ WAS 41 FT (12.5 m) $\Rightarrow$ $\underline{L_1 = 44.3}$ FT $\boxed{45\text{ FT}}$

THERMAL STORAGE SUBSYSTEMS CALCULATIONS

QUADRILLE WORK SHEET

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY-WEST

MCDONNELL DOUGLAS CORPORATION

ANALYSIS TS FEEDWATER

PAGE 1 OF 19

PREPARED BY JER

MODEL

DATE 4/21/80

PLANT SOLAR I

REPORT NO.

PACKAGE SUMMARY

THIS PACKAGE DEFINES:

1. MINIMUM FEEDWATER PRESSURE AT THE INLET TO THE TS STEAM GENERATOR SKIDS — 500 psia

2. MAXIMUM FEEDWATER PRESSURE TO WHICH THE PIPING AND FLOW ELEMENTS MUST BE DESIGNED — 615 psia

3. ALL FLOW PRESSURE DROPS BETWEEN THE OUTLET OF THE FEED PUMP AND INLET TO THE STEAM GENERATOR SKIDS

QUADRILLE WORK SHEET

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY-WEST

MCDONNELL DOUGLAS CORPORATION

ANALYSIS THERMAL STORAGE FEEDWATER
PAGE 2 OF 19
PREPARED BY JER
MODEL
DATE 4/21/80
PLANT SOLAR I
REPORT NO.

I. PURPOSE :

DEFINE FEEDWATER CONDITIONS ARRIVING AT THE THERMAL STORAGE STEAM GENERATOR EQUIPMENT

II. ASSUMPTIONS :

(a) TS FEEDWATER PUMP (P-903) SUPPLIED BY SCE.

ESTIMATED PUMP CHARACTERISTICS

(Q)	(H)	
236 gpm	1137 FT	(FROM SCE) 4/18/80
0 gpm	1375 FT	[SEE FIG 1]

(b) DEAERATOR CAN OPERATE ANYWHERE WITHIN THE RANGE OF 20 - 50 psia

(c) TS FEEDWATER PIPE ROUTING AS SHOWN ON ANALYSIS ISOMETRIC (P13-5) — 40P300513 2011

NOTE: PORTION INSIDE EPGS NOT FIRM DUE TO INCOMPLETE SCE DESIGN.

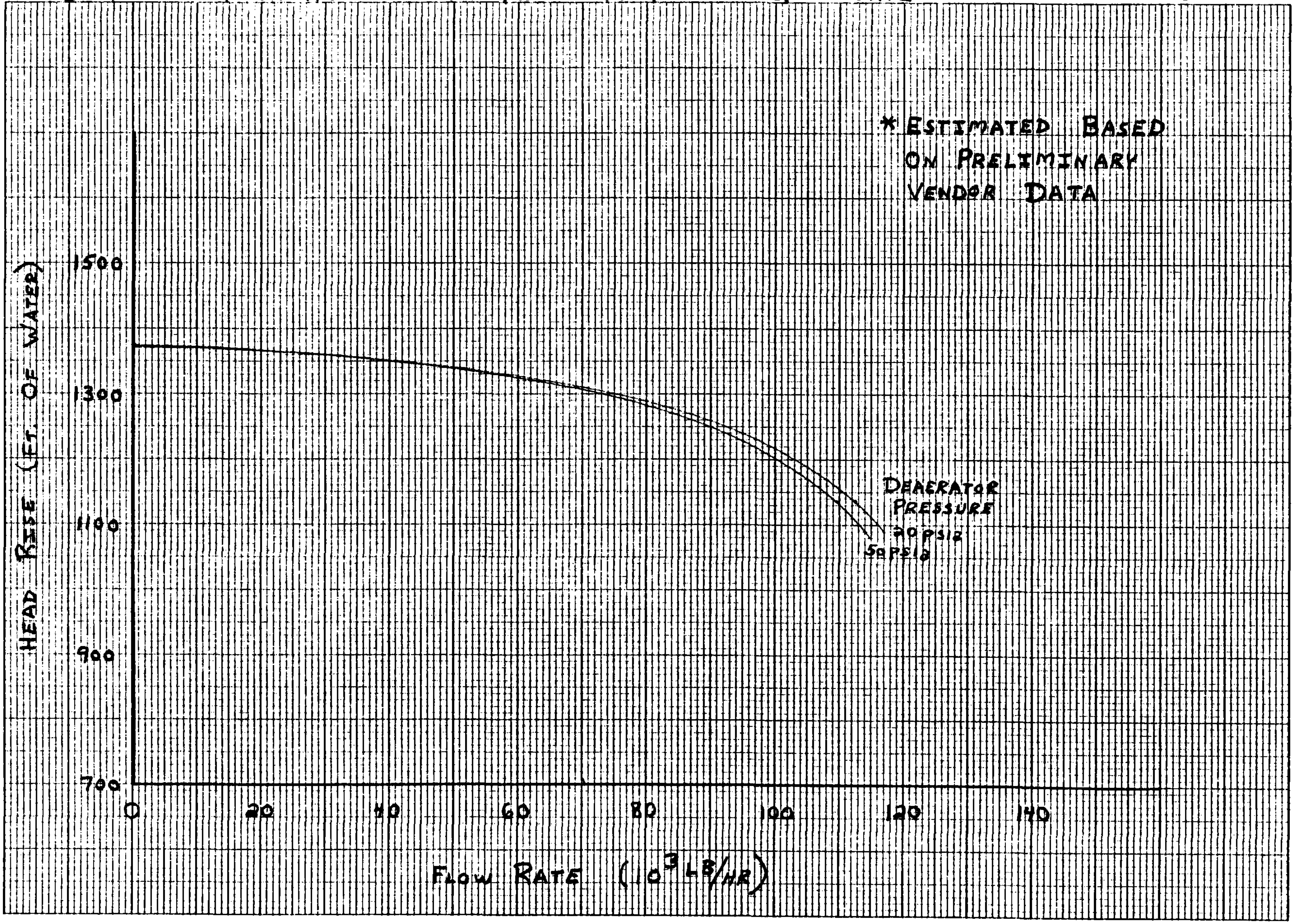
III. PUMP OUTPUT PRESSURE

(a) INLET CONDITIONS

DEAERATOR PRESS	20 psia (ρ_{H_2O} = 59.4 LB/FT^3)	50 psia (ρ = 57.9 LB/F
VERT. COLUMN (30 FT MAX)	12.4 psia	12.06 [illegible]
(TOTAL INLET PRESS)	32.4 psia	62.06 psia

4/21/80
JER

FIG 1 THERMAL STORAGE FEED PUMP H - Q CURVE *



* ESTIMATED BASED
ON PRELIMINARY
VENDOR DATA

3 OF 19

QUADRILLE WORK SHEET

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY-WEST

MCDONNELL DOUGLAS CORPORATION

ANALYSIS TS FEEDWATER

PAGE 4 OF 17

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(b) OUTLET CONDITIONS

DEAERATOR PRESSURE	20 psia	50 psia
@ 110,000 LB/HR TOTAL FLOW		
HEAD RISE	1155 FT (476.6 psia)	1130 FT (454.3 ps
+ INLET PRESS	32.4 psia	62.06 ps
TOTAL OUTLET	509.0 psia	516.36 ps
@ 0 LB/HR TOTAL FLOW		
HEAD RISE	1375 FT (567 psia)	1375 (552.9 psia)
+ INLET PRESS	32.4 psia	62.06 psia
TOTAL OUTLET	599.4 psia	614.96 psia
@ 80,000 LB/HR TOTAL FLOW		
HEAD RISE	1290 FT (532.3 psia)	1282 FT (515.5 psia)
+ INLET PRESS	32.4 psia	62.06 psia
TOTAL OUTLET	564.7 psia	577.56 ps

ANALYSIS TS FEEDWATER		PAGE 5 OF 19
PREPARED BY JER		MODEL
DATE 4/21/80	PLANT SOLAR ONE	REPORT NO.

IV. TS FEEDWATER LINE LOSS

CALCULATIONS ACCOMPLISHED IN TWO STEPS:

(i) LOSSES FROM PUMP OUTLET TO PIPING SPLIT POINT (SEE ANALYSIS ISOMETRIC P13-5 ZN E-6, POINT ⑬)

(ii) LOSSES DOWNSTREAM OF THE SPLIT POINT TO THE STEAM GENERATOR INTERFACE POINTS. (76 I + 77 I)

PIPING CHARACTERISTICS:

	(PUMP TO SPLIT)	(SPLIT TO 76 I)	(SPLIT TO 77 I)
PIPE:	129.65 FT 4" SCH 40	85.4 FT 2½" SCH 40	54.7 FT 2½" SCH 40
VALVES:	1	0	0
RT. ANGLES	11	4	4

CALCULATIONS PUMP TO SPLIT

4" SCH 40 LINE DROP:

236 gpm (129 FT) ⟶ <u>1.55 psid</u>

REF VOGT F-11 CATALOG TABLE 3B PAGE 289

ELBOWS:

$$\Delta H = K \frac{V^2}{2g}$$

ASSUME K = 0.21
RT ANGLE REFERENCE
STEARNS ROGER
STANDARD (LONG SWEEP)

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TABLE 3B
FLOW OF WATER IN SCHEDULE 40 PIPE
PRESSURE DROP PER 100 FT. OF SCHEDULE 40 PIPE AT VARIOUS FLUID VELOCITIES*

Gallons per Minute	SIZE PIPE, INCHES															
	¼		⅜		½		¾		1		1¼		1½		2	
	V	ΔP	V	ΔP	V	ΔP	V	ΔP	V	ΔP	V	ΔP	V	ΔP	V	ΔP
1	3.1	6.54	1.7	1.25	1.1	.39	—	—	—	—	—	—	—	—	—	—
2	6.2	26.2	3.4	5.00	2.1	1.56	1.2	.34	—	—	—	—	—	—	—	—
3	9.3	58.9	5.0	11.3	3.2	3.52	1.8	.77	—	—	—	—	—	—	—	—
4	12.3	104.6	6.7	20.0	4.2	6.26	2.4	1.36	1.5	.39	—	—	—	—	—	—
5	—	—	8.4	31.3	5.3	9.78	3.0	2.13	1.9	.61	1.1	.15	—	—	—	—
10	—	—	—	—	10.6	39.1	6.0	8.52	3.7	2.44	2.2	.59	1.6	.25	—	—
15	—	—	—	—	—	—	9.0	19.2	5.6	5.49	3.2	1.33	2.4	.56	—	—
20	—	—	—	—	—	—	12.0	34.1	7.4	9.76	4.3	2.37	3.2	1.0	1.9	.27
25	—	—	—	—	—	—	—	—	9.3	15.3	5.4	3.70	3.9	1.56	2.4	.42
30	—	—	—	—	—	—	—	—	11.0	22.0	6.4	5.33	4.7	2.24	2.9	.61
35	—	—	—	—	—	—	—	—	—	—	7.5	7.25	5.5	3.05	3.4	.83
40	—	—	—	—	—	—	—	—	—	—	8.6	9.47	6.3	3.98	3.8	1.09
45	—	—	—	—	—	—	—	—	—	—	9.7	12.0	7.1	5.04	4.3	1.37
50	—	—	—	—	—	—	—	—	—	—	10.7	14.8	7.9	6.23	4.4	1.70
70	—	—	—	—	—	—	—	—	—	—	—	—	11.1	12.20	6.7	3.33
90	—	—	—	—	—	—	—	—	—	—	—	—	14.2	20.17	8.6	5.50
100	—	—	—	—	—	—	—	—	—	—	—	—	—	—	9.6	6.79
120	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11.5	9.78
140					—	—	—	—	—	—	—	—	—	—	13.4	13.31

Gallons per Minute	SIZE PIPE, INCHES															
	2½		3		4		5		6		8		10		12	
	V	ΔP	V	ΔP	V	ΔP	V	ΔP	V	ΔP	V	ΔP	V	ΔP	V	ΔP
15	1.0	.059	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20	1.3	.11	—	—	—	—	—	—	—	—	—	—	—	—	—	—
25	1.7	.17	1.1	.053	—	—	—	—	—	—	—	—	—	—	—	—
30	2.0	.24	1.3	.076	—	—	—	—	—	—	—	—	—	—	—	—
35	2.4	.32	1.5	.10	—	—	—	—	—	—	—	—	—	—	—	—
40	2.7	.42	1.7	.13	1.0	.033	—	—	—	—	—	—	—	—	—	—
45	3.0	.53	2.0	.17	1.1	.041	—	—	—	—	—	—	—	—	—	—
50	3.4	.66	2.2	.21	1.3	.051	—	—	—	—	—	—	—	—	—	—
70	4.7	1.29	3.0	.41	1.8	.100	1.1	.030	—	—	—	—	—	—	—	—
100	6.7	2.64	4.3	.84	2.5	.204	1.6	.062	1.1	.025	—	—	—	—	—	—
125	8.4	4.13	5.4	1.32	3.2	.319	2.0	.096	1.4	.038	—	—	—	—	—	—
150	10.0	5.94	6.5	1.90	3.8	.46	2.4	.14	1.7	.055	—	—	—	—	—	—
175	11.7	8.08	7.6	2.58	4.4	.62	2.8	.19	1.9	.075	—	—	—	—	—	—
200	13.4	10.6	8.7	3.37	5.0	.82	3.2	.25	2.2	.098	—	—	—	—	—	—
225	15.1	13.4	9.8	4.27	5.7	1.03	3.6	.31	2.5	.12	1.4	.029	—	—	—	—
250	—	—	10.9	5.27	6.3	1.28	4.0	.39	2.8	.15	1.6	.036	—	—	—	—
275	—	—	11.9	6.38	6.9	1.54	4.4	.47	3.1	.19	1.8	.044	—	—	—	—
300	—	—	13.0	7.59	7.6	1.84	4.8	.56	3.3	.22	1.9	.052	—	—	—	—
350	—	—	—	—	8.8	2.50	5.6	.76	3.9	.30	2.2	.071	—	—	—	—
400	—	—	—	—	10.1	3.26	6.4	.99	4.4	.39	2.6	.093	—	—	—	—
450	—	—	—	—	11.3	4.13	7.2	1.25	5.0	.50	2.9	.12	—	—	—	—
475	—	—	—	—	12.0	4.60	7.6	1.39	5.3	.56	3.0	.13	—	—	—	—
500	—	—	—	—	12.6	5.10	8.0	1.54	5.6	.62	3.2	.15	2.0	.044	—	—
550	—	—	—	—	13.9	6.17	8.8	1.87	6.1	.74	3.5	.18	2.2	.053	—	—
600	—	—	—	—	15.1	7.34	9.6	2.22	6.7	.89	3.9	.21	2.4	.063	—	—
650	—	—	—	—	—	—	10.4	2.61	7.2	1.04	4.2	.25	2.6	.074	—	—
700	—	—	—	—	—	—	11.2	3.02	7.8	1.21	4.5	.29	2.9	.085	2.0	.035
750	—	—	—	—	—	—	12.0	3.47	8.3	1.38	4.8	.33	3.1	.098	2.2	.041
800	—	—	—	—	—	—	12.8	3.95	8.9	1.57	5.1	.37	3.3	.11	2.3	.046
850	—	—	—	—	—	—	13.6	4.46	9.4	1.78	5.5	.42	3.5	.13	2.4	.052
900	—	—	—	—	—	—	14.4	5.00	10.0	1.99	5.8	.47	3.7	.14	2.6	.059
950	—	—	—	—	—	—	—	—	10.6	2.22	6.1	.53	3.9	.16	2.7	.065
1000	—	—	—	—	—	—	—	—	11.1	2.46	6.4	.58	4.1	.17	2.9	.072
1100	—	—	—	—	—	—	—	—	12.2	2.98	7.1	.71	4.5	.21	3.2	.087
1200	—	—	—	—	—	—	—	—	—	—	7.7	.84	4.9	.25	3.4	.10
1500	—	—	—	—	—	—	—	—	—	—	9.6	1.31	6.1	.39	4.3	.16
2000	—	—	—	—	—	—	—	—	—	—	12.8	2.33	8.1	.70	5.7	.29
2500	—	—	—	—	—	—	—	—	—	—	16.0	3.64	10.2	1.09	7.2	.45
3000	—	—	—	—	—	—	—	—	—	—	—	—	12.2	1.57	8.6	.65
3500	—	—	—	—	—	—	—	—	—	—	—	—	14.2	2.13	10.0	.89
4000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11.5	1.16
4500	—	—	—	—	—	—	—	—	—	—	—	—	—	—	12.9	1.46

*Above table for water at 60°F flowing in clean commercial steel or wrought iron pipe. V = Velocity in feet per second. ΔP = Pressure drop in PSI.

To determine the pressure drop for pipe lengths other than 100 feet, multiply the pressure drop from the above table by the following ratio:

$$R = \frac{L}{100}$$, where L is length of pipe in feet for which the pressure drop is required.

To determine the pressure drop for a pipe other than Schedule 40, multiply the value from the above table by the value for the appropriate pipe size and schedule below.

Pipe Size, Inches	¼	⅜	½	¾	1	1¼	1½	2	2½	3	4	5	6	8	10	12
SCHEDULE 80	2.55	2.15	1.92	1.69	1.58	1.47	1.42	1.38	1.36	1.33	1.29	1.27	1.29	1.26	1.26	
SCHEDULE 160			4.23	4.35	3.53	2.38	2.52	2.74	2.12	2.18	2.20	2.19	2.18	2.21	2.28	
DOUBLE EXTRA			93.1	24.7	16.5	8.67	6.72	4.92	5.27	4.22	3.40	2.96	2.91	2.11		

ANALYSIS TS FEEDWATER

PREPARED BY JER

DATE 4/21/80

PLANT SOLAR ONE

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MODEL

REPORT NO.

$$\Delta H = (11)(0.21)\frac{(5.96\ FT/SEC)^2}{(2)(32.2)}$$

$$\Delta H = 1.28\ FT$$

$\Delta P = \underline{0.53\ psia}$ ASSUMING $\rho_{H_2O} = 59.4\ LB/FT^3$

ΔP VALVE + SENSOR = $\underline{3\ psia}$ (ASSUMED AT FULL FLOW)

$$\boxed{\Delta P_{TOTAL}\ (PUMP\ TO\ SPLIT) = 5.1\ psia\ @\ 110{,}000\ LB/HR}$$

@ 80,000 LB/HR

$$\Delta P = 5.1\left(\frac{80{,}000}{110{,}000}\right)^2 = 2.7\ psia$$

ABSOLUTE PRESSURE AT SPLIT

(DEAERATOR PRESSURE)	(20 psia)	(50 psia)
PUMP OUTLET @ 110,000 LB/HR	509.0 psia	516.36 psia
LOSSES TO SPLIT	5.1 psia	5.1 psia
SPLIT PRESSURE	503.9 psia	511.3 psia
PUMP OUTLET @ 80,000 LB/HR	564.7 psia	577.56 psia
LOSSES TO SPLIT	2.7 psia	2.7 psia
SPLIT PRESSURE	562.0 psia	574.9 psia

ANALYSIS TS FEEDWATER
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(20 psia) (50 psia)

AT 0 LB/HR FLOW, FLOW LOSSES = 0 psia

∴ SPLIT PRESS = PUMP OUTLET = 599.4 psia 614.96 psia

VARIATION OF SPLIT POINT PRESSURE WITH FLOW

SEE FIGURE 2

PRESSURE DROP CALC SPLIT POINT TO INTERFACES 76 I + 77 I

2½" SCH 40 LINE LOSS :

118 gpm (85.4 FT) → 3.18 psia TO 76 I

118 gpm (54.7 FT) → 2.04 psia TO 77 I

FROM VOGT F-11 CATALOG
TABLE 3B P 298

ELBOWS

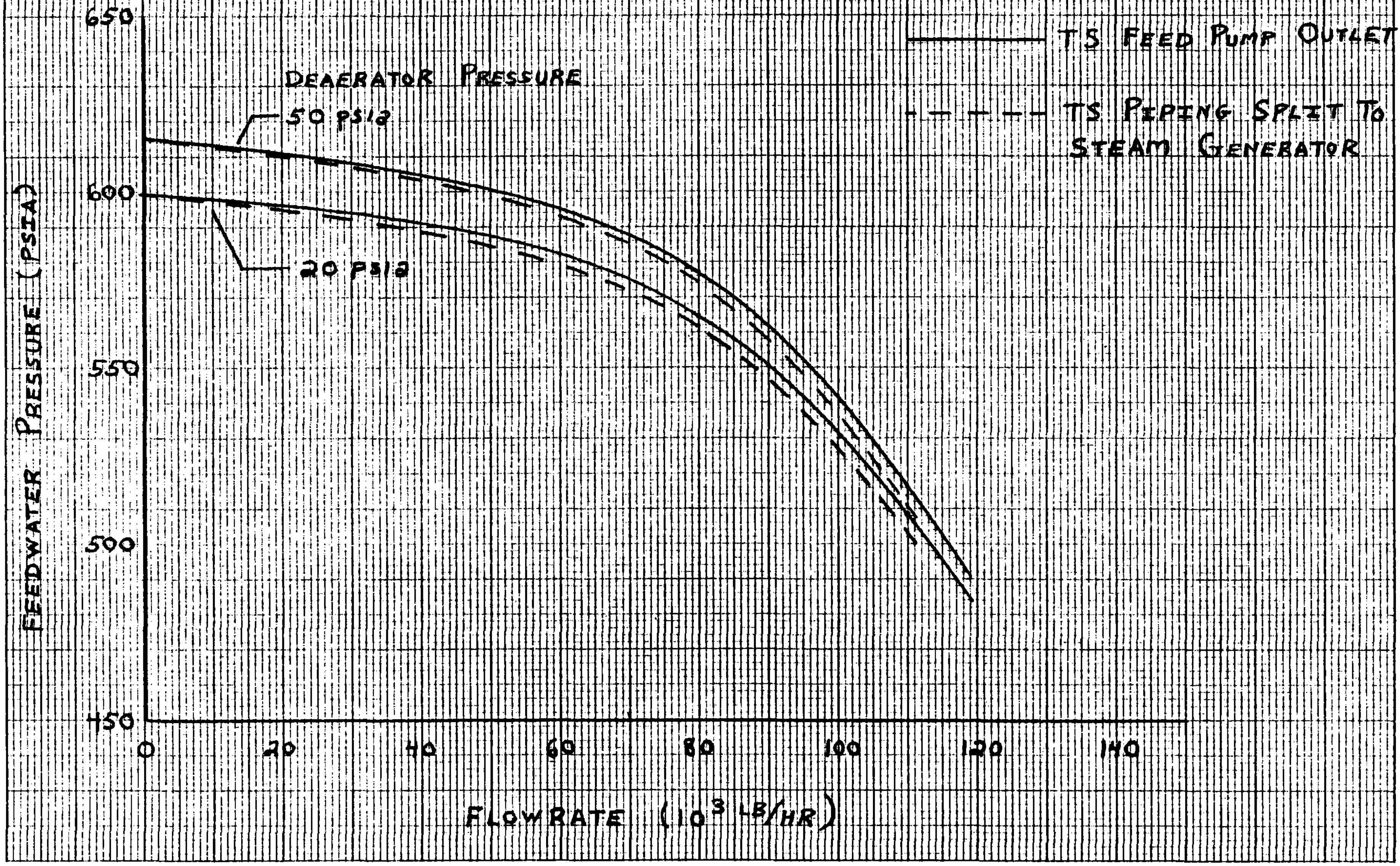
$$\Delta H = K\frac{V^2}{2g}$$

$$= (0.21)(4\text{ BENDS})\frac{(7.9\text{ FT/SEC})^2}{(2)(32.2)}$$

$$= 0.81\text{ FT } H_2O$$

4/21/80

FIG 2 THERMAL STORAGE FEEDWATER PRESSURE



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QUADRILLE WORK SHEET

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY-WEST

MCDONNELL DOUGLAS CORPORATION

ANALYSIS TS FEEDWATER

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ΔP_{ELBOWS} = <u>0.34 psia</u>

MIN PRESSURE AT 76I = 503.9 − 3.18 − 0.34

= 500.4 psia

MAX PRESSURE AT 76I = 614.96 psia
(DEAD HEAD CONDITION
@ 50 psia DEAERATOR)

MIN PRESS AT 77I = 503.9 − 2.04 − 0.34

= 501.5 psia

MAX PRESSURE AT 77I = 614.96 psia
(SAME AS FOR 76I)

∴ MINIMUM PRESSURE AT INTERFACE TO

TS STEAM GENERATORS = <u>500 psia</u>

25-S-6 (23 SEP 70)

8/1/80
11 OF 19

AUDIT QUESTIONS INVOLVING THE TS FEEDWATER CIRCUI

CALCULATIONS SHOULD BE REVISED TO REFLECT

1. ΔP MOV-1132
2. ΔP RECIRC VALVE
3. ΔP FE 35B
4. ΔP FE 56
5. TEE
6. REDUCER

1. ΔP MOV-1132

- NO ΔP SPECIFIED FOR GATE VALVE IN CP 9
- USE "TYPICAL" GATE VALVE

YOUR: FULL PORT GATE $k = 0.48$

GATE VALVE (WIDE OPEN) $k = 0.19$

REF: ESSENTIALS OF ENGINEERING FLUID MECHANICS P 219

$$\Delta H = K \frac{v^2}{2g} = (0.19)\frac{(5.96)^2}{(2)(32.2)}$$

$$\Delta H = 0.105 \text{ FT} \rightarrow \Delta P = 0.043 \text{ PSID}$$

(MOV-1132)

YOUR 0.26 FT $\frac{(.26)(\cancel{144})}{144} 59.4 = 0.107$ PSI = ΔP

2. ΔP RECIRC VALVE

CONVERSATION WITH CLEM SVOBODA 8/4/80

TS FEED PUMP RECIRC VALVE

YARWAY — ΔP = 3.6 PSI @ 236 GPM

8/11/80
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3. ΔP FE 35B

2.5" ID ELEMENT

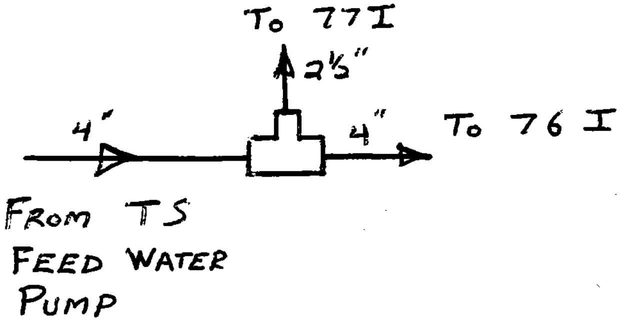
$\Delta P = 2.53$ psid @ 110,000 LB/HR @ T = 281°F
485 psig

$\Delta P = 0.65$ psid @ 55,000 LB/HR

FROM REID BICKNELL
8/11/80

4. ΔP FE 56 → NO LONGER IN THE SYSTEM PER SCE

5. ΔP TEE



$$Re = \frac{50.6\ Q\rho}{d\ \mu}$$
$$= \frac{(50.6)(236\ \text{GPM})(59.4\ \text{LB}/}{(4.026)\ (4\times10^{-5})(47900)}$$
$$= 9.19\times10^{4}$$
$$= 91900$$
$$f = 0.021$$

FLOW THROUGH RUN (To 76I)

L/D EQUIVALENT = 20
REF: CRANE
P A-30

$$V_2 = \frac{5.96\ \text{FT/SEC}}{2} = 2.48\ \text{FT/SEC}$$

$D_2 = 4.026$

$f = 0.023$ $Re \sim 45000$

$$\Delta h = K \frac{V^2}{2g}$$

$$= f \frac{L}{D} \frac{V^2}{2g} = (0.023)(20)\left(\frac{2.48^2}{(2)(32.2)}\right)$$

$$\Delta h = 0.044 \text{ FT} \rightarrow \Delta P = 0.018 \text{ psia}$$

FLOW THROUGH BRANCH (TO 77I)

$V_2 = 2.48$ FT/SEC

$D_2 = 2.469$ IN

$\frac{L}{D}$ EQUIVALENT = 60

$$R_E = \frac{(50.6)(118 \text{ GPM})(59.4 \frac{LB}{FT^3})}{(2.469)(4 \times 10^{-5})(47900)}$$

$R_E = 74972$

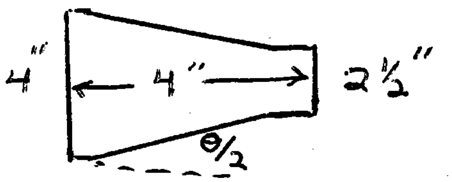
$f = 0.022$

$$\Delta h = f \frac{L}{D} \frac{V^2}{2g}$$

$$= 0.022 (60) \frac{2.48^2}{(2)(32.2)}$$

$$= 0.126 \text{ FT} \rightarrow .052 \text{ psi}$$

6 REDUCER



$$\tan \frac{\theta}{2} = \frac{0.75}{4} = 0.188$$

$$\theta/2 = 10.6°$$

$$\theta = 21.2°$$

$$\beta = \frac{2.469}{4.026} = .613$$

$$k = 0.5 (1 - \beta^2) \sqrt{\sin(\theta/2)}$$

$$= .5 (1 - .613^2) \sqrt{\sin 10.6°} = .134$$

8/1/80
14 OF 19

$V_2 = 2.48$ FT/SEC

$$\Delta h = k \frac{V^2}{2g}$$

$$= .134 \left(\frac{2.48^2}{(2)(32.2)} \right)$$

$$= 0.013 \text{ FT}$$

TS FEEDWATER
JER
4/21/80 SOLAR ONE

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IV. TS FEEDWATER LINE LOSS

CALCULATIONS ACCOMPLISHED IN TWO STEPS:

(i) LOSSES FROM PUMP OUTLET TO PIPING SPLIT POINT (SEE ANALYSIS ISOMETRIC P13-5 ZN E-6, POINT ⑬)

(ii) LOSSES DOWNSTREAM OF THE SPLIT POINT TO THE STEAM GENERATOR INTERFACE POINTS. (76I + 77I)

PIPING CHARACTERISTICS:

	(PUMP TO SPLIT)	(SPLIT TO 76 I)	(SPLIT TO 77 I)
PIPE:	129.65 FT 4" SCH 40	85.4 FT 2½" SCH 40	54.7 FT 2½" SCH 4
VALVES:	1	0	0
RT. ANGLES	11	4	4

CALCULATIONS PUMP TO SPLIT

4" SCH 40 LINE DROP:
236 gpm (129 FT) ⟶ 1.55 psig

REF VOGT F-11 CATALOG TABLE 3B
PAGE 289

ELBOWS:

$$\Delta H = K \frac{V^2}{2g}$$

ASSUME K = 0.21
RT ANGLE REFERENC
STEARNS ROGER
STANDARD (LONG SWEE

TS FEEDWATER
JER
4/21/80

SOLAR ONE

16 OF 1

$$\Delta H = (11)(0.21)\frac{(5.96\ \text{FT/SEC})^2}{(2)(32.2)}$$

$$\Delta H = 1.28\ \text{FT}$$

ΔP = 0.53 psia ASSUMING $\rho_{H_2O} = 59.4\ \text{LB/FT}^3$

ΔP [illegible] 432 = 0.07 psia
ΔP [illegible] = 3.6 psia
ΔP FE 35B 2.5 psia
6.2 psia

ΔP VALVE + SENSOR = 3 psia (ASSUMED AT FULL FLOW)

$$\boxed{\Delta P_{\text{TOTAL}}\ (\text{PUMP TO SPLIT}) = 5.1\ \text{psia} \quad @\ 110{,}000\ \text{LB/HR}}$$

5.3 psia

@ 80,000 LB/HR

$$\Delta P = 5.1\left(\frac{80{,}000}{110{,}000}\right)^2 = 2.7\ \text{psia}$$

ABSOLUTE PRESSURE AT SPLIT

(DEAERATOR PRESSURE)	(20 psia)	(50 psia)
PUMP OUTLET @ 110,000 LB/HR	509.0 psia	516.36 psia
LOSSES TO SPLIT	5.3 ~~5.1~~ psia	5.3 5.1 psia
SPLIT PRESSURE	503.9 psia 503.7	511.3 psia 511.1
PUMP OUTLET @ 80,000 LB/HR	564.7 psia	577.56
LOSSES TO SPLIT	2.7 psia	2.7 p
SPLIT PRESSURE	562.0 psia	574.9 p

TS FEEDWATER

PREPARED BY JER

DATE 4/21/80 PLANT SOLAR I

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MODEL

REPORT NO.

(20 psia) (50 psia)

AT 0 LB/HR FLOW, FLOW LOSSES = 0 psia

$\therefore$ SPLIT PRESS = PUMP OUTLET = 599.4 psia 614.96 psia

VARIATION OF SPLIT POINT PRESSURE WITH FLOW:

SEE FIGURE 2

PRESSURE DROP CALC SPLIT POINT TO INTERFACES 76 I + 77 I

2½" SCH 40 LINE LOSS, + REDUCER 0.005 + TEE (RUN) 0.02

118 gpm (85.4 FT) → $\frac{\text{3.18 psia}}{\text{To 76 I}}$ } 3.2[illegible]

TEE BRANCH 0.05

118 gpm (54.7 FT) → $\frac{\text{2.04 psia}}{\text{To 77 I}}$ } 2.0[illegible] PSI

FROM VOGT F-11 CATALOG TABLE 3B P 298

ELBOWS

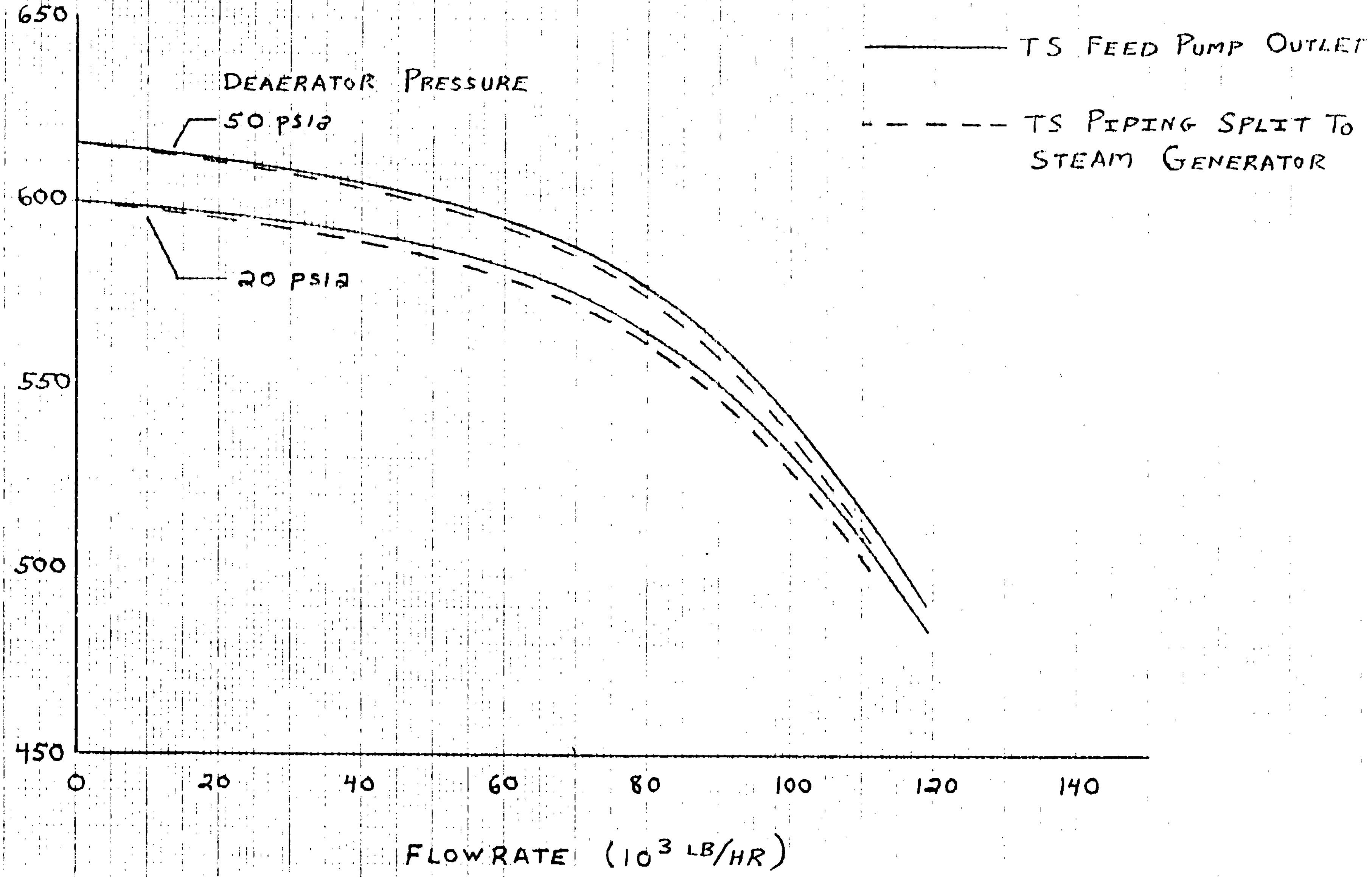
$$\Delta H = K \frac{V^2}{2g}$$

$$= (0.21)(4\ \text{BENDS}) \frac{(7.9\ \text{FT/SEC})^2}{(2)(32.2)}$$

$$= 0.81\ \text{FT}\ H_2O$$

4/21/8

FIG 2 THERMAL STORAGE FEEDWATER PRESSURE



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TS FEEDWATER
JER
4/21/80 SOLAR I

ΔP ELBOWS = 0.34 psia

MIN PRESSURE AT 76I =
500.7 3.21
~~503.9~~ - ~~3.18~~ - 0.34

497.1
= ~~500.4~~ psia

MAX PRESSURE AT 76I = 614.96 psia
(DEAD HEAD CONDITION
(@ 50 psia DEAERATOR)

MIN PRESS AT 77I =
500.7 2.09
~~503.9~~ - ~~2.04~~ - 0.34

498.3
= ~~501.5~~ psia

MAX PRESSURE AT 77I = 614.96 psia
(SAME AS FOR 76I)

∴ MINIMUM PRESSURE AT INTERFACE TO TS STEAM GENERATORS = 500 psia

4/21/90
1 OF 9

DEFINITION OF REQUIREMENTS FOR
PCV-3207 (THSWPR-1)
PCV-3307 (THSWPR-2)

OBJECTIVE :

DEFINE PRESSURE CONTROL VALVE REQUIREMENTS TO MAINTAIN CHARGING HEAT EXCHANGER IN "HOT STANDBY" CONDITION WITHOUT REQUIRING CONTINUOUS OIL CIRCULATION TO PREVENT AN OVER TEMP OF THE OIL. THESE VALVES WORK WHEN ONE OF THE TWO TRAINS (CHARGING LOOPS) IS OPERATING. SINCE DESUPERHEATER OPERATION IS REQUIRED.

THE VALVE MUST BE SIZED TO ACCOMODATE HEAT LOSS THROUGH INSOLATED SURFACES AND STEAM LOSS THROUGH NON CONDENSIBLE GAS BLEED ORIFICES SIMULTANEOUSLY.

4/21/80
2 OF 7

REQUIREMENTS FOR PCV - 3207 (THSWPR - 1)
PCV - 3307 (THSWPR - 2)

APPROX STEAM CONDITIONS UPSTREAM OF SA-302 + 303

650°F 1400 psia → $h = 1250.6$ BTU/LB

EXPAND STEAM SO THAT SUPERHEAT MAX TEMP ≤ 575 °F

$$\left.\begin{matrix} 575°F \\ 1250.6\ \text{BTU/LB} \end{matrix}\right\} \rightarrow 800\ \text{psia} \qquad T_{SAT} = 518°F$$

REVISE SPEC TO REGULATE TO 800 psia (785 psig)

7/11/80
3 OF 9

CONDENSER UNIT HEAT LOSS ESTIMATE

CONDENSER DIMENSIONS :

$L = 47.64$ FT

$D = 3.24$ FT

$r = 19.44$ IN

TOTAL END AREA

$\pi R^2 (2) = \pi \left(\frac{19.44}{144}\right)^2 (2) = 16.48 \text{FT}^2$

INSULATION REQ'T : USE S-R STANDARD DP30.1

24" OD AND LARGER
600 – 699 °F
} PP 6 → 4 IN MIN THICKNESS

CALCIUM SILICATE WITH ALUMINUM LAGGING

$\frac{1}{h} = .68$ °F-HR-FT²/BTU SURFACE ASSUMPTION

(HIGH WIND) → $\frac{1}{h} = .17$ °F-HR-FT²/BTU

$k_{INSUL} = 0.04$ BTU/HR-FT² °F/FT JOHNS MANVILLE IND-3211 3-76 p.36

AVERAGE TEMPERATURE IN VESSEL MAINTAINED @ 518°F

(TSAT @ 800psia = 518 °F

TSUPERHEATED = 575°F — EXPANDING FROM 1400psia 650°F)

$\Delta T = 518 - 55°F = 463$ °F

HEAT LEAK (H-X)

$$q = \frac{k\, 2\pi\, L\, \Delta T}{\ln\left(\frac{r_2}{r_1}\right)}$$

$$= \frac{(.04)(2\pi)(47.64)(463)}{\ln\left(\frac{23.44}{19.44}\right)}$$

$= 29626$ BTU/HR

END LOSS

$$q = k A \frac{\Delta T}{\Delta X} = (.04)(16.48)\frac{(463)}{.333}$$

$= 916$ BTU/HR

$$\boxed{\text{TOTAL H-X HEAT LEAK} \quad 30542 \text{ BTU/HR}}$$

7/11/80
4 OF 9

VENT LOSS

NORMAL OPERATION → VENT 1/2% CONTINUOUS

$\dot{m} = 65000\ ^{LB}/_{HR}$

$p = 1400\,psia$

$T = 650\,°F$

$\rho = 2.86\ ^{LB}/_{FT^3}$

$\Big\}\ 1/2\% = 325\ ^{LB}/_{HR}$

EXPAND TO 800psia ($h = 1250.6\ ^{BTU}/_{LB}$) →

$\rho = 1.54\ ^{LB}/_{FT^3}$

$$\dot{m} \sim \sqrt{\rho\, P_1}$$

$$\therefore\ \dot{m}_{@800psia} = \dot{m}_{1400psia}\,\frac{\sqrt{(1.54\ ^{LB}/_{FT^3})(800psia)}}{\sqrt{(2.86\ ^{LB}/_{FT^2})(1400psia)}}$$

$$= (325\ ^{LB}/_{HR})\ (.5547)$$

$\dot{m}_{@\,800psia} = 180\ ^{LB}/_{HR}$ DUE TO REDUCED UPSTREAM PRESSURE AND DENSITY

ENERGY CONTENT OF BLEED STEAM

$h_{IN} = 1250.6\ ^{BTU}/_{LB}$

$h_{SAT\ LIQ} = 509.7\ ^{BTU}/_{LB}$

$\Big\}\ \Delta h = 740.9\ ^{BTU}/_{LB}$

$$\dot{m} = \frac{30542}{740.9} = 41.2\ ^{LB}/_{HR}$$

~~6" INSUL~~

~~$\frac{16409}{740.9} = 22\ ^{LB}/_{HR}$~~

~~$22 + 180 = 202\ ^{LB}/_{HR}$~~

180

~~$\dot{m}_{TOT} = \dot{m}_{BLEED} + \dot{m}_{VENT}$~~

~~$= 21.3\ ^{LB}/_{HR}$~~

7/11/80
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HEAT LOSS THROUGH PIPES

39 FT 6" PIPE (3½" INSULATION THICKNESS)

120 FT 1" PIPE (2" INSULATION THICKNESS)

$$\dot{q} = \frac{k\,2\pi L\,\Delta T}{\ln\left(\frac{x_2}{x_1}\right)}$$

$\Delta T = 518 - 95 = 423$ °F
(SEE 7/11/80 ①)

6" PIPE

$$\dot{q}_6 = \frac{(0.04)(2)(\pi)(39)(463)}{\ln\left(\frac{6.81}{3.312}\right)}$$

$$= 6296 \text{ BTU/HR}$$

1" PIPE

$$\dot{q}_1 = \frac{(0.04)(2)(\pi)(120)(463)}{\ln\left(\frac{2.658}{.6575}\right)}$$

$$= 9996 \text{ BTU/HR}$$

TOTAL PIPE LOSS = 16292 BTU/HR

ADDITIONAL FLOW INCREMENT $\frac{16292 \text{ BTU/HR}}{740.9 \text{ BTU/LB}} = 21.99 \frac{\text{LB}}{\text{HR}}$

CONVERSATION WITH DON LANDY : (7/11/80)

ORIFICES ARE 0.090" (MIN ACCEPTABLE OPENING)

- LEAKAGE PER CONDENSER* AT FULL PRESS = 650 LB/HR
- LEAKAGE PER CONDENSER* AT 800 psig = 360 LB/HR

* 2 ORIFICES PER CONDENSER

7/11/80
6 OF 9

SUMMARY FLOW PER CONDENSER TRAIN

• LEAKAGE @ 800 psia	360 LB/HR	
• HEAT LOSS – CONDENSER	41.2 LB/HR	30542 BTU/H)
• HEAT LOSS – 6" PIPE • HEAT LOSS – 1" PIPE	21.99 LB/HR	(16292 BTU/HR)
TOTAL	423.2 LB/HR	

From Carmen Winaiski. 7-14-80
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The Bleeds (Non-Condensables) from Charging HX'S Should be 0.10 TO 0.15% $\dot{W}$ max & use a needle valve instead of an orifice & put a T[illegible]D/S to adjust valve.

From John Raetz

$\dot{W}_{Heatloss} = 58$ #/HR

13000 #/HR
6500
Per John 65 TO 100 #/HR

$\dot{W}$ ~~Leakage~~ Bleed = ??

Size THSWPR for 220 #/HR @ 80% open

Change orifices to Lee Visco Jets. Size Jets for 35 (×2) #/HR
50 (×2) #/HR
90 (×2) #/HR

7) F 9

APPENDIX 3

PRESSURE VESSEL AND TANK SCHEDULE

The following vessels and tanks shall be insulated and jacketed as specified in Construction Package No. 12 and in accordance with the following insulation thicknesses:

Item	Operating Temperature, F	Minimum Insulation Thickness *	Location Indoors/ Outdoors**
1) Desuperheater (DS-301)	985°	5"	Outdoors
2) TSS Flash Tank (V-304)	650°	4"	Outdoors
3) Thermal Storage Condenser (E-302)	675°	4"	Outdoors
4) Thermal Storage Condenser (E-301)	675°	4"	Outdoors
5) Thermal Storage Subcooler (E-311)	675°	4"	Outdoors
6) Thermal Storage Subcooler (E-312)	675°	4"	Outdoors
7) Thermal Storage Heater Drain Tank (V-305)	610°	4"	Outdoors
8) Thermal Storage Heater Drain Tank (V-306)	610°	4"	Outdoors

---

* Single layer insulation unless otherwise specified.

**Vessels and tanks located outdoors will be heat traced by others.

APPENDIX 3

PRESSURE VESSEL AND TANK SCHEDULE (CONTD)

Item		Operating Temperature, F	Minimum Insulation Thickness *	Location Indoors/ Outdoors**
9)	Superheater (E-307)	600°	4"	Outdoors
10)	Superheater (E-308)	600°	4"	Outdoors
11)	Boiler (E-305)	600°	4"	Outdoors
12)	Boiler (E-306)	600°	4"	Outdoors
13)	Preheater (E-303)	600°	4"	Outdoors
14)	Preheater (E304)	600°	4"	Outdoors
15)	Thermal Storage Surge Tank (V-309)	675°	4"	Outdoors
16)	Thermal Storage Surge Tank (V-310)	675°	2"	Outdoors
17)	Thermal Storage Blowdown Tank (V-308)	225°	2"	Outdoors

---

* Single layer insulation unless otherwise specified.

**Vessels and tanks located outdoors will be heat traced by others.

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A3-255-EP-RES-543
21 June 1979

MEMORANDUM

Subject: TSSG AND TS CHARGING HEATER PERFORMANCE REQUIREMENTS

To: R. G. Riedesel / J. E. Raetz

From: R. E. Snyder, A3-255

Copies to: G. C. Coleman; M. H. Lobell; E. J. Riel

This memorandum documents the results of an analysis of off-design performance of both the Thermal Storage Steam Generator and the T. S. Charging Heater, heat exchanger trains.

The procedure followed in this study is as follows:

- Size the units in both trains to meet the design point requirements.
- Operate at constant maximum steam flow rate for both trains 65,000 #/hr. for the Charging Heater and 55,000 #/hr. for the TSSG.
- Using these units, explore the off-design performance of the TSSG and TS Charging Heater throughout their operating regimes.
- Impose the appropriate system constraints to the results and and determine any additional constraints caused by the imposed limits, including constraints on one train caused by the other.
- Present these data in a manner that defines the operating envelope of both trains from which design requirements can be generated.

The above was accomplished and the results are shown in figures 1 through 4; figures 5 and 6 show the design points of the TSSG and TS Charging Heater, respectively.

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The system constraints used are:

TSSG

Maximum oil temperature	590°F
Maximum oil flow	110% design flow
Steam pressure	$400 {}^{+20}_{-0}$ psia
Steam temperature	$530 {}^{+20}_{-0}$ °F

TS CHARGING HEATER

Maximum oil temperature	590°F
Maximum oil flow	110% design flow
Maximum steam pressure	1500 psia
Steam temperature	$650 {}^{+30}_{-50}$ °F

Imposing the oil flow limit of 110% of design for the TSSG, as shown in figure 1, when coupled with the minimum outlet steam temperature of 530°F and maximum steam pressure of 420 psia, sets the minimum oil inlet temperature of 568°F. In other words, if the steam pressure is controlling at 420 psia, and the pump is operating at maximum flow, a minimum inlet oil temperature of 568°F is required to ensure a 530°F outlet oil temperature.

The maximum oil flow requirement of 110% of design limits the minimum operating steam pressure of the TS Charging Heater train to 1335 psia, as shown in figure 3. The operating envelope shown in figure 4 is bounded by the maximum and minimum steam pressures, outlet oil temperatures and inlet steam temperatures imposed on the TS Charging Heater train.

Note that the minimum oil inlet temperature (out of storage) of 568°F required for the TSSG is imposed on the TS Charging Heater as the minimum oil outlet temperature into storage.

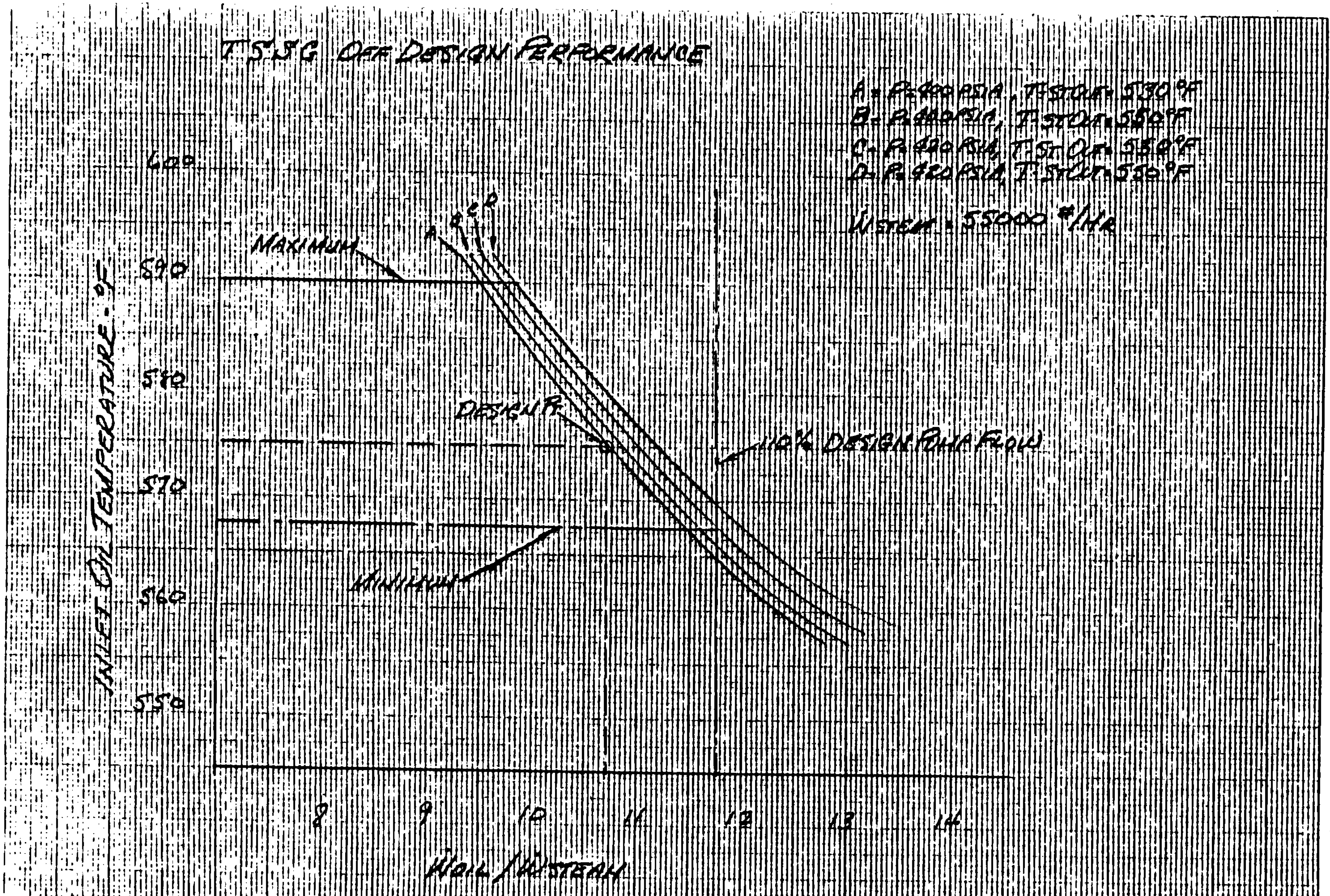
In summary, figures 1 and 2 describe the allowable operating range of the TSSG, and figures 3 and 4 show the same for the TS Charging Heater.

Figures 5 and 6 are schematics showing the design point performance of the TSSG and TS Charging Heater, respectively, and is included for information only.

For further information, contact the undersigned.

R. E. SNYDER

RES:ss
Attachments: (as noted)



TSSG OFF DESIGN PERFORMANCE

FIG. 1

ATTACHMENT to:
A3-255-EP-RES-543

ATTACHMENT to:
A3-255-EP-RES-543

T55G OFF DESIGN PERFORMANCE

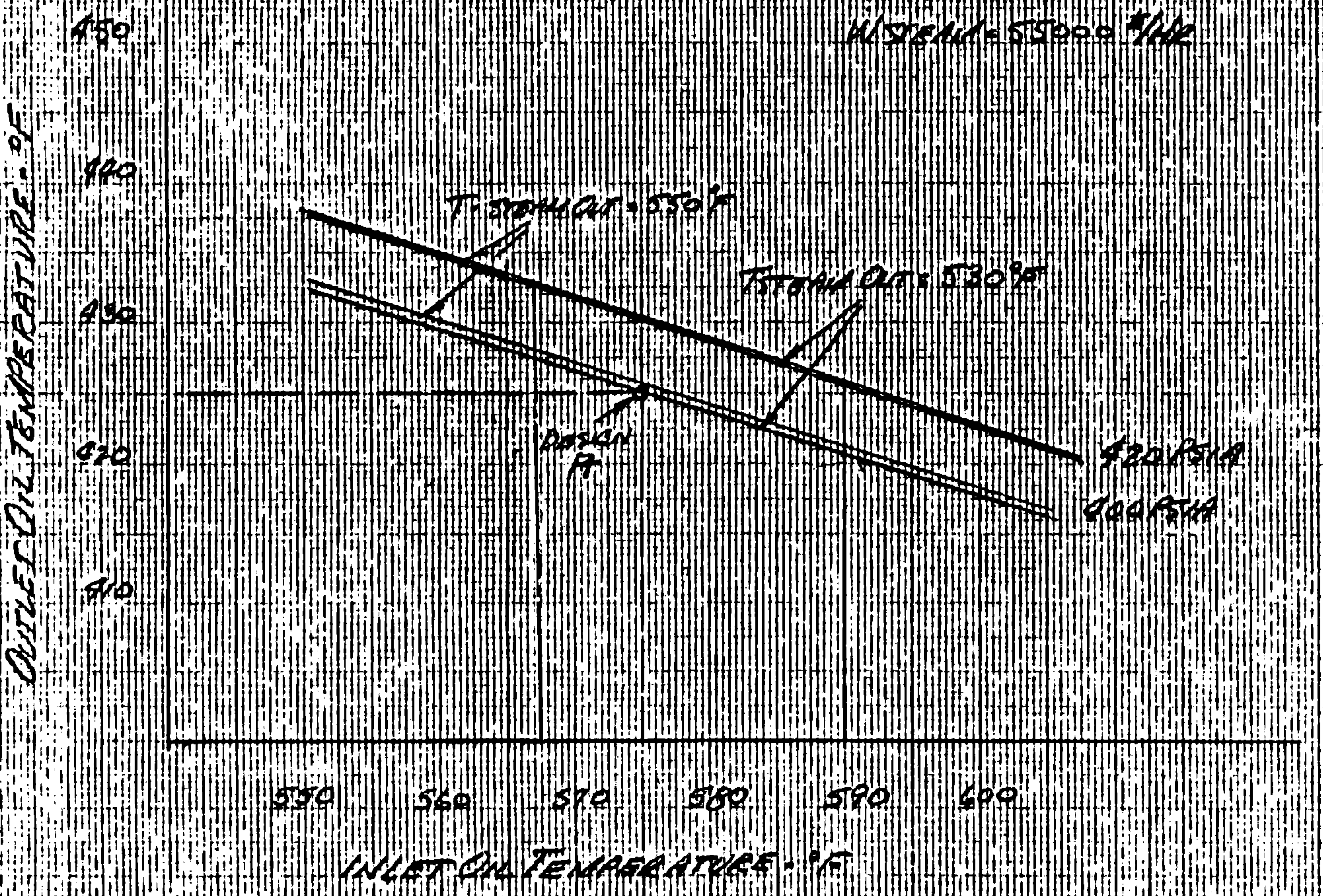


FIG 2

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T.S. CHARGING HEATER OFF DESIGN PERFORMANCE

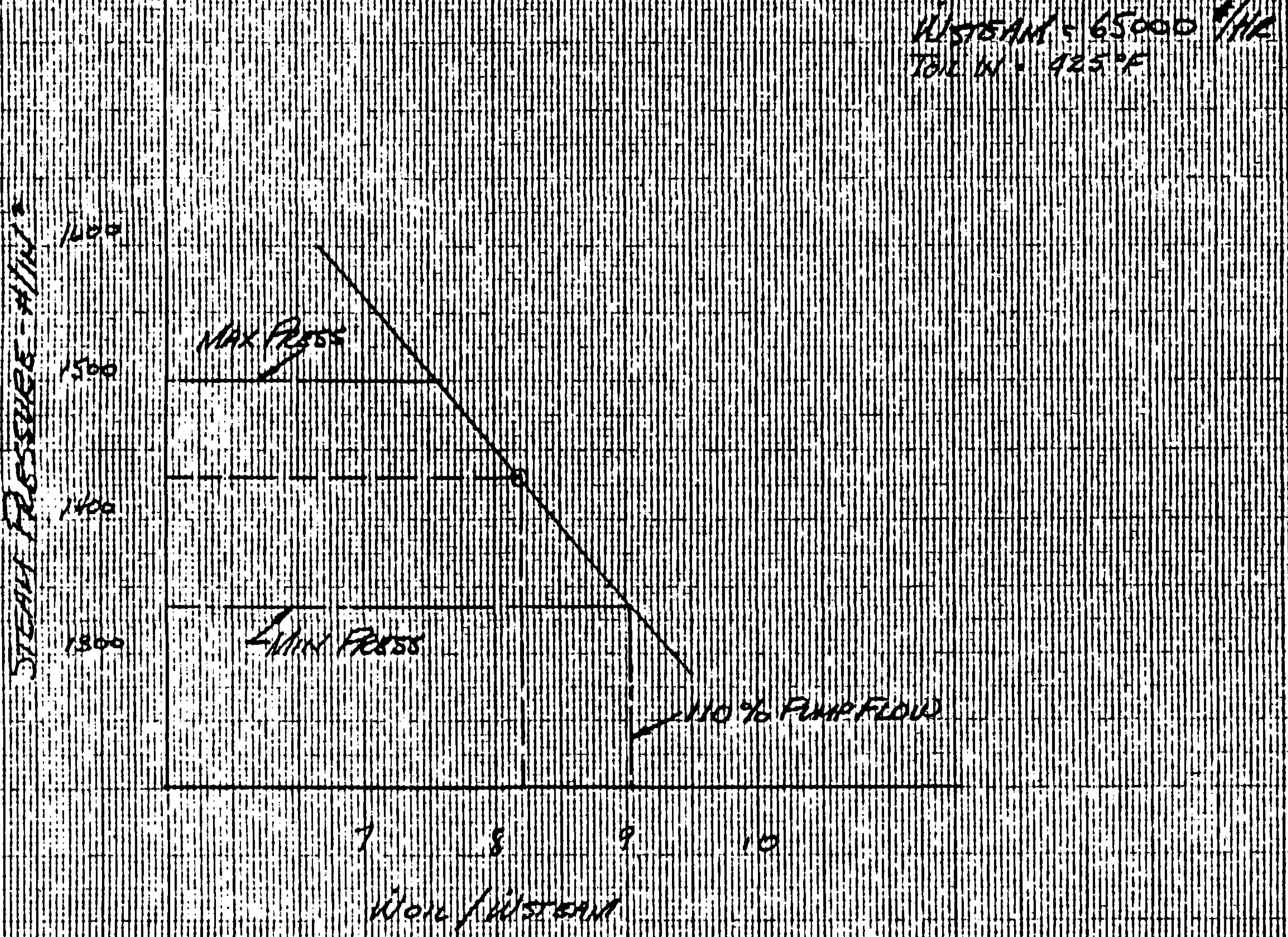

FIG 5

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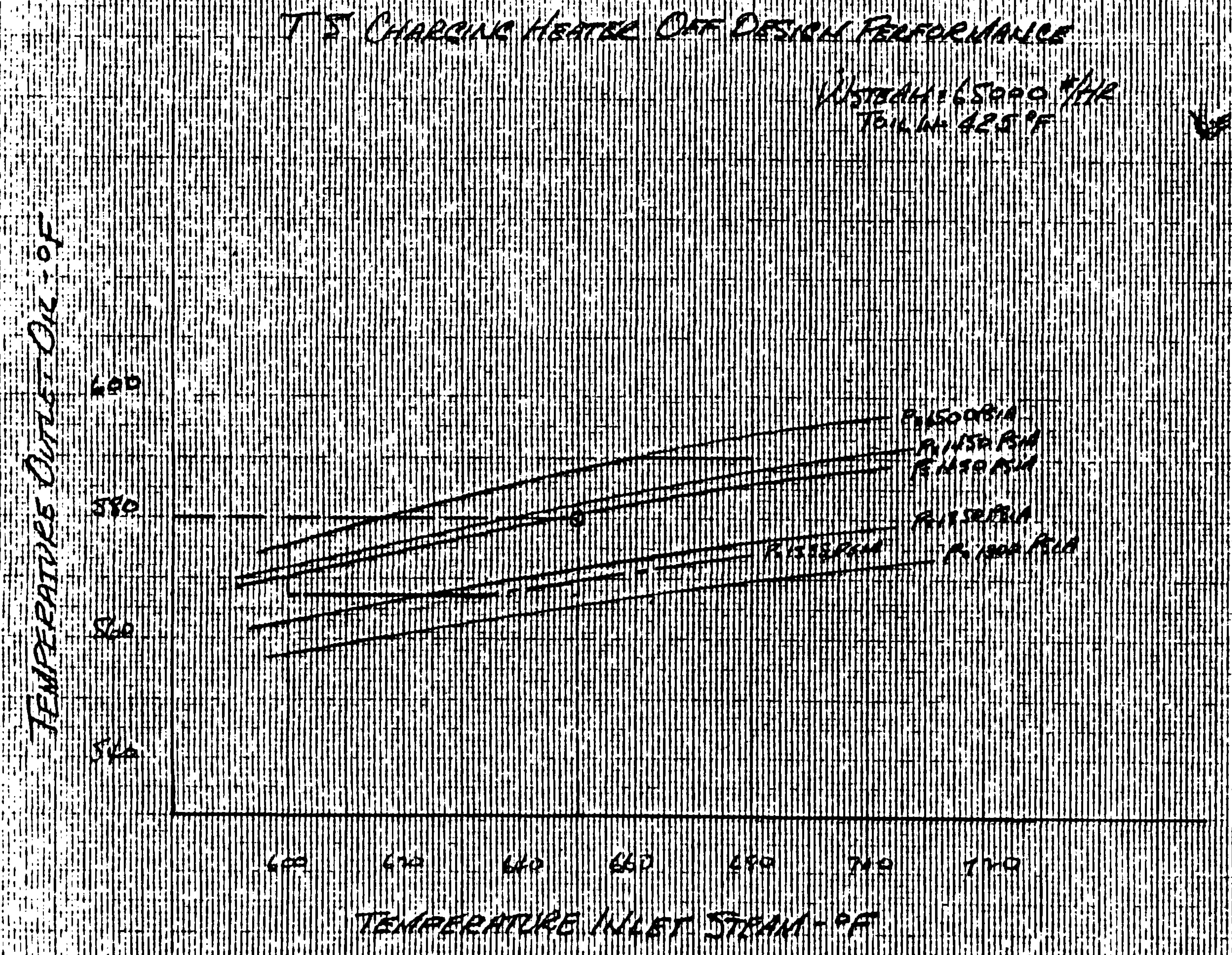
T S CHARGING HEATER OFF DESIGN PERFORMANCE
W STEAM = 65000 #/HR
T OIL IN = 425 °F
TEMPERATURE OUTLET OIL - °F
600
580
560
540
TEMPERATURE INLET STEAM - °F
620
640
660
680
700
720
740
P=1500 PSIA
P=1450 PSIA
P=1400 PSIA
P=1350 PSIA
P=1325 PSIA
P=1300 PSIA

FIG 4

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ATTACHMENT to:
A3-255-EP-RES-543

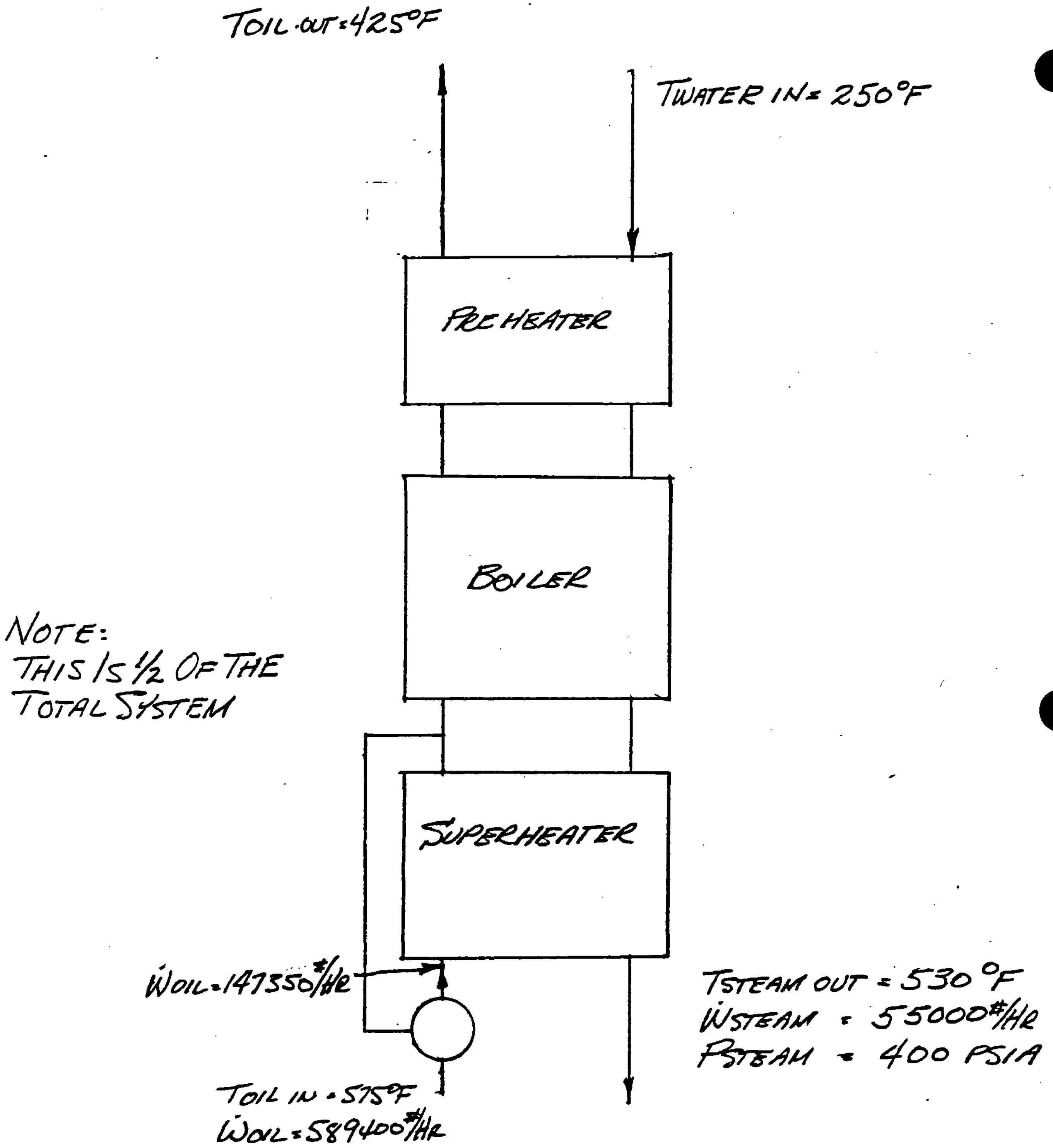
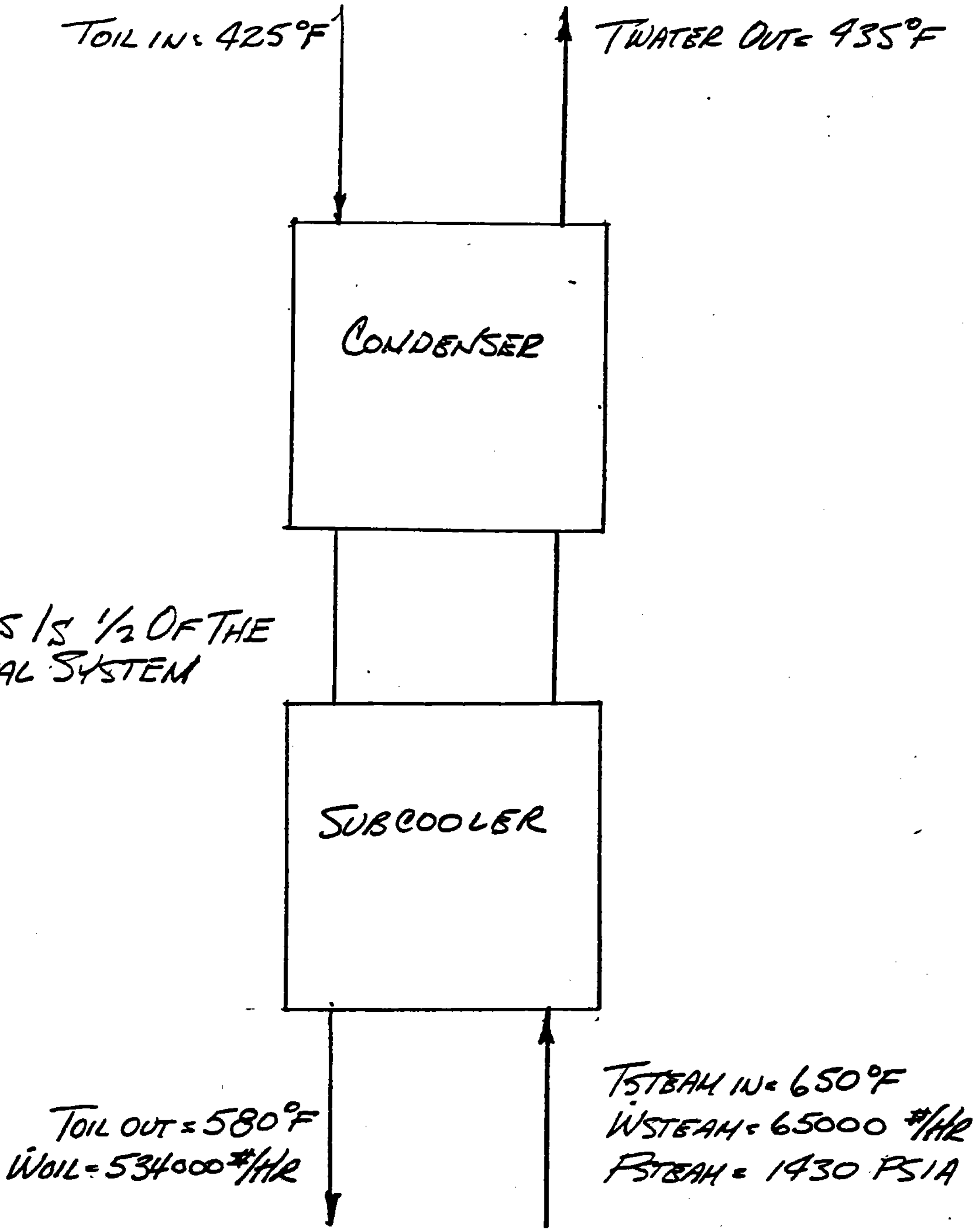


FIGURE 5 - TSSG DESIGN POINT PERFORMANCE



NOTE: THIS IS 1/2 OF THE TOTAL SYSTEM

FIGURE 6 - TS CHARGING HEATER DESIGN POINT PERFORMANCE

3/14/79
1 OF 9
JER

ALTERNATE THERMAL STORAGE DESIGNS

ASSUMPTIONS

- 28 MWHe EQUIVALENT CAPACITY
- SAME AUTOMATIC ADMISSION TURBINE AS USED WITH CALORIA STORAGE ⟶ MINOR CHANGE IN CONVERSION EFFICIENCY (ASSUME 13000 BTU/KWH GROSS
- HITEC STORAGE UTILIZES DUAL MEDIA THERMOCLINE DESIGN
- SODIUM STORAGE USES SEPARATE HOT AND COLD TANKS
- EACH APPROACH USES A LOW AND HIGH TEMP. LOOP
- ASSUME IDENTICAL THERMODYNAMIC DESIGN FOR BOTH ALTERNATE APPROACHES

SIZING DATA

28 MWHe NET = 31.2 MWHe GROSS
(4 HOUR OPERATION @ 0.8 MWe PARASITIC LOAD)

STORAGE ENERGY = (31200 KWH)(13000 BTU/KWH)
= 4.056×10^8 BTU

TANK #1 = 6.895×10^7 BTU
TANK #2 = 3.366×10^8 BTU

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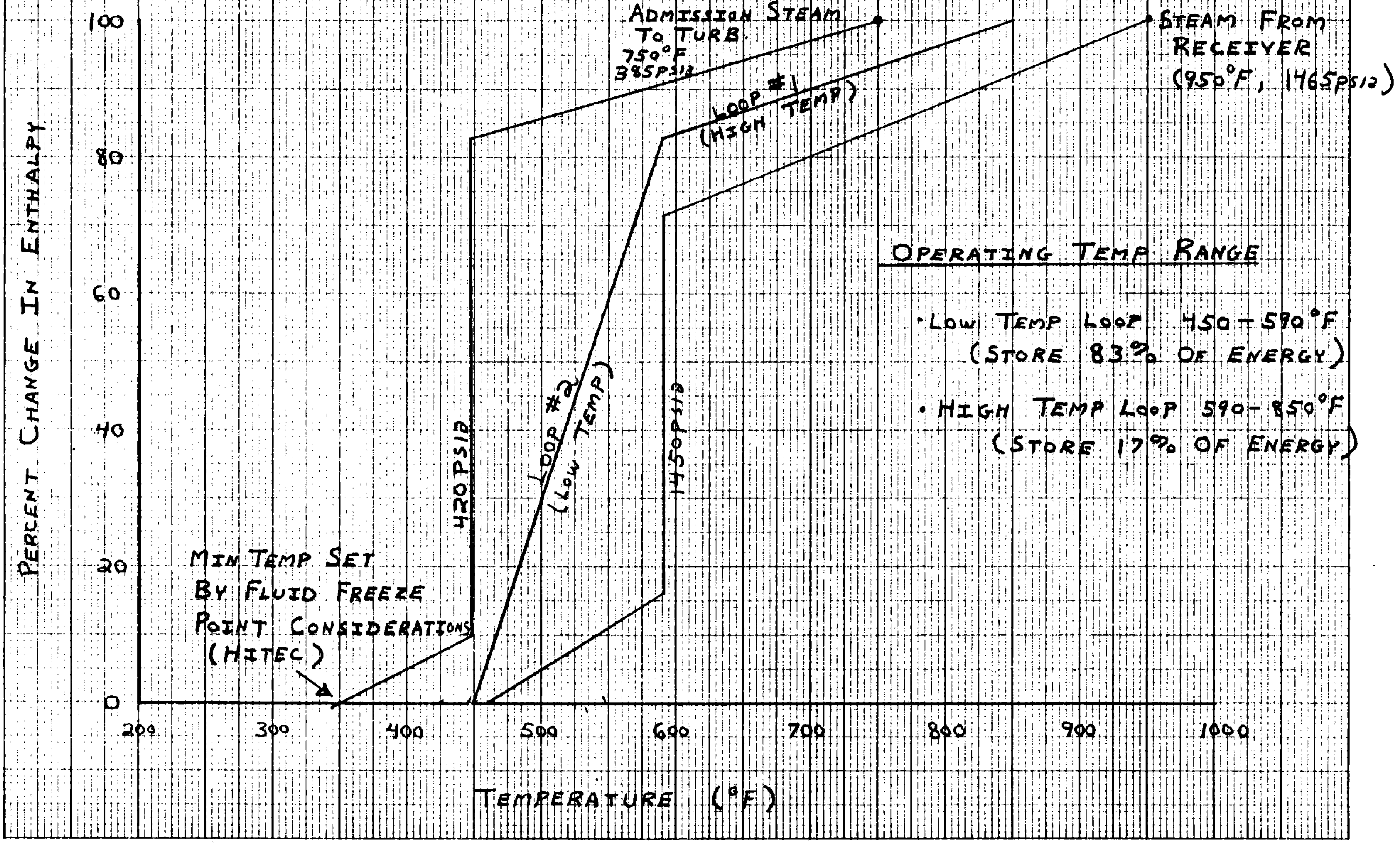
JER

ESTIMATED THERMODYNAMIC CHARACTERISTICS FOR

ADVANCED THERMAL STORAGE



OPERATING TEMP RANGE

- LOW TEMP LOOP 450 – 590°F (STORE 83% OF ENERGY)
- HIGH TEMP LOOP 590 – 850°F (STORE 17% OF ENERGY)

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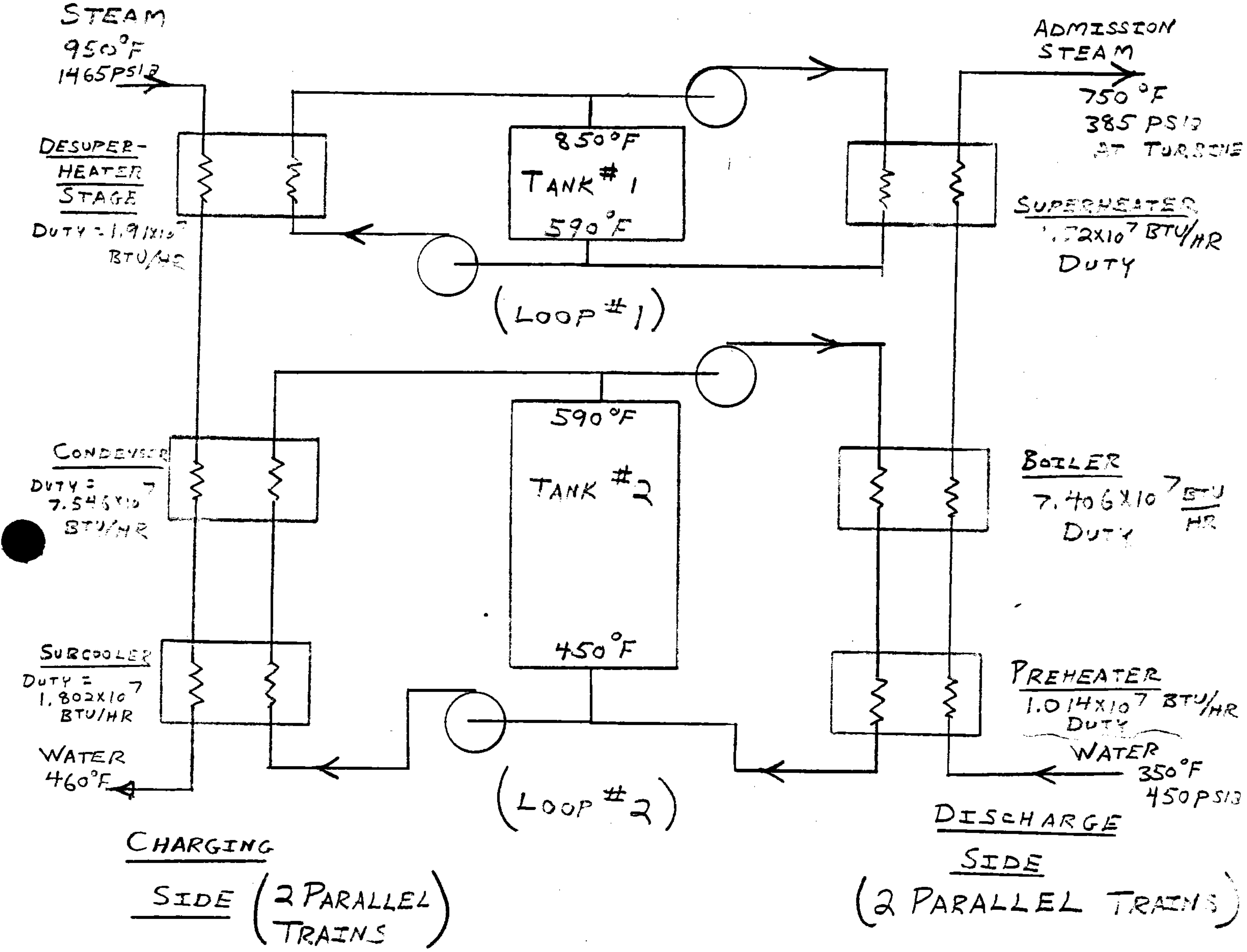
HITEC STORAGE CONCEPT
(DUAL MEDIA - HITEC/ROCK - THERMOCLINE)



HITEC / ROCK THERMAL CAPACITANCE $= 34.07\ \text{BTU}/\text{FT}^3\text{-}^\circ\text{F}$

TANK #1 $\quad \text{VOL} = \dfrac{Q}{c(\Delta T)} = \dfrac{6.895\times10^{7}\ \text{BTU}}{(34.07\ \text{BTU}/\text{FT}^3\text{-}^\circ\text{F})(260^\circ\text{F})} = 7784\ \text{FT}^3$

DIMENSIONS H = 44 FT
D = 15 FT

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JER

HITEC STORAGE CONCEPT

TANK # 2 $V = \frac{3.366 \times 10^8}{(34.07)(590-450)} = 70569 \text{ FT}^3$

DIMENSIONS	H = 44 FT
	D = 45 FT

HEAT EXCHANGER ESTIMATED DIMENSIONS (ROM)

CHARGING EQUIPMENT	(No UNITS)	(L)	(D)
DESUPERHEATER STAGE	2	25 FT	3.0 F
CONDENSER	2	32 FT	3.4 F
SUBCOOLER	2	25 FT	2.2 FT
DISCHARGING EQUIPMENT			
PREHEATER	2	15 FT	2.1 FT
BOILER	2	33 FT	5.2 FT
SUPERHEATER	2	24 FT	2.5 FT

3/14/79
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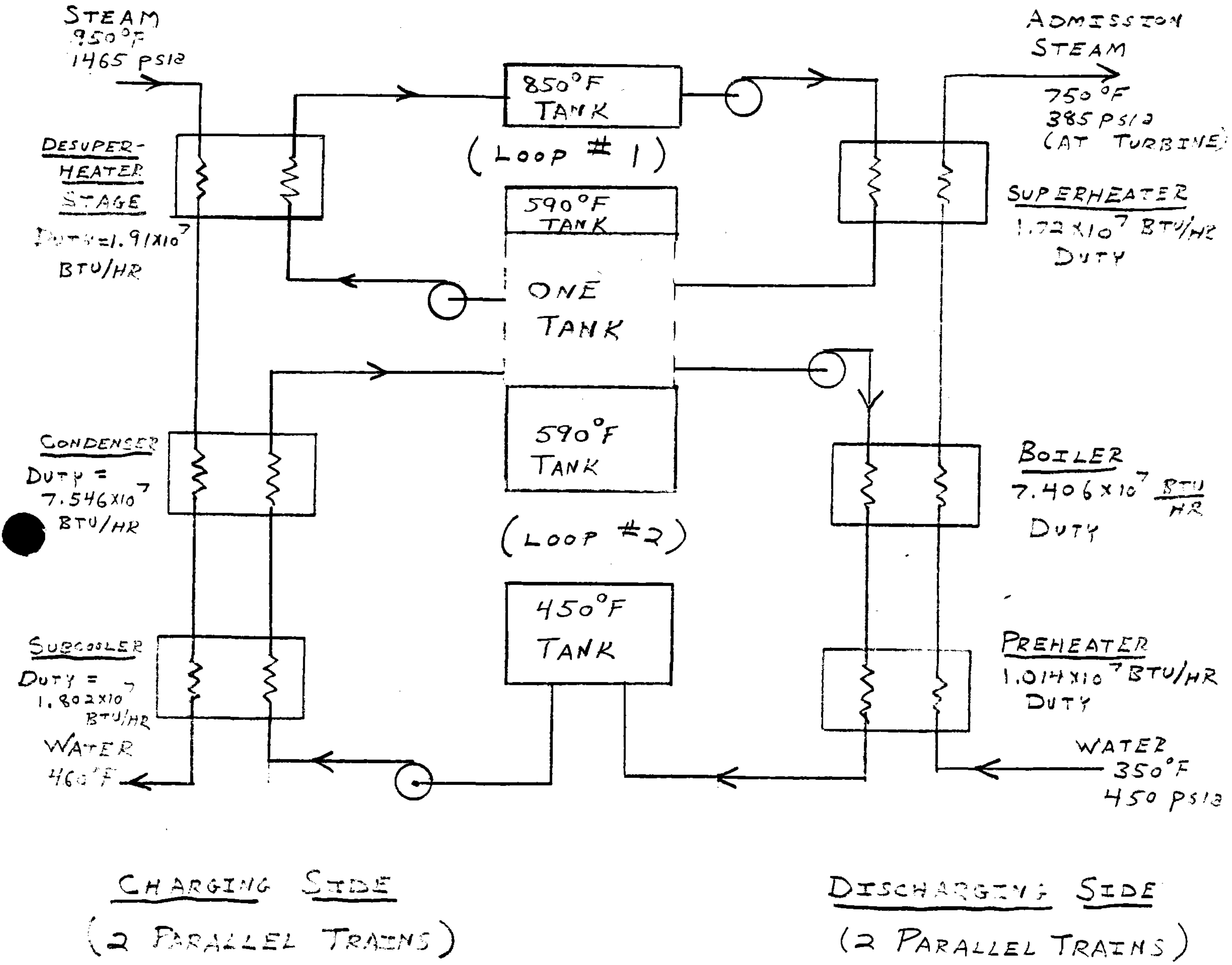
JER

SODIUM STORAGE CONCEPT
(SEPARATE HOT TANK - COLD TANK EACH LOOP)



SODIUM DATA

	$1/\rho$			Cp	
	(m^3/kg)	(ft^3/LB)	ρ	(KJ/kg-°C)	(BTU/LB °F)
850°F	1.194×10^{-3}	1.915×10^{-2}	52.2 lb/ft³	1.34	.321
590°F	1.145×10^{-3}	1.837×10^{-2}	54.4 lb/ft³	1.30	.311
450°F	1.114×10^{-3}	1.787×10^{-2}	55.96 lb/ft³	1.26	.302

Table 3-26. Thermodynamic Properties of Mercury*

Temp., K	Pressure, bars†	Specific volume, m³/kg		Enthalpy, kJ/kg		Entropy, kJ/kg · K	
		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
250	2.212.−8	7.325.−5	5.56.+6	39.81	347.49	0.3544	1.5943
260	6.926.−8	7.339.−5	1.80.+6	41.22	348.53	0.3597	1.5453
270	1.990.−7	7.352.−5	6.37.+5	42.63	349.57	0.3649	1.5028
280	4.956.−7	7.365.−5	2.44.+5	44.03	350.60	0.3699	1.4651
290	1.237.−6	7.378.−5	1.00.+5	45.43	351.64	0.3748	1.4309
300	2.903.−6	7.392.−5	4.38.+4	46.83	352.67	0.3795	1.3993
310	6.438.−6	7.405.−5	2.03.+4	48.22	353.71	0.3841	1.3698
320	1.357.−5	7.418.−5	9880	49.61	354.75	0.3885	1.3423
330	2.732.−5	7.432.−5	5030	50.99	355.78	0.3928	1.3165
340	5.516.−5	7.445.−5	2679	52.38	356.82	0.3969	1.2925
350	1.022.−4	7.459.−5	1480	53.75	357.86	0.4009	1.2699
360	1.829.−4	7.472.−5	847	55.13	358.89	0.4048	1.2487
370	3.169.−4	7.486.−5	500	56.50	359.93	0.4085	1.2287
380	5.334.−4	7.499.−5	304	57.87	360.96	0.4122	1.2099
390	8.733.−4	7.513.−5	185	59.24	362.00	0.4157	1.1921
400	1.394.−3	7.526.−5	120	60.61	363.04	0.4192	1.1754
450	1.053.−2	7.595.−5	18.0	67.41	368.21	0.4354	1.1037
500	5.261.−2	7.664.−5	3.98	74.19	373.38	0.4495	1.0479
550	0.1917	7.735.−5	1.18	80.95	378.53	0.4624	1.0035
600	0.5695	7.807.−5	0.432	87.72	383.64	0.4741	0.9698
650	1.6836	7.881.−5	0.187	94.51	388.68	0.4850	0.9376
700	3.1527	7.957.−5	0.092	101.34	392.62	0.4949	0.9127
750	6.197	8.036.−5	0.049	108.24	398.41	0.5046	0.8915
800	11.18	8.118.−5	0.029	115.23	403.04	0.5136	0.8733
850	18.82	8.203.−5	0.018	122.31	407.44	0.5221	0.8576
900	29.88	8.292.−5	0.012	129.53	411.61	0.5302	0.8437
950	45.23	8.385.−5	0.008	136.89	415.49	0.5381	0.8313
1000	65.74	8.482.−5	0.006	144.42	419.08	0.5456	0.8203

* The notation 5.293.−7; 2.44.+5; etc. signifies 5.293×10^{-7}; $2.44. \times 10^{5}$; etc.

† To convert to pascals (newtons per square meter) multiply by 10^{5}.

Table 3-27. Thermodynamic Properties of Sodium*

DATA USED

Temp., K	Pressure, bars†	Specific volume, m³/kg		Enthalpy, kJ/kg		Entropy, kJ/kg · K	
		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
380	2.631.−10	1.081.−3	5.222.+9	500	5003	2.853	14.703
400	1.385.−9	1.086.−3	1.044.+9	527	5020	2.924	14.156
450	4.594.−8	1.100.−3	3.537.+7	595	5062	3.084	13.010
500	7.523.−7	1.114.−3	2.395.+6	662	5101	3.225	12.102
550	7.377.−6	1.129.−3	2.679.+5	728	5137	3.351	11.366
600	4.926.−5	1.145.−3	4.359.+4	793	5168	3.464	10.756
650	2.448.−4	1.160.−3	9452	858	5196	3.567	10.242
700	9.649.−4	1.177.−3	2566	922	5220	3.662	9.803
750	3.160.−3	1.194.−3	833.2	985	5241	3.749	9.424
800	8.904.−3	1.211.−3	312.8	1048	5260	3.831	9.095
850	2.217.−2	1.229.−3	132.3	1111	5277	3.907	8.808
900	4.980.−2	1.247.−3	61.78	1174	5292	3.979	8.555
950	0.1025	1.271.−3	31.36	1237	5307	4.046	8.331
1000	0.1963	1.286.−3	17.08	1299	5322	4.111	8.134
1100	0.6002	1.327.−3	6.023	1426	5352	4.231	7.801
1200	1.5037	1.372.−3	2.572	1554	5386	4.343	7.536
1300	3.2454	1.419.−3	1.264	1685	5420	4.448	7.321
1400	6.2538	1.469.−3	0.691	1820	5453	4.548	7.142
1500	11.014	1.523.−3	0.409	1959	5481	4.644	6.991
1600	18.02	1.581.−3	0.259	2104	5504	4.737	6.862
1700	27.78	1.643.−3	0.171	2255	5524	4.828	6.751
1800	40.91	1.713.−3	0.118	2410	5540	4.916	6.654
1900	57.97	1.792.−3	8.35.−2	2570	5552	5.000	6.570
2000	79.49	1.884.−3	6.09.−2	2734	5558	5.083	6.495
2100	106.0	1.993.−3	4.54.−2	2905	5558	5.164	6.427
2200	137.9	2.123.−3	3.44.−2	3085	5550	5.244	6.365
2300	175.6	2.285.−3	2.64.−2	3275	5531	5.325	6.306
2400	219.5	2.493.−3	2.04.−2	3480	5497	5.407	6.248
2500	269.8	2.781.−3	1.57.−2	3708	5441	5.495	6.188
2600	327.0	3.230.−3	1.19.−2	3977	5342	5.594	6.119
2700	390.9	4.201.−3	8.33.−3	4369	5122	5.733	6.012
2733‡	413.6	5.501.−3	5.50.−3	4773	4773		

Reproduced and converted from A. Padilla, Argonne National Laboratory Report ANL8095. 1974 and private communication, August 1974.

* The notation 2.631.−10, 5.222.+9, etc. signifies 2.631×10^{-10}, $5,222 \times 10^{9}$ etc.

† To convert to pascals (newtons per square meter) multiply by 10^{5}.

‡ Critical temperature.

850°F = 454°C = 727°K

590°F = 310°C = 583°K

450°F = 232°C = 505°K

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REVISED 3/29/7

SODIUM STORAGE CONCEPT

LOOP #1 TOTAL STORAGE CAPACITY

6.895×10^7 BTU (FROM HITEC DESIGN)

$$m = \frac{Q}{c_p \Delta T} = \frac{6.895 \times 10^7}{(.321)(260°F)} = 8.261 \times 10^5 \text{ LB}$$

VOL @ 850°F $= 1.583 \times 10^4 \text{ FT}^3$

850°F TANK DIMENSIONS
H = 27.2 FT
D = 27.2 FT

LOOP #2 STORAGE CAPACITY

3.366×10^8 BTU (FROM HITEC DESIGN)

$$m = \frac{Q}{c_p \Delta T} = \frac{3.366 \times 10^8}{(.302)(140°F)} = 7.961 \times 10^6 \text{ LB}$$

VOL @ 450°F $= 1.423 \times 10^5 \text{ FT}^3$

450°F TANK DIMENSIONS
H = 56.5 FT
D = 56.5 FT

590°F TANK

$m = 8.261 \times 10^5 + 7.961 \times 10^6 \text{ LB} = 8.787 \times 10^6 \text{ LB}$

$V = 1.615 \times 10^5 \text{ FT}^3$

590°F TANK DIMENSIONS H = D = 59 FT

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Sodium Storage Concept

Heat Exchanger Estimated Dimensions (Rom)

(Use Same Quantity And Dimensional Information As Specified For Hitec Exchangers)

Note: It Is Conceptually Possible To Use The Same Heat Exchangers For Both The Hitec And Sodium Thermal Storage Approaches. This Would Depend On Materials, Fab Techniques, Design Codes, Ability To Carry Inerts To Prevent Fluid Contamination Etc. This Would Reduce The Cost Of Implementing The Second Advanced Design Concept Once The First Concept Had Been Completely Investigated.

HITEC/ROCK + CALORIA/ROCK SYSTEM

ASSUME: HITEC/ROCK TANK HAS 30% THERMAL ENERGY CAPACITY AS CALORIA/ROCK TANK

HITEC/ROCK TANK STORED ENERGY

$$= (.3) \times (4.056 \times 10^8 \text{ BTU}) = 1.217 \times 10^8 \text{ BTU}$$

$$\Delta T = 850 - 525 \text{ °F} = 325 \text{ °F}$$

$$VOL = \frac{Q}{C(\Delta T)} = \frac{1.217 \times 10^8}{(34.07)(325)} = 11000 \text{ FT}^3$$

$$H = 40 \text{ FT}$$

$$D = \sqrt{\frac{4(11000)}{\pi(40)}} \cong 19 \text{ FT}$$

SODIUM + CALORIA/ROCK SYSTEM

ASSUME: SODIUM TANK(S) HAVE 30% THERMAL ENERGY CAPACITY OF CALORIA/ROCK TANK

SODIUM TANK STORED ENERGY = 1.217×10^8 BTU

$$\Delta T = 325 \text{ °F}$$

$$\frac{M}{\cancel{VOL}} = \frac{Q}{c_p \Delta T} = \frac{1.217 \times 10^8}{(.315)(325)} = 1.19 \times 10^6 \ \cancel{\text{FT}^3} \text{ LB}$$

$$\rho = 52.2 \text{ LB/FT}^3$$

$$VOL = \frac{1.19 \times 10^6 \text{ LB}}{52.2 \text{ LB/FT}^3} = 22800 \text{ FT}^3$$

$$H = 44 \text{ FT}$$

$$D = \sqrt{\frac{4(22800)}{\pi(44)}} = 25.7 \text{ FT}$$ EACH (HOT & COLD)

NOTE: 30% IS CONSERVATIVE — 18% IS PROBABLY BETTER NUMBER.

ANALYSIS OF PLANT COST REDUCTION OPTIONS

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1 OF 15

IMPACT OF REDUCING THE COLLECTOR FIELD SIZE

OBJECTIVE:

DETERMINE THE IMPACT ON PLANT RATING AND OVERALL ENERGY OUTPUT OF REDUCING THE BASELINE HELIOSTAT FIELD BY INCREMENTS OF 100 HELIOSTATS UP TO A TOTAL REDUCTION OF 500 HELIOSTATS.

DEFINE THE NUMBER OF "BASELINE" MARTIN AND MDAC HELIOSTATS AND THE CORRESPONDING NUMBER OF "LARGE" MARTIN AND MDAC HELIOSTATS REQUIRED FOR THE FOLLOWING SIZING CONDITIONS:

(i) 10 MWe – FOUR HOURS ON WINTER DAY

(ii) 10 MWe – NOON ON WINTER DAY

(iii) 10 MWe – NOON ON SUMMER DAY

(iv) ~ 8 MWe – WINTER NOON

(v) ~ 8 MWe – SUMMER NOON

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IMPACT OF REVISED SIZING ASSUMPTIONS

	(JULY 30TH DESIGN)	(REVISED DATA)
DESIGN POINT	WINTER 2 PM	WINTER 2 PM
DESIGN POINT ELECT. POWER (10MWe NET)	11.8 MWe (1.8 MWe PARASITIC)	11.7 MWe (1.7 MW PARA
ABSORBED THERMAL POWER	34.4 MWt	34.1 MWt
RECEIVER LOSSES	4.7 MWt	4.7 MWt
AVE REC ABSORPTANCE	(0.93)	(0.95)
REC INCID POWER	42.04 MWt	40.84 MWt
REC INTERCEPT. FACTOR	(0.976)	(0.976)
ATM. ATTENUATION	(0.978)	(0.978)
FIELD COSINE	(0.792)	(0.792)
BLOCK + SHADOWING	(0.898)	(0.898)
AVE HELIO. REFLECT.	(0.86)	(0.89)
IDEAL POWER REQUIREMENT	72.0 MWt	67.6 MW
DIRECT INSOLATION	917 W/m^2	917 W/m^2
REQUIRED GLASS AREA	844,923 ft	793222 ft^2
No STMPO HELIOSTATS	1878	1762

REVISED DATA (B+S ADJUST) BASELINE HELIOSTATS

MARTIN: $1762 \left(\frac{.898}{.911}\right)\left(\frac{450}{430}\right) = 1818$ HELIOSTATS

MDAC: $1762 \left(\frac{.898}{.887}\right)\left(\frac{450}{479}\right) = 1676$ HELIOSTATS

BIG MDAC: $1762 \left(\frac{.898}{.877}\right)\left(\frac{450}{514}\right) = 1580$ HELIOSTATS

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IMPACT OF REVISED SIZI ASSUMPTIONS

(WINTER) TIME	REF INC. PWR MWt	1818 HELIO		1718 HELIO		1618 HELIO		1518 HELIO		1418 HELIO	
		INCID MWt	ABSORB MWt	INCID MWt	ABSORB MWt	INCID MWt	ABSORB MWt	INCID MWt	ABSORB MWt	INCID MWt	ABSORB MWt
NOON	48.482	46.30	39.28	43.75	36.86	41.21	34.45	38.66	32.03 (9.29 MWe)	36.11	29.60 (8.46 MWe)
.64	48.016	45.85	38.86	43.33	36.46	40.81	34.07	38.29	31.67	35.76	29.27
1.28	46.547	44.45	37.53	42.00	35.20	39.56	32.89	37.12	30.56	34.67	28.23
1.92	43.447	41.49	34.72	39.20	32.55	36.93	30.38	34.64	28.21	32.36	26.04
2.00	42.765	40.84	34.10	38.59	31.96	36.35	29.83	34.10	27.70	31.85	25.56
2.56	37.921	36.21	29.70	34.22	27.81	32.23	25.92	30.24	24.03	28.24	22.13
3.20	30.154	28.80	22.66	27.21	21.15	25.63	19.65	24.04	18.14	22.46	16.63
3.85	19.765	18.88	13.23	17.84	12.24	16.80	11.26	15.76	10.27	14.72	9.28
-.64	47.916	45.76	38.77	43.24	36.38	40.73	33.99	38.21	31.60	35.69	29.20
-1.28	46.547	44.45	37.53	42.00	35.20	39.56	32.89	37.12	30.56	34.67	28.23
-1.92	43.494	41.54	34.76	39.25	32.59	36.97	30.42	34.68	28.25	32.39	26.07
-2.56	38.399	36.67	30.14	34.65	28.22	32.64	26.31	30.62	24.39	28.60	22.47
-3.20	30.534	29.16	23.00	27.55	21.48	25.95	19.96	24.35	18.43	22.74	16.90
-3.85	21.715	20.74	15.00	19.60	13.92	18.46	12.83	17.32	11.75	16.17	10.66

$$P_{ABS} = P_{INC} * .95 - 4.7$$

[illegible]

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(WINTER)	1318 HELIOSTATS INCID MWt	ABSORB MWt
NOON	33.57	27.19 (7.63) ([illegible])
.64	33.24	26.88
1.28	32.23	25.91
1.92	30.08	23.88
2.00	29.61	23.43
2.56	26.25	20.24
3.20	20.88	15.13
3.85	13.68	8.30
-.64	33.17	26.82
-1.28	32.23	25.91
-1.92	30.11	23.90
-2.56	26.59	20.56
-3.20	21.14	15.38
-3.85	15.03	9.58

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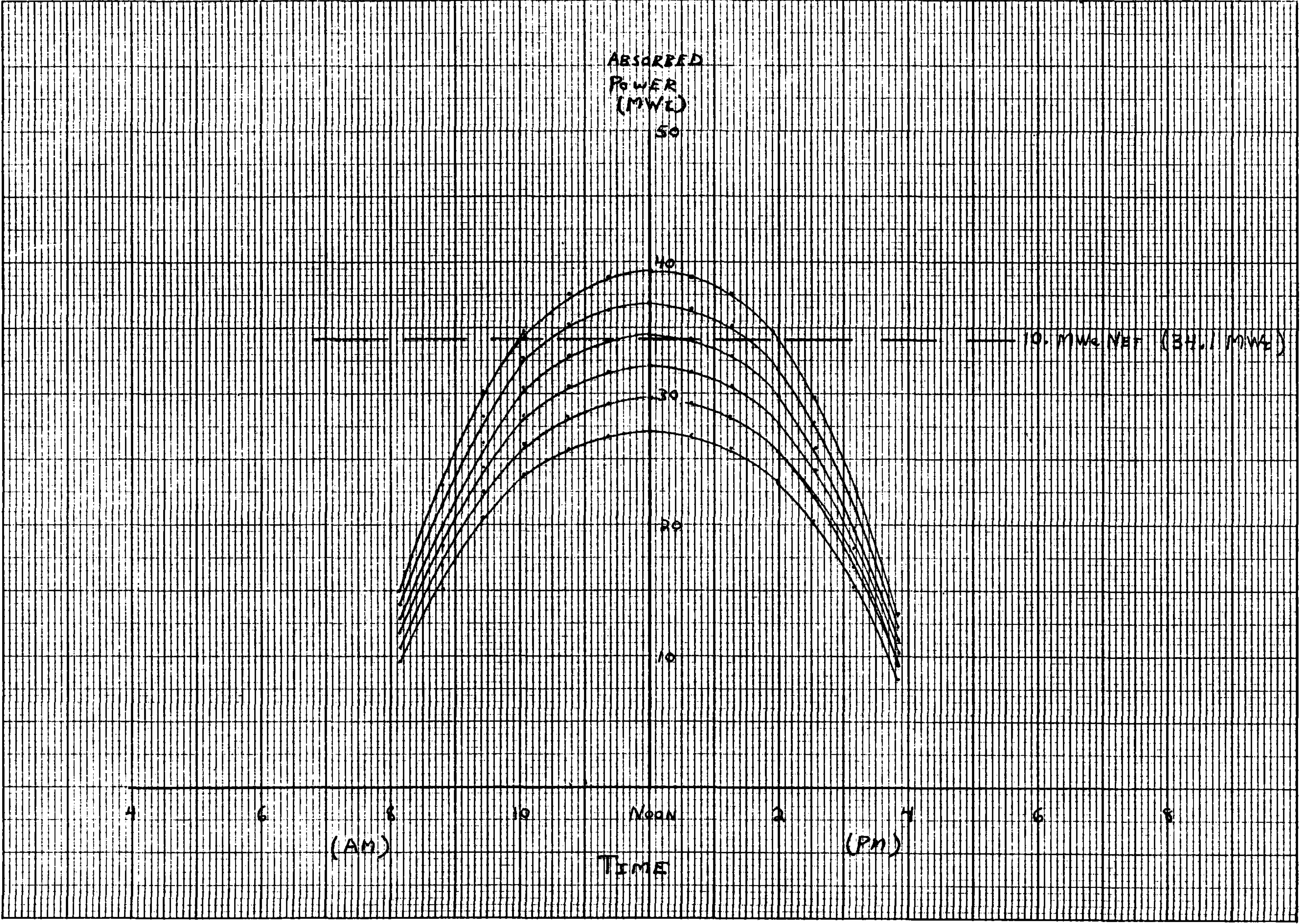
IMPACT OF REVISED SIZING ASSUMPTIONS (WINTER)



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IMPACT OF REVISED SIZING ASSUMPTIONS

(INTEGRATION OF WINTER CURVE)

	TIME INCREMENT	1818 HELIO	1718 HELIO	1618 HELIO	1518 HELIO	1418 HELIO	1318 HELIO
	.85	20.5	19.0	17.2	16.1	15.0	13.8
(AM)	1	30.5	28.2	26.0	24.5	22.7	20.7
	1	36.4	34.4	32.0	29.5	27.4	25.0
	1	39.0	36.5	34.0	31.7	29.4	27.0
	1	39.0	36.4	34.0	31.8	29.5	26.8
(PM)	1	36.8	34.0	32.0	29.8	27.5	25.0
	1	30.0	28.0	26.0	24.3	22.5	20.3
	.85	19.5	18.0	16.5	16.0	14.7	13.0
		245.7 MWH_t	229 MWH_t	212.6 MWH_t	198.9 MWH_t	184 MWH_t	168 MWH_t

FROM WILLIAMSON SCALING DATA: (9/22/79)

$\int$ SUMMER ENERGY = 431.8 MWH_t

$\int$ WINTER ENERGY = 248.4 MWH_t

$\int$ EQUINOX ENERGY = 372.4 MWH_t → 86.2 % SUMMER

EQUINOX	366.1 MWH_t	342.8 MWH_t	320.6 MWH_t	297.5 MWH_t	274.8 MWH_t	260.5 MWH_t

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IMPACT OF REVISED SIZING ASSUMPTIONS

SUMMER

TIME	REF INC PWR MWt	1818 HELIO INCID MWt	1818 HELIO ABSORB MWt	1718 HELIO INCID MWt	1718 HELIO ABSORB MWt	1618 HELIO INCID MWt	1618 HELIO ABSORB MWt	1518 HELIO INCID MWt	1518 HELIO ABSORB MWt
-6.28	16.588	15.84	10.15	14.97	9.32	14.10	8.49	13.23	7.67
-5.23	31.482	30.06	23.66	28.41	22.09	26.76	20.52	25.10	18.95
-4.18	41.260	39.40	32.53	37.23	30.47	35.07	28.42	32.90	26.35
-3.14	45.774	43.71	36.63	41.31	34.34	38.91	32.06	36.50	29.77
-2.09	49.858	47.61	40.33	44.99	37.84	42.38	35.36	39.76	32.86
-1.05	51.116	48.82	41.47	46.12	38.92	43.45	36.38	40.76	33.82
NOON	51.411	49.10	41.74	46.39	39.17	43.70	36.61	40.99	34.04
1.05	50.973	48.68	41.34	45.99	38.80	43.32	36.26	40.64	33.71
2.09	48.887	46.69	39.45	44.11	37.01	41.55	34.58	38.98	32.13
3.14	46.399	44.31	37.19	41.87	34.88	39.44	32.57	36.99	30.25
4.18	41.857	39.97	33.07	37.77	30.98	35.58	28.90	33.37	26.81
5.23	32.141	30.69	24.26	29.00	22.65	27.32	21.05	25.63	19.45
6.28	15.381	14.69	9.05	13.88	8.29	13.07	7.52	12.26	6.75

ABS = INC * .95 - 4.9

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SUMMER TIME	1418 HELIO		1318 HELIO	
	INCID MWt	ABSORB MWt	INCID MWt	ABSORB MWt
-6.28	12.35	6.84	11.48	6.01
-5.23	23.45	17.37	21.79	15.81
-4.18	30.73	24.29	28.57	22.24
-3.14	34.09	27.49	31.69	25.21
-2.09	37.13	30.38	34.52	27.89
-1.05	38.07	31.27	35.39	28.72
NOON	38.29	31.47 (9.10MW)	35.59	28.91 (8.23MW)
1.05	37.96	31.16	35.29	28.63
2.09	36.41	29.69	33.85	27.25
3.14	34.56	27.93	32.12	25.62
4.18	31.17	24.72	28.98	22.63
5.23	23.94	17.84	22.25	16.24
6.28	11.46	5.98	10.65	5.22

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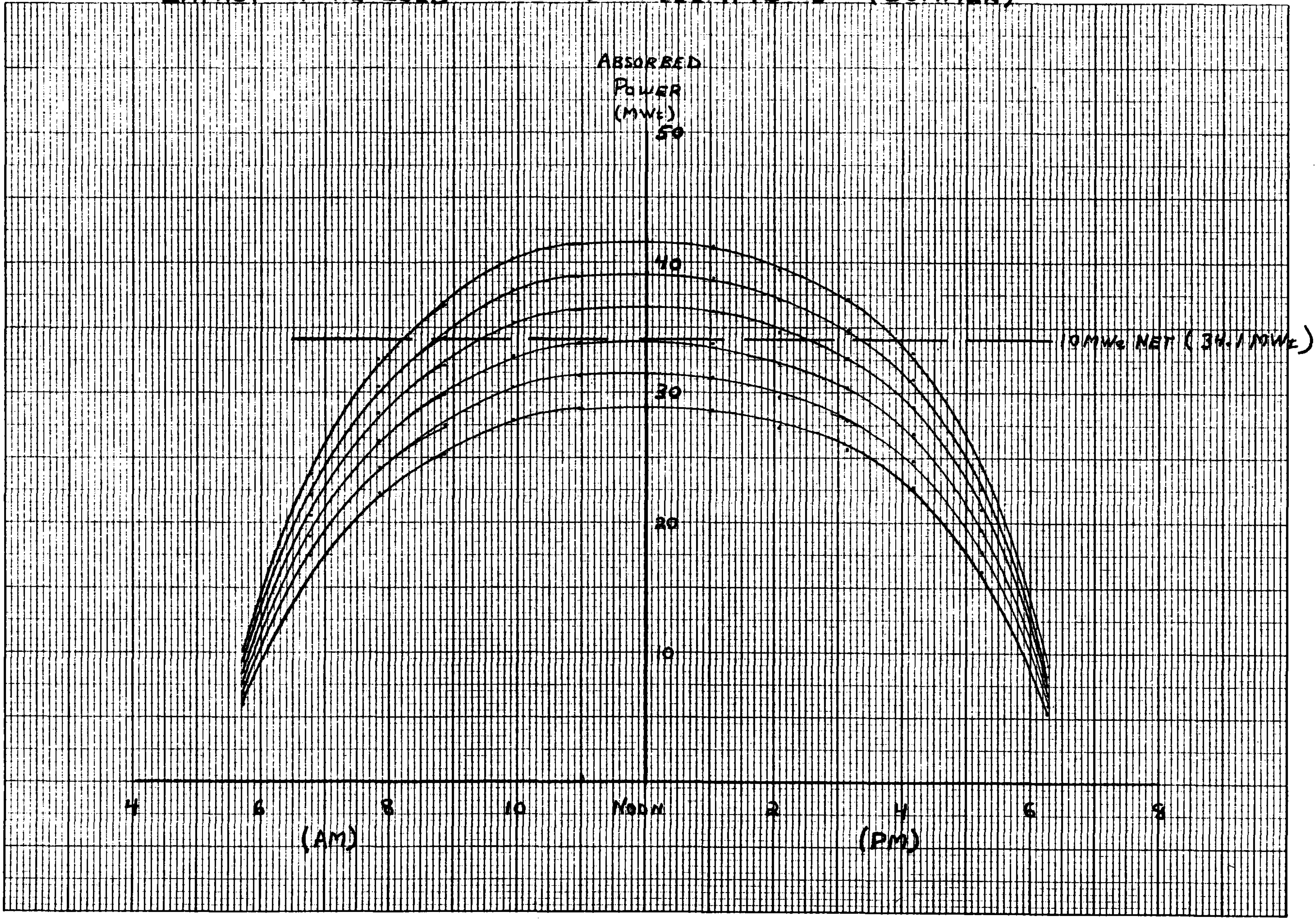
IMPACT OF REVISED SIZING ASSUMPTIONS (SUMMER)



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IMPACT OF REVISED SIZING ASSUMPTIONS
(INTEGRATION OF SUMMER CURVES)

	TIME INCREMENT	1818 HELIO	1718 HELIO	1618 HELIO	1518 HELIO	1418 HELIO	1318 HELIO
↑	.28 HR	12.5	11.5	10.5	9.5	9.0	8.0
	1	21.0	19.7	18.5	17.0	15.8	14.0
	1	30.2	28.1	26.2	24.2	22.5	20.3
	1	35.5	33.2	31.0	28.8	26.7	24.5
AM	1	39.2	36.8	34.3	32.8	29.5	27.0
	1	41.1	38.8	36.2	33.5	31.2	28.5
↓	1	41.5	39.0	36.5	34.0	31.5	28.9
↑	1	41.5	39.0	36.5	33.8	31.3	28.8
	1	40.6	38.2	35.8	33.0	30.5	28.3
	1	38.8	36.4	34.0	31.6	29.5	27.1
PM	1	36.0	33.5	31.5	29.3	27.0	25.0
	1	30.8	28.7	26.8	24.7	22.7	20.7
	1	21.6	19.8	18.5	17.0	15.5	13.8
↓	.28 HRS	11.5	11.0	10.5	9.3	8.5	7.2
		424.5 MWHt	397.5 MWHt	371.7 MWHt	344.9 MWHt	318.6 MWHt	302.1 MWH

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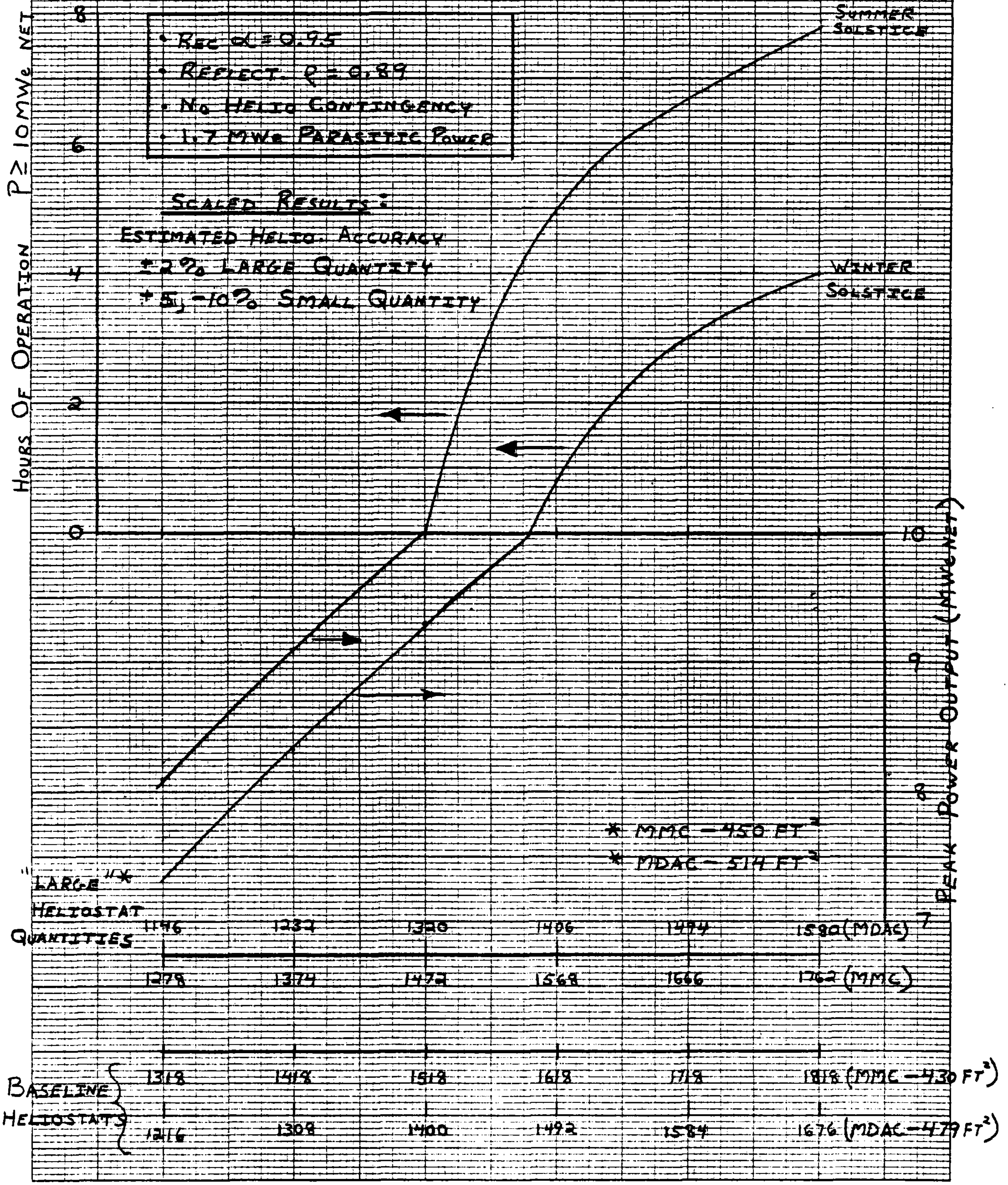
IMPACT OF REVISED SIZING ASSUMPTIONS ON HELIOSTAT REQUIREMENTS AND PLANT RATING



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SUMMARY OF PLOTTED DATA

No HELIOSTATS				SUMMER		WINTER	
MMC	MDAC	MMC'	MDAC'	HOURS @ 10MW	MAX PWR	HOURS @ 10MW	MAX PWR
1818	1676	1762	1580	7.8		4	
1718	1584	1666	1494	6.6		3	
1618	1492	1568	1406	5.0		0.8	
1518	1400	1472	1320	0	10		9.29
1418	1308	1374	1232		9.1		8.46
1318	1216	1278	1146		8.23		7.63

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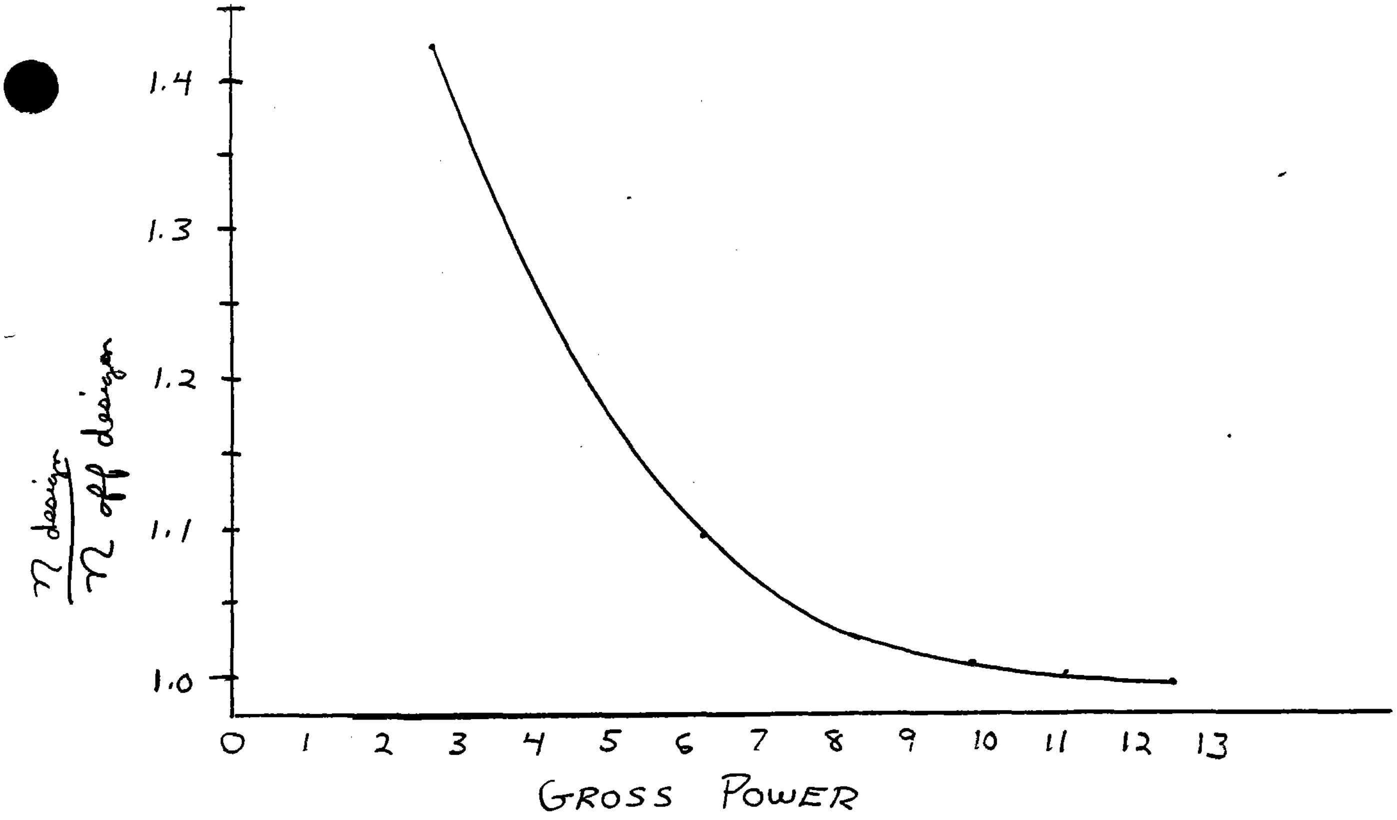
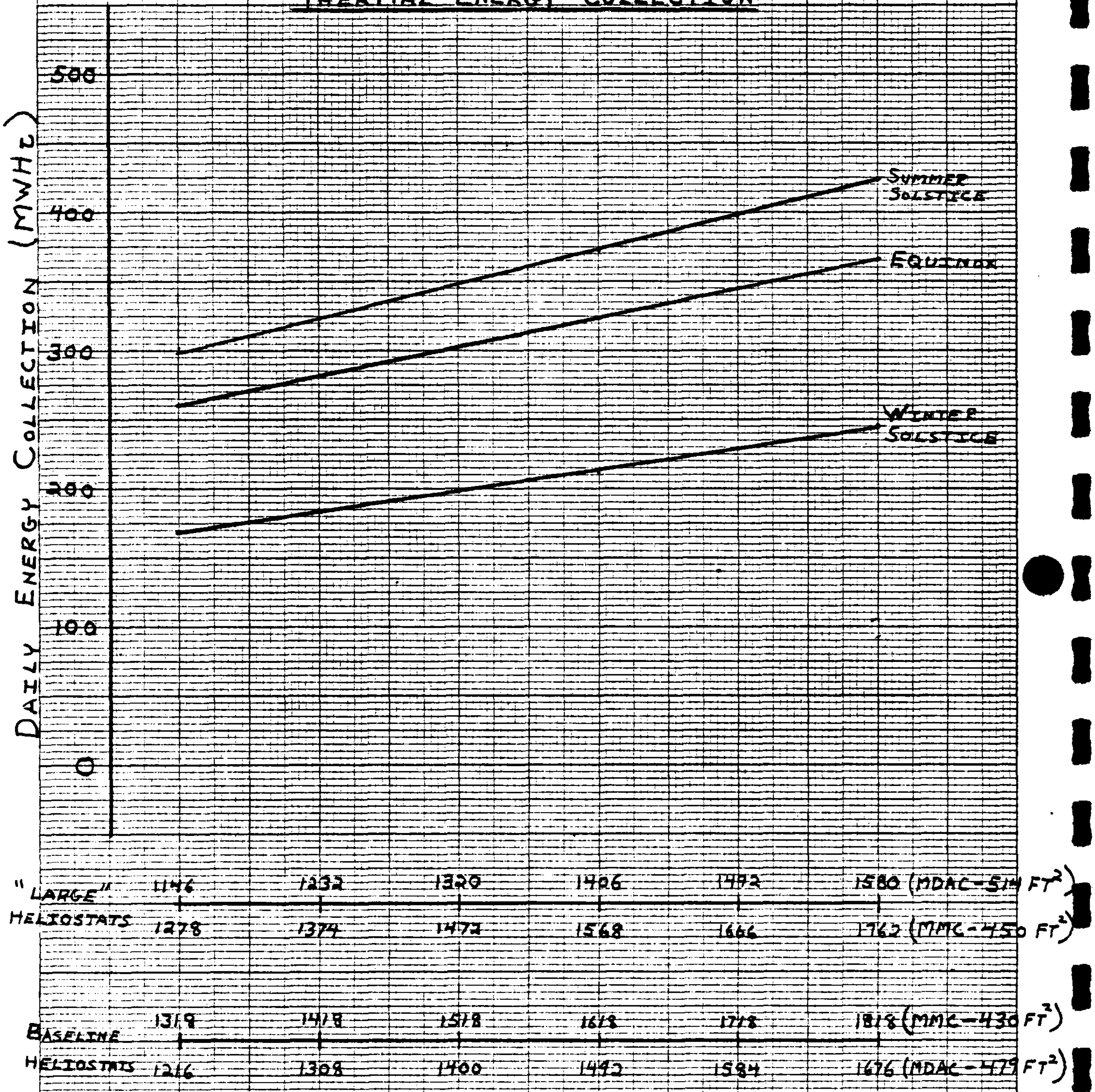
H R	MW out	
9895	12.52	1.0
9969	11.18	1.007
10068	9.87	1.017
10839	6.31	1.095
14111	2.69	1.426

DEGRADED TURBINE PERFORMANCE



10/30/79
14 OF 15

IMPACT OF HELIOSTAT REDUCTION ON DAILY THERMAL ENERGY COLLECTION



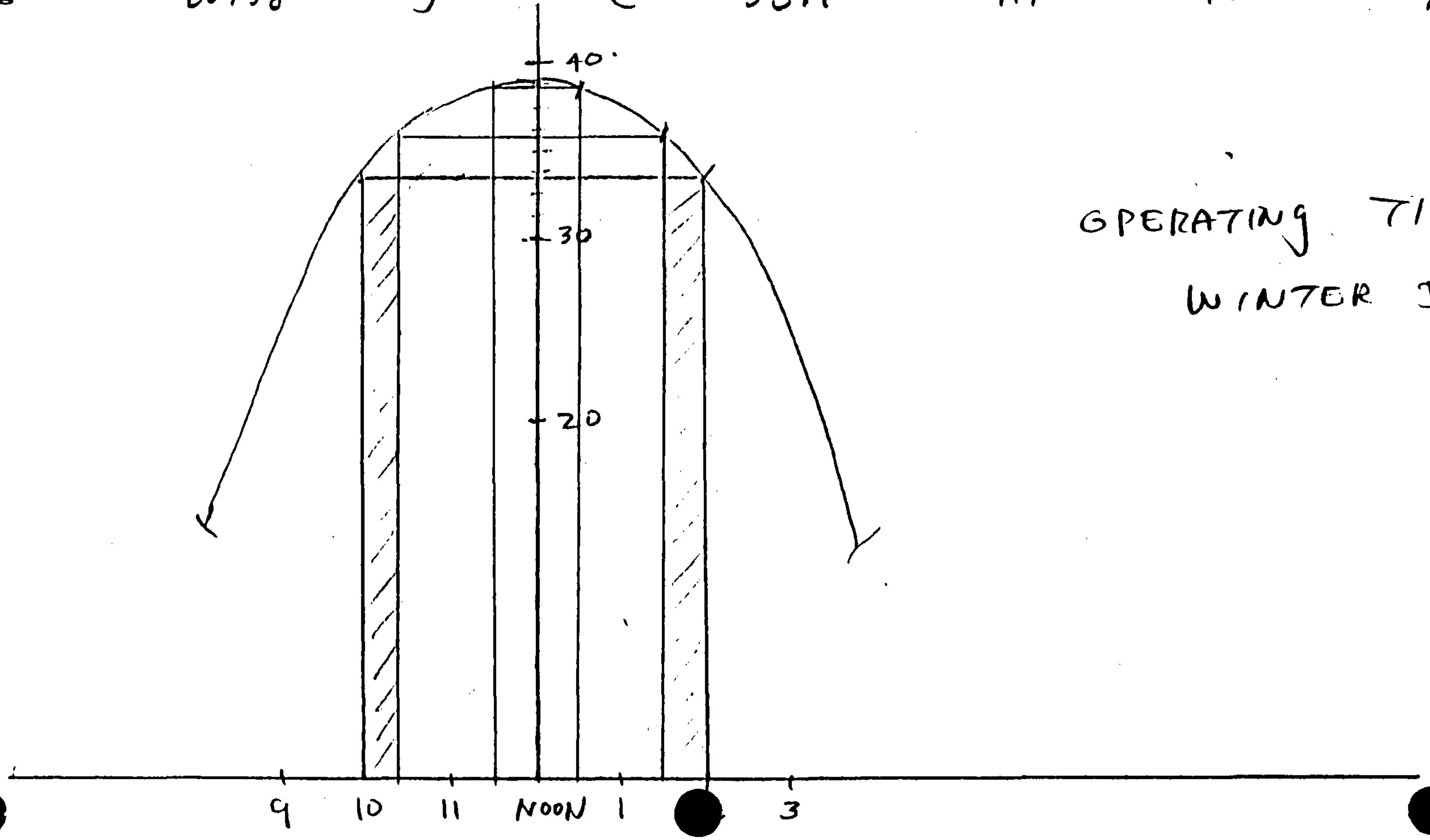
11/1/79

IMPACT ON MDAC "LARGE" HELIOSTATS
(514 FT^2 REFLECTIVE SURFACE)

No. HELIOSTATS	ASSUMPTIONS
1720	• 4 HOUR @ 10 MW (WINTER 2PM DESIGN PT) • $\alpha = .93$ (REC ABSORP) • $\rho = .86$ (HELIO REFLECT) • 1.8 MWe PARASITIC POWER • 32 HELIOSTAT CONTINGENCY
1580	• 4 HOURS @ 10 MWe (WINTER 2PM DESIGN POINT) • $\alpha = .95$ (REC ABSORP) • $\rho = .89$ (HELIO REFLECT) • 1.7 MWe PARASITIC POWER • NO HELIOSTAT CONTINGENCY
1388	• 10 MWe AT WINTER NOON • $\alpha = .95$ (REC ABSORP) • $\rho = .89$ (HELIO REFLECT) • 1.7 MWe PARASITIC POWER • NO HELIOSTAT CONTINGENCY
1514	• 10 MWe AT WINTER NOON • $\alpha = .93$ (REC ABSORP) • $\rho = .86$ (HELIO REFLECT) • 1.8 MWe PARASITIC • 32 HELIOSTAT CONTINGENCY

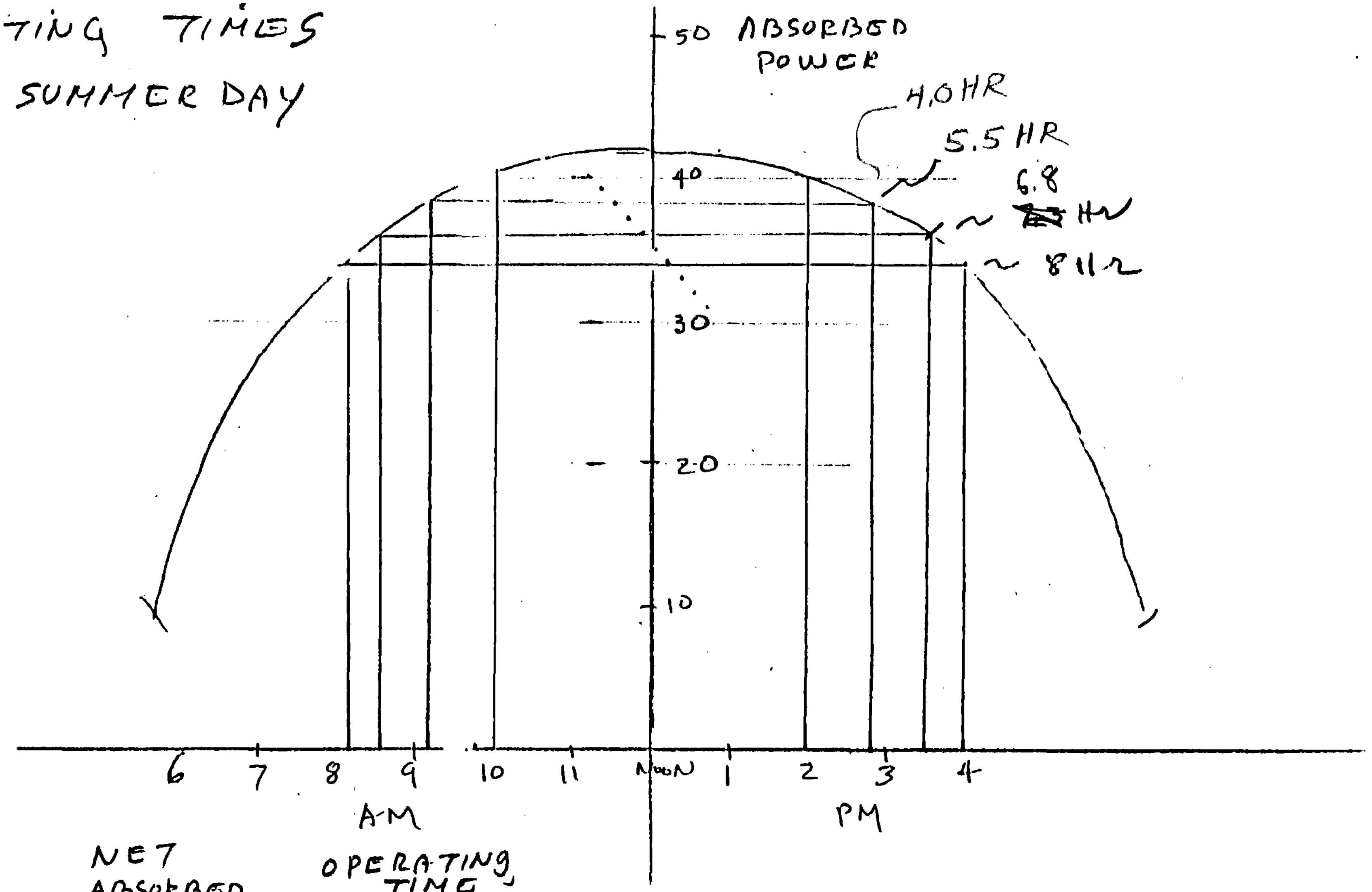
1 OF 3

No. of MARTIN HELIOSTATS	IDEAL POWER GENERATED	FIXED FIELD LOSSES	TOTAL Absorbed POWER	FIXED WINTER LOSSES (approx)	NET ABSORBED POWER	OPERATING TIME 10MWe
1956	71.552 MW_T	-54.64%	39.1 MW_T	4.7 MW_T	34.4 MW_T	4 Hr
1856	67.894 "		37.1 "	4.7 "	32.4 "	3 Hr
1756	64.24 "		35.1	4.7 "	30.4 "	1 Hr
1656	60.58 "		33.1	4.7 "	28.4 "	NO WAY



OPERATING TIMES
WINTER DAY

OPERATING TIMES
BEST SUMMER DAY



NO. of MARTIN HELIOSTATS	NET ABSORBED POWER	OPERATING TIME 10MWe
1956	33.8 MW_T	7.8 Hr
1856	~ 31.8	6.8 Hr
1756	~ 29.8	5.5 Hr
1656	~ 27.8	4.0 Hr

ESTIMATED IMPACT OF CHANGES IN COSINE AND BLOCKING / SHADOWING FOR 1656 HELIOSTAT CASE

WINTER NOON DATA	(COMPLETE FIELD)	(APPROX VALUE FOR 1656 HELIO)
INTERCEPTION	.9746	.980
B + S	.935	.938

IMPACT OF REDUCED HELIOSTAT QUANTITY (WINTER) 6/11/79

1 OF 7

TIME	REF INCID PWR	PWR FOR 1956 HELIO		PWR FOR 1856 HELIO	
		(INC)	(ABS)	(INC)	(ABS)
NOON	48.482	47.66	39.62	45.22	37.36
.64	48.016	47.20	39.20	44.78	36.95
1.28	46.547	45.76	37.85	43.42	35.68
1.92	43.447	42.71	35.02	40.53	32.99
2.00	42.765	42.04	34.4	39.89	32.40
2.56	37.921	37.28	29.97	35.37	28.20
3.20	30.154	29.64	22.87	28.12	21.46
3.85	19.765	19.43	13.37	18.44	12.45
-.64	47.916	47.10	39.11	44.69	36.86
-1.28	46.547	45.76	37.85	43.42	35.68
-1.92	43.494	42.76	35.06	40.57	33.03
-2.56	38.399	37.75	30.41	35.82	28.61
-3.20	30.534	30.02	23.22	28.49	21.79
-3.85	21.715	21.35	15.15	20.26	14.14

6/11/79
2 OF 4

TIME	(WINTER) PWR FOR 1756 HELIO (INC)	 (ABSORB.)	PWR FOR 1656 HELIO (INC)	 (ABSORB)
NOON	42.79	35.09	40.35	32.82 (7.46 MWe NET)
.64	42.37	34.71	39.96	32.46
1.28	41.08	33.51	38.74	31.33
1.92	38.34	30.96	36.16	28.93
2.00	37.74	30.40	35.59	28.40
2.56	33.47	26.43	31.56	24.65
3.20	26.61	20.05	25.09	18.64
3.85	17.44	11.52	16.45	10.60
-.64	42.28	34.62	39.87	32.38
-1.28	41.08	33.51	38.74	31.33
-1.92	38.39	31.00	36.20	28.97
-2.56	33.89	26.82	31.96	25.02
-3.20	26.95	20.36	25.42	18.94
-3.85	19.17	13.12	18.08	12.11

9/11/79
Continuation
of 6/11/79
3 OF 7

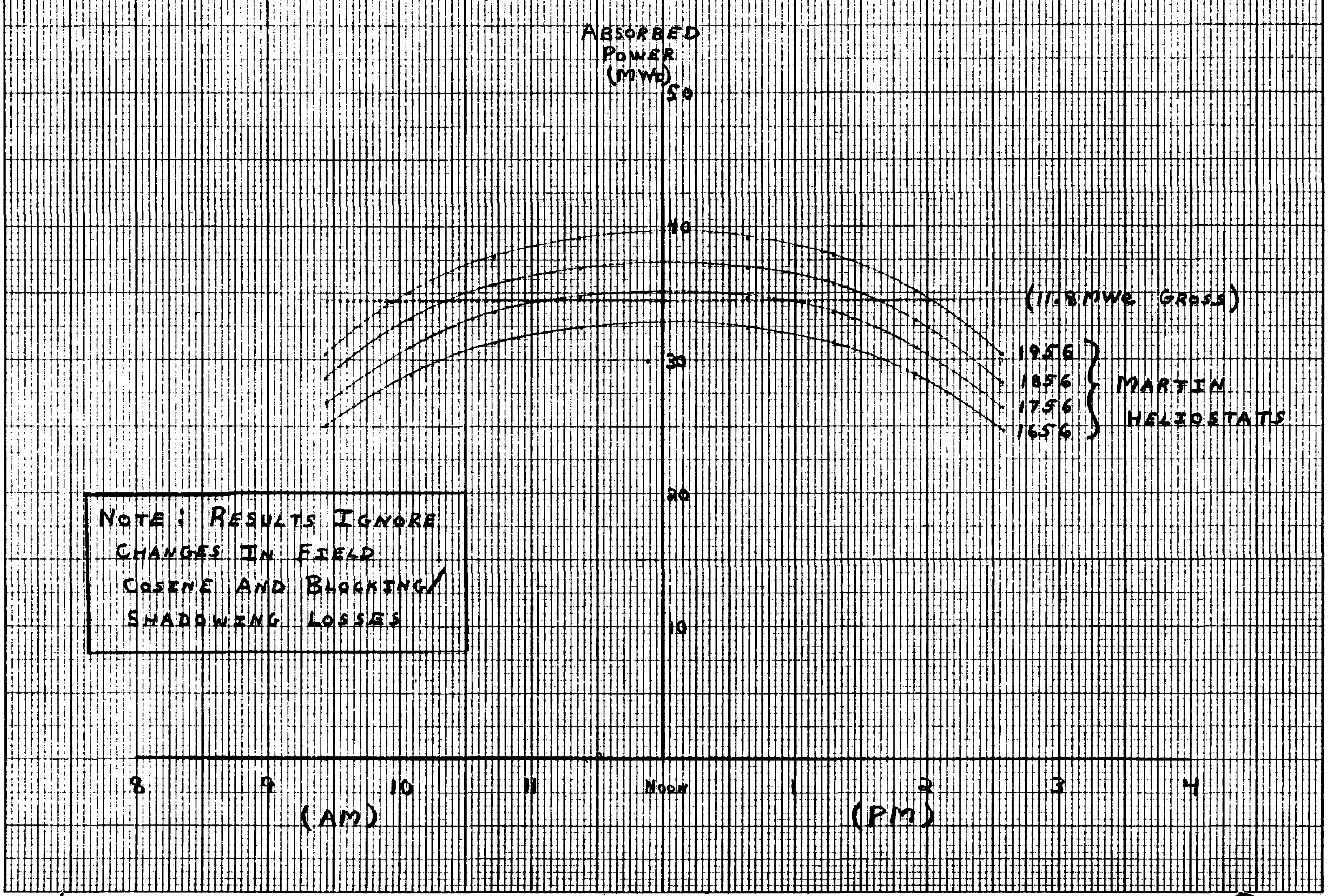
(WINTER)

TIME	PWR FOR (INC)	1556 HELIO (ABSORB)	PWR FOR (INC)	1456 HELIO (ABSORB)
NOON	37.91	30.56 (8.68 MWe)	35.48	28.29 (7.90 MWe Net)
.64	37.55	30.22	35.13	27.98
1.28	36.40	29.15	34.06	26.98
1.92	33.98	26.99	31.79	24.87
2.00	33.44	26.40	31.29	24.40
2.56	29.66	22.88	27.75	21.11
3.20	23.57	17.23	22.06	15.82
3.85	15.46	9.67	14.46	8.75
-.64	37.47	30.15	35.06	27.91
-1.28	36.40	29.15	34.06	26.97
-1.92	34.01	26.93	31.83	24.90
-2.56	30.03	23.23	28.10	21.43
-3.20	23.88	17.51	22.34	16.08
-3.85	16.98	11.09	15.89	10.08

4 of 7

APPROXIMATE IMPACT OF REDUCTION IN HELIOSTATS

(WINTER PERFORMANCE)



NOTE: RESULTS IGNORE CHANGES IN FIELD COSINE AND BLOCKING/SHADOWING LOSSES

9/12/79
5 OF 7

IMPACT OF REDUCTION IN HELIOSTAT QUANTITY

MARTIN	(LARGE)	MDAC	(LARGE)	HOURS AT 10MWe WINTER	SUMMER	PEAK POWER SUMMER	WINTE
1968	1910	1822	1720	4	7.8		
1868	1818	1730	1634	3.2	6.8		
1768	1714	1636	1544	1.85	5.5		
1668	1618	1544	1458		2.5		9.46
1568	1522	1452	1370			9.43	8.68
1468	1424	1360	1284			8.60	7.90

ADJUSTMENT FOR BIG MDAC + MMC HELIOSTATS 10/19

1. MDAC @ 514 FT²

$$(1790)\left(\frac{479}{514}\right)\left(\frac{.887}{.877}\right)+32 = 1720 \text{ HELIOSTATS}$$

1822-32 ↗ ← B+S FACTOR

2. MMC @ 450 FT²

$$(1936)\left(\frac{430}{450}\right)\left(\frac{.911}{.898}\right)+32 = 1910 \text{ HELIOSTATS}$$

1968 - 32 ↗

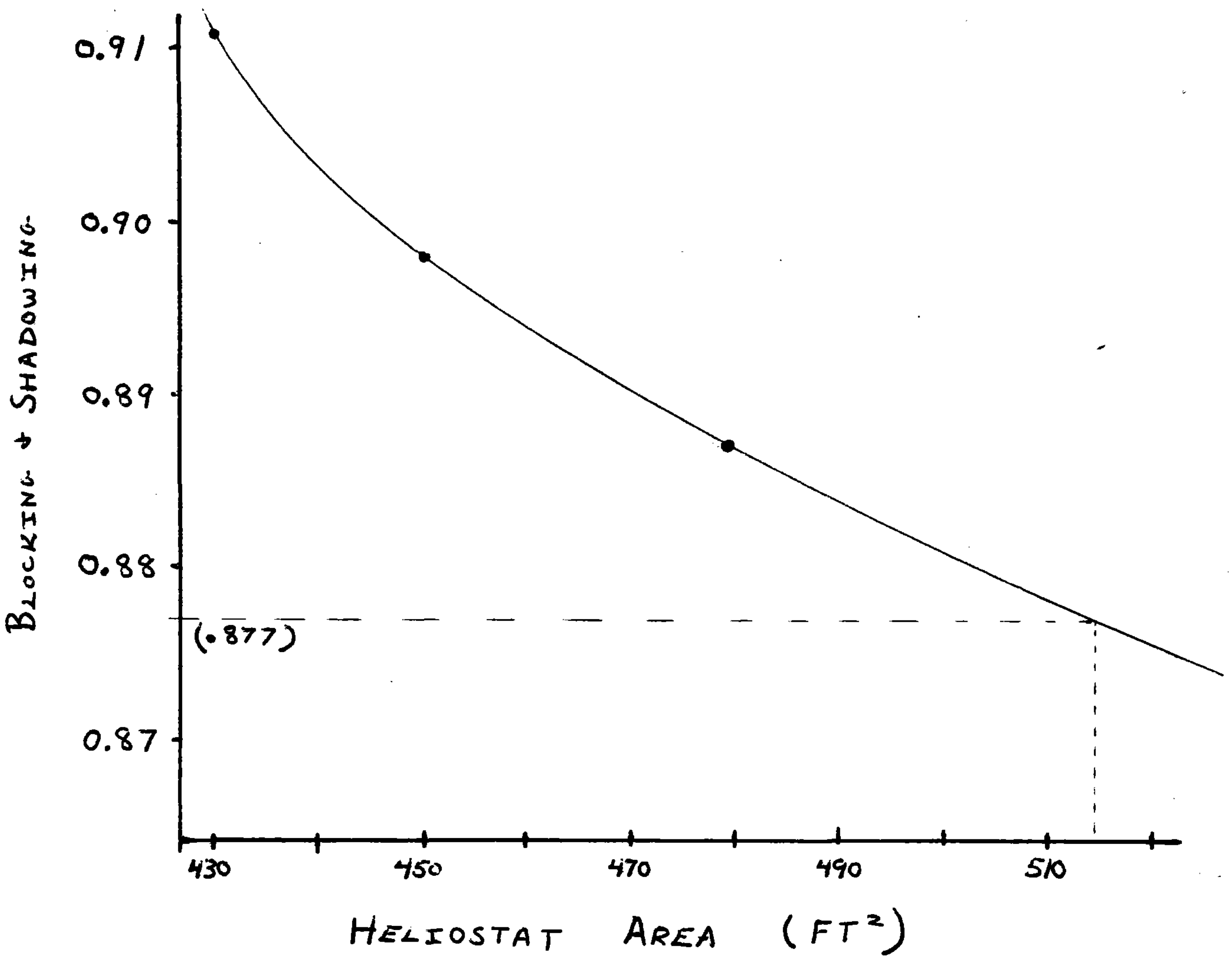
10/20/79
6 OF 7

IMPACT OF HELIOSTAT AREA ON BLOCKING AND SHADOWING

(ANALYSIS OF "LARGE" MDAC AND MMC HELIOSTATS)

BLOCKING AND SHADOWING @ WINTER 2 PM

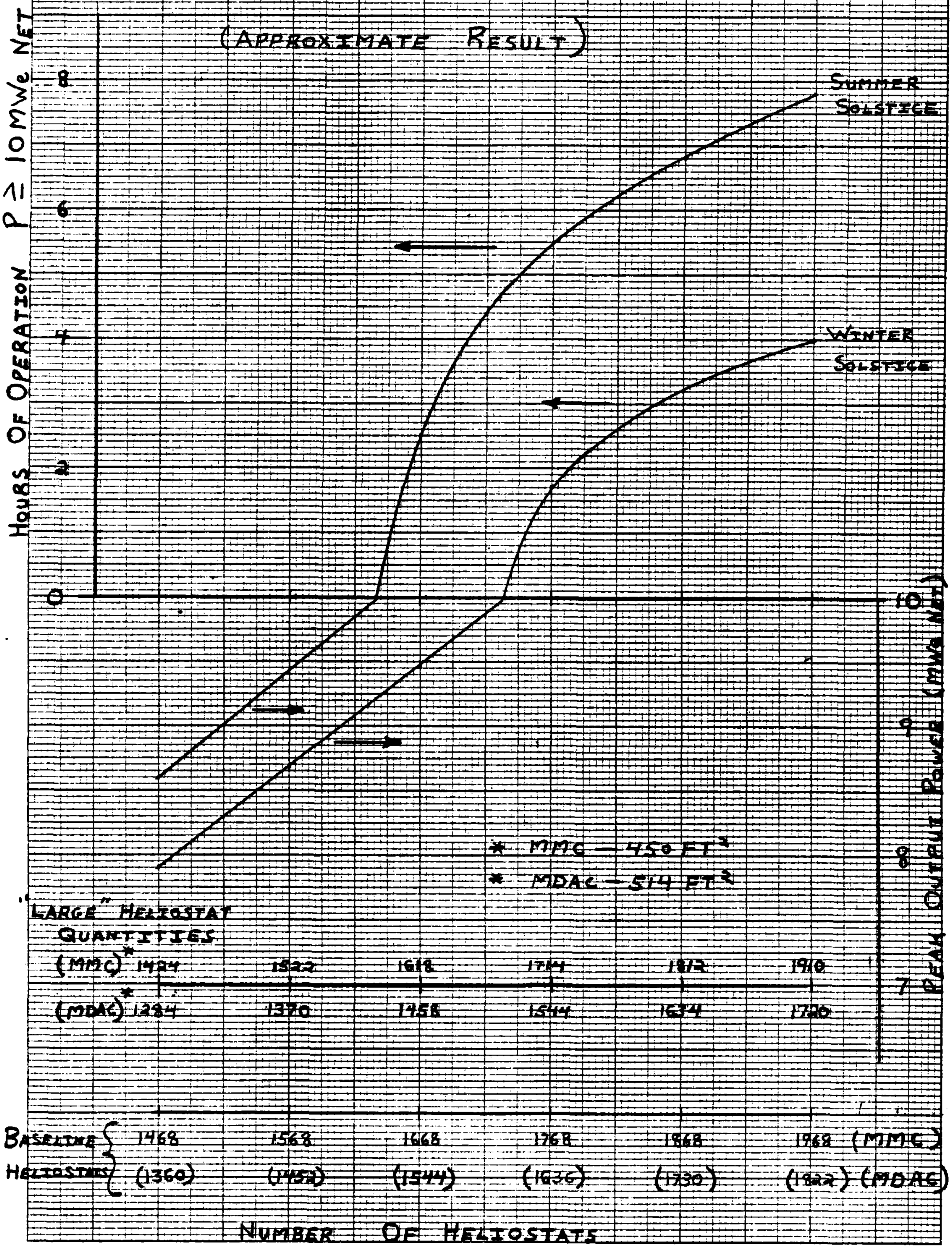
AREA	B+S
430 FT²	.911
450 FT²	.898
479 FT²	.887
514 FT²	(?)



7 of 7
9/12/79
Rev 10/20/79

IMPACT OF HELIOSTAT REDUCTION ON PLANT RATING

(APPROXIMATE RESULT)



* MMC — 450 FT²
* MDAC — 514 FT²

COLLECTOR FIELD DESIGN AND PLANT POWER CALCULATIONS

4/1/80
1 OF 4

COLLECTOR FIELD AREA

OBJECTIVE :

DEFINE

(i) ACTUAL FIELD AREA OCCUPIED BY HELIOSTATS

(ii) TOTAL AREA OF THE FOUR FIELD QUADRANTS (BETWEEN THE ROADS)

(iii) TOTAL AREA OF ROADS AND CORE AREA COMBINED

4/1/80
2 OF 4

TOP QUADRANT (RIGHT SIDE)

INSIDE PERIMETER ROAD
(INCLUDING 1/2 OF SPOKE ROADS
AND 1/4 CENTRAL CORE)

28
28
27.8
27.7
27.6
27.4
27.2
26.9
26.6
26.3
25.9
25.4
25.0
24.4
23.8
23.2
22.4
21.5
21.0
19.9
18.8
17.7
16.4
15.0
13.2
4.0 (12*1/3)

591.1

$(50 \times 50)(591.1) = 1.4778 \times 10^6 FT^2$

$\frac{A_{CORE}}{4} = \frac{\pi D^2}{16} = \frac{\pi (219)^2}{16} = 9417 FT^2$

NORTH ROAD

$23.5 \times 50 \times 9 = 10620 FT^2$

EAST ROAD

$20.8 \times 50 \times 9 = 9360 FT^2$

$A_{QUAD} = 1.448 \times 10^6 FT^2$
(INSIDE ROADS)

AREA OCCUPIED BY
HELIOSTATS (INCLUDI
PART OF SPOKE ROADS)

27
27
26.5
26.5
26.3
26.2
26.0
25.7
25.5
25.1
24.7
24.3
23.6
23.1
22.5
21.8
21.1
20.2
19.5
18.5
15.5
14.2
10.0
(-8)

512.8

$(50 \times 50)(512.8) = 1.282 \times 10^6 F$

$\frac{A_{CORE}}{4} = 9417 FT^2$

NORTH ROAD

$23.0 \times 50 \times 9 = 10350 FT^2$

EAST ROAD

$16.5 \times 50 \times 9 = 7425 FT^2$

$A_{QUAD} = 1.2548 \times 10^6 F$
HELIOSTAT AREA

4/1/80
3 OF 4

BOTTOM QUADRANT (RIGHT SIDE)

INSIDE PERIMETER ROAD
(INCLUDING 1/2 OF SPOKE ROADS
AND 1/4 CENTRAL CORE)

15
15
14.9
14.8
14.7
14.5
14.3
14.0
13.7
13.4
13.2
12.6
12.2
11.6
11.2
10.5
9.9
9.2
8.4
7.5
6.5
5.4
4.0
2.6
.5 (1×.5)

269.6

$(50 \times 50)(269.6) = 6.74 \times 10^5 \text{ FT}^2$

AREA CORE /4 = 9417 FT^2

SOUTH ROAD

$(10.5)(50)(25) = 13125 \text{ FT}^2$

EAST ROAD

$20.8 \times 50 \times 9 = 9360 \text{ FT}^2$

A QUAD
(INSIDE ROADS) $= 6.421 \times 10^5 \text{ FT}^2$

AREA OCCUPIED BY
HELIOSTATS (INCLUDING PARTS OF
SPOKE ROADS)

11.5
11.7
11.6
11.2
11.6
12.0
12.0
11.5
11.8
12.0
11.8
12.0
11.2
11.0
10.2
8.5
6.0
5.5
4.0

197.1

$(50 \times 50)(197.1) = 4.9275 \times 10^5 \text{ FT}^2$

AREA CORE /4 = 9417 FT^2

SOUTH ROAD

$(7.2)(50)(25) = 9000 \text{ FT}^2$

EAST ROAD

$15.5 \times 50 \times 9 = 6975 \text{ FT}^2$

A QUAD $= 4.674 \times 10^5 \text{ FT}^2$
(HELIOSTAT AREA)

4/1/80
4 OF 4

AREA HELIOSTATS

Σ 4 QUADRANTS = $2(4.674 \times 10^5 \text{ FT}^2) + 2(1.2548 \times 10^6 \text{ FT}^2)$

$3.4444 \times 10^6 \text{ FT}^2 = 79.07$ ACRES

AREA QUADRANTS

Σ 4 QUADRANTS = $2(6.421 \times 10^5) + 2(1.448 \times 10^6 \text{ FT}^2)$

$= 4.1802 \times 10^6 = 95.96$ ACRES

CORE AREA

$4(9417) = 37668 \text{ FT}^2$

EAST + WEST ROAD

$(20.8)(50)(18)(2) = 37440 \text{ FT}^2$

NORTH ROAD

$(23.5)(50)(18) = 21{,}150 \text{ FT}^2$

SOUTH ROAD

$(10.5)(50)(50) = 26250 \text{ FT}^2$

$122508 \text{ FT}^2 = 2.81$ ACRES

1/18/80
1 OF 14

TIME FOR HELIOSTAT WIRE WALK

OBJECTIVE:

CALCULATE THE TYPICAL TIME REQUIRED TO EXECUTE A WIRE WALK FOR A CLOSE IN HELIOSTAT THAT HAS A LONG ANGULAR TRAVEL. CARRYOUT THE CALCULATIONS FOR TWO REPRESENTATIVE WIRES:

(i) BOTTOM OF WIRE ABOVE EAST ROAD
(624 FT EAST + 80 FT UP)

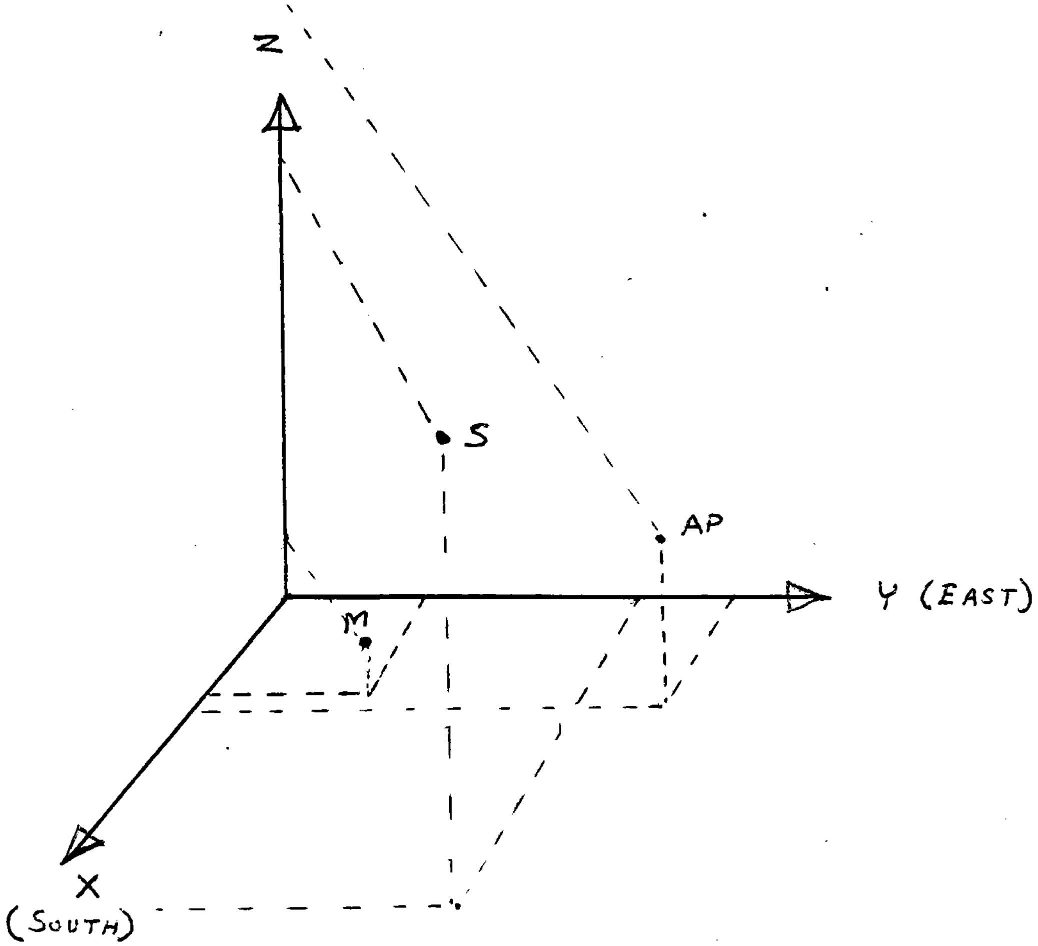
(ii) BOTTOM OF WIRE NORTH OF EAST ROAD
(634 FT EAST, 192 FT NORTH, + 80 FT UP)

NOTES:

- TEST HELIOSTAT IS No. 0119

- THIS ANALYSIS IGNORES ANY POTENTIAL SINGULARITY OR DRIVE SYSTEM TRAVEL LIMITS

1/18/80
2 OF 14



$\overline{M}$ = MIRROR = X_M, Y_M, Z_M LOCATION OF CENTER OF REFLECTOR RELATIVE TO 0, 0, 0 REFERENCE

$\overline{S}$ = SUN LOCATION = X_S, Y_S, Z_S LOCATION OF SUN RELATIVE TO 0,0,0 REFERENCE

$\overline{AP}$ = AIM POINT FOR WIRE WALK = X_{AP}, Y_{AP}, Z_{AP}

$\overline{V}_{M-S} = (X_S - X_M)\bar{i} + (Y_S - Y_M)\bar{j} + (Z_S - Z_M)\bar{k}$ MIRROR TO SUN

$\overline{V}_{M-AP} = (X_{AP} - X_M)\bar{i} + (Y_{AP} - Y_M)\bar{j} + (Z_{AP} - Z_M)\bar{k}$ MIRROR TO AIM POINT

IN GENERAL $\overline{V} = a\bar{i} + b\bar{j} + c\bar{k}$

$$v = (a^2 + b^2 + c^2)^{1/2}$$

BISECTOR OF ANGLES $\overline{V}_1$ AND $\overline{V}_2$

$$\overline{V}_{BISECTOR} = r\left(\frac{\overline{V}_1}{v_1} \pm \frac{\overline{V}_2}{v_2}\right) \qquad r = 1$$

$$\overline{V}_{BISECTOR} = \left[\frac{a_1\bar{i} + b_1\bar{j} + c_1\bar{k}}{\underbrace{(a_1^2 + b_1^2 + c_1^2)^{1/2}}_{D_1}} + \frac{a_2\bar{i} + b_2\bar{j} + c_2\bar{k}}{\underbrace{(a_2^2 + b_2^2 + c_2^2)^{1/2}}_{D_2}}\right]$$

$$\overline{V}_{BISECTOR} = \frac{D_2 a_1\bar{i} + D_2 b_1\bar{j} + D_2 c_1\bar{k}}{D_1 D_2} + \frac{D_1 a_2\bar{i} + D_1 b_2\bar{j} + D_1 c_2\bar{k}}{D_1 D_2}$$

$$\overline{V}_{BISECTOR} = \frac{D_2 a_1 + D_1 a_2}{D_1 D_2}\bar{i} + \frac{D_2 b_1 + D_1 b_2}{D_1 D_2}\bar{j} + \frac{D_2 c_1 + D_1 c_2}{D_1 D_2}\bar{k}$$

WHERE

$a_1 = X_S - X_M$ $\qquad a_2 = X_{AP} - X_M$

$b_1 = Y_S - Y_M$ $\qquad b_2 = Y_{AP} - Y_M$

$c_1 = Z_S - Z_M$ $\qquad c_2 = Z_{AP} - Z_M$

$$D_1 = (a_1^2 + b_1^2 + c_1^2)^{1/2}$$

$$D_2 = (a_2^2 + b_2^2 + c_2^2)^{1/2}$$

(STORAGE LOCATION ASSIGNMENTS)

STO 00 — X_{AP}
01 — Y_{AP}
02 — Z_{AP}
03 — X_M
04 — Y_M
05 — Z_M

06 — X_S
07 — Y_S
08 — Z_S
09 — a_1
10 — b_1
11 — c_1

12 — a_2
13 — b_2
14 — c_2
15 — D_1
16 — D_2
17 — $\dfrac{D_2 a_1 + D_1 a_2}{D_1 D_2}$ $\bar{i}$ COEFFIC.
18 — $\dfrac{D_2 b_1 + D_1 b_2}{D_1 D_2}$ $\bar{j}$ COEFFIC.
19 — $\dfrac{D_2 c_1 + D_1 c_2}{D_1 D_2}$ $\bar{k}$ COEFFIC.

1/18/80
4 OF 14

PROGRAM: HELIOSTAT ANGLE 1 of 2

```
LBL
A
RCL
0   } xs
6
-
RCL
0   } xm
3
=
STO
0   } a1
9
RCL
0   } ys
7
-
RCL
0   } ym
4
=
STO
1   } b1
0
RCL
0   } zs
8
-
```

```
RCL
0   } zm
5
=
STO
1   } c1
1
RCL
0   } xAP
0
-
RCL
0   } xm
3
=
STO
1   } a2
2
RCL
0   } yAP
1
-
RCL
0   } ym
4
=
STO
1   } b2
3
```

```
RCL
0   } zAP
2
-
RCL
0   } zm
5
=
STO
1   } c2
4
RCL
0
9
x²
+
RCL
1
0
x²
+
RCL
1
1
x²
=
√x
STO
```

```
1   } D1
5
RCL
1
2
x²
+
RCL
1
3
x²
+
RCL
1
4
x²
=
√x
STO
1   } D2
6
(
RCL
1   } D2
6
*
RCL
0   } a1
9
```

1/18/80
5 OF 14

PROGRAM: HELIOSTAT ANGLE 2 of 2

```
+
RCL
1     } D1
5
*
RCL
1     } a2
2
)
÷
(
RCL
1     } D1
5
*
RCL
1     } D2
6
)
=
STO
1     } D2a1+D1a2
7       ---------
          D1D2
(
RCL
1     } D2
6
```

```
*
RCL
1     } b1
0
+
RCL
1     } D1
5
*
RCL
1     } b2
3
)
÷
(
RCL
1     } D1
5
*
RCL
1     } D2
6
)
=
STO
1     } D2b1+D1b2
8       ---------
          D1D2
```

```
(
RCL
1     } D2
6
*
RCL
1     } c1
1
+
RCL
1     } D1
5
*
RCL
1     } c2
4
)
÷
(
RCL
1     } D1
5
*
RCL
1     } D2
6
)
=
```

```
STO
1     } D2c1+D1c2
9       ---------
          D1D2
HLT
```

6 OF 14

TITLE HELIOSTAT ANGLE PAGE 1 OF 2

PROGRAMMER DATE 1/18/80

SR-52 Coding Form

LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LABELS
000 112		LBL				−				X^2		A HELIO ANGLE
		A				RCL				+		B
		RCL		040 152		0				RCL		C
		0				3				1		D
		6				=		080 192		1		E
005 117		−				STO				X^2		A'
		RCL				1				=		B'
		0		045 157		2				$\sqrt{X}$		C'
		3				RCL				STO		D'
		=				0		085 197		1		E'
010 122		STO				1				5		REGISTERS
		0				−				RCL		00 — X_{AP}
		9		050 162		RCL				1		01 Y_{AP}
		RCL				0				2		02 Z_{AP}
		0				4		090 202		X^2		03 X_m
015 127		7				=				+		04 Y_m
		−				STO				RCL		05 Z_m
		RCL		055 167		1				1		06 X_s
		0				3				3		07 Y_s
		4				RCL		095 207		X^2		08 Z_s
020 132		=				0				+		09 a_1
		STO				2				RCL		10 b_1
		1		060 172		−				1		11 c_1
		0				RCL				4		12 a_2
		RCL				0		100 212		X^2		13 b_2
025 137		0				5				=		14 c_2
		8				=				$\sqrt{X}$		15 D_1
		−		065 177		STO				STO		16 D_2
		RCL				1				1		17 $\frac{D_2 a_1 + D_1 a_2}{D_1 D_2}$
		0				4		105 217		6		18 $\frac{D_2 b_1 + D_1 b_2}{D_1 D_2}$
030 142		5				RCL				(		19 $\frac{D_2 c_1 + D_1 c_2}{D_1 D_2}$
		=				0				RCL		FLAGS
		STO		070 182		9				1		0
		1				X^2				6		1
		1				+		110 222		*		2
035 147		RCL				RCL				RCL		3
		0				1						4
		0		075 187		0						

TEXAS INSTRUMENTS
INCORPORATED

TITLE HELIOSTAT ANGLE PAGE 2 OF 2

PROGRAMMER DATE 1/18/80

SR-52 Coding Form 7 OF 14

LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS
112		0				RCL				1	
		9				1				5	
		+		040 152		3				*	
		RCL				)				RCL	
		1				÷		080 192		1	
005 117		5				(				6	
		*				RCL				)	
		RCL		045 157		1				=	
		1				5				STO	
		2				*		085 197		1	
010 122		)				RCL				9	
		÷				1				HLT	NOT UNIT VECTOR
		(		050 162		6				LBL	ADD LBL B TO FIND
		RCL				)				B	UNIT FACTOR ($1/x$)
		1				=		090 202		RCL	AND STO 00
015 127		5				STO				1	NOTE THIS WIPES OUT
		*				1				7	OLD 00 VALUE
		RCL		055 167		8				x^2	
		1				(				+	
		6				RCL		095 207		RCL	
020 132		)				1				1	
		=				6				8	
		STO		060 172		*				x^2	
		1				RCL				+	
		7				1		100 212		RCL	
025 137		(				1				1	
		RCL				+				9	
		1		065 177		RCL				x^2	
		6				1				=	
		*				5		105 217		$\sqrt{x}$	
030 142		RCL				*				$1/x$	
		1				RCL				STO	
		0		070 182		1				0	
		+				4				0	
		RCL				)		110 222		HLT	
147		1				÷					
		5				(					
		*		075 187		RCL					

LABELS	
A	
B	
C	
D	
E	
A'	
B'	
C'	
D'	
E'	

REGISTERS	
00	
01	
02	
03	
04	
05	
06	
07	
08	
09	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	

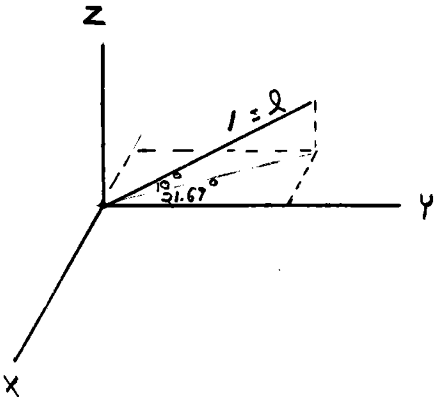
FLAGS	
0	
1	
2	
3	
4	
–	

TEXAS INSTRUMENTS
INCORPORATED

MORNING SUN

(SUMMER 10° ELEV $\qquad Z = 111.69^\circ \qquad El = 10^\circ$

$$\begin{array}{r} \underline{90.00} \\ 21.69^\circ \end{array}$$ NORTH OF EAST



$|\bar{\ell}| = 1 \qquad |\bar{\ell}|_{PROJ} = 1\,(\cos 10^\circ) = .9848$

$X_{PROJ} = .9848\,(\sin 21.69^\circ) = -.3696$

$Y_{PROJ} = .9848\,(\cos 21.69^\circ) = .9292$

$Z_{PROJ} = 1\,(\sin 10^\circ) = .1736$

INCREMENTAL TIME CALCULATIONS

AZIMUTH INCREMENT : $\Theta_1 = \tan^{-1}\left|\frac{Y_1}{X_1}\right| \qquad \Theta_2 = \tan^{-1}\left|\frac{Y_2}{X_2}\right|$

$$\Delta\Theta_{BEAM} = \Theta_2 - \Theta_1$$

$$\Delta\Theta_{HELIO} = \frac{\Delta\Theta_{BEAM}}{2}$$

$$TIME = \frac{\Delta\Theta_{HELIO}}{\text{DRIVE RATE HELIO AZIMUTH}}$$

ELEV. INCREMENT

$$\Phi_1 = \tan^{-1}\frac{Z_1}{\sqrt{X_1^2 + Y_1^2}} \qquad \Phi_2 = \tan^{-1}\frac{Z_2}{\sqrt{X_2^2 + Y_2^2}}$$

$$\Delta\Phi_{BEAM} = \Phi_2 - \Phi_1$$

$$\Delta\Phi_{HELIO} = \frac{\Delta\Phi_{BEAM}}{2}$$

$$TIME = \frac{\Delta\Phi_{HELIO}}{\text{ELEV DRIVE RATE}}$$

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TIME INCREMENT PROGRAM PROGRAM -1

X_{i+1} — STO 00 Y_{i+1} — STO 01 Z_{i+1} — STO 02

X_i — 03 Y_i — 04 Z_i — 05

Θ_{i+1} - 06 Θ_i - 07 Φ_{i+1} - 08

Φ_i - 09 AZ DRIVE RATE - 10 EL DRIVE RATE - 11

```
LBL
A
RCL
0
1
÷
RCL
0
2
=
x²
√x
INV
TAN
STO ┐
0   ├ θi+1
6   ┘
RCL
0
4
```

```
÷
RCL
0
3
=
x²
√x
INV
TAN
STO ┐
0   ├ θi
7   ┘
−
RCL
0
6
=
x²
√x
HLT ΔΘ BEAM
```

```
÷
2
÷
RCL
1
0
=
HLT AZ TIME INCRE.
RCL
0
2
÷
(
RCL
0
0
x²
+
RCL
```

```
0
1
x²
)
√x
=
INV
TAN
STO ┐
0   ├ φi+1
8   ┘
RCL
0
5
÷
(
RCL
0
3
x²
+
```

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TIME INCREMENT - 2

RCL
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4
x^2
)
$\sqrt{x}$
=
INV
TAN
STO
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9
$\Big\} \Phi_i$
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RCL
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8
=
x^2
$\sqrt{x}$
HLT $\Delta\Phi$ BEAM
÷
2
÷
RCL
1
1
=
HLT ELEV TIME INCREM

LBL
B
RCL
0
0
STO
0
3
RCL
0
1
STO
0
4
RCL
0
2
STO
0
5
HLT

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TITLE HELIOSTAT TIME INCREMENT PAGE 1 OF 2
PROGRAMMER DATE 1/19/80

SR-52 Coding Form

L	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LABELS
00		LBL				√x				0		A START
		A				HLT	Δθ BEAM			3		B SHIFT i+1 → i STORAGE
		RCL		040 152		÷				x²		C
		0				2				+		D
		1				÷		080 192		RCL		E
005 117		÷				RCL				0		A'
		RCL				1				4		B'
		0		045 157		0				x²		C'
		0				=				)		D'
		=				HLT	Az TIME INCRE	085 197		√x		E'
010 122		x²				RCL				=		REGISTERS
		√x				0				INV		00 x_{i+1}
		INV		050 162		2				TAN		01 y_{i+1}
		TAN				÷				STO		02 z_{i+1}
		STO				(		090 202		0		03 x_i
015 127		0				RCL				9		04 y_i
		6				0				−		05 z_i
		RCL		055 167		0				RCL		06 θ_{i+1}
		0				x²				0		07 θ_i
		4				+		095 207		8		08 ϕ_{i+1}
020 132		÷				RCL				=		09 ϕ_i
		RCL				0				x²		10 Az DRIVE RATE i
		0		060 172		1				√x		11 ELEV DRIVE RATE
		3				x²				HLT	Δϕ BEAM	12
		=				)		100 212		÷		13
025 137		x²				√x				2		14
		√x				=				÷		15
		INV		065 177		INV				RCL		16
		TAN				TAN				1		17
		STO				STO		105 217		1		18
030 142		0				0				=		19
		7				8				HLT	ELEV TIME INCR	FLAGS
		−		070 182		RCL				LBL		0
		RCL				0				B		1
		0				5		110 222		RCL		2
035 147		6				÷				0		3
		=				(		TEXAS INSTRUMENTS INCORPORATED				4
		x²		075 187		RCL						

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TITLE HELIOSTAT TIME INCREMENT PAGE 2 OF 2
PROGRAMMER
DATE 1/19/80

SR-52 Coding Form

LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LABELS
000 1		0										A
		STO										B
		0		040 152								C
		3										D
		RCL						080 192				E
005 117		0										A′
		1										B′
		STO		045 157								C′
		0										D′
		4						085 197				E′
010 122		RCL										REGISTERS
		0										00
		2		050 162								01
		STO										02
		0						090 202				03
015 127		5										04
		HLT										05
				055 167								06
												07
								095 207				08
020 132												09
												10
				060 172								11
												12
								100 212				13
025 137												14
												15
				065 177								16
												17
								105 217				18
030 142												19
												FLAGS
				070 182								0
												1
								110 222				2
035 147												3
								TEXAS INSTRUMENTS INCORPORATED				4
				075 187								

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WORKSHEET
FORM 30-103-1 (RL... 10-67)

HELIOSTAT MOVEMENT DURING WIRE WALK (FROM HELIOSTAT ANGLE PROGRAM)

(5-WIRE EXPANDED)

10° SUMMER MORNING

13°/MIN DRIVE

unit vector

	00 X_{AP}	01 Y_{AP}	02 Z_{AP}	03 X_m	04 Y_m	05 Z_m	06 X_s	07 Y_s	08 Z_s	$\bar{i}$ COEFF	$\bar{j}$ COEFF	$\bar{k}$ COEFF	$\Delta\theta$ BEAM	AZ TIME	$\Delta\phi$ BEAM	EL TIME
MIRROR 011900	0	624.06	80	49.487	234.66	12	-.3696 x10⁹	.9292 x10⁹	.1736 x10⁹	-.4884 -.246	1.893 .9538	.3417 .1722				
													.738	.0284	2.548	.098
	0	561.1	100	"	"	"	"	"	"	-.5089 -.256	1.8709 .9422	.4286 .2158				
													1.134	.0436	3.504	.1348
	0	498	120							-.5354 -.2704	1.827 .9226	.5449 .2751				
													1.733	.0667	4.904	.1887
	0	435	140							-.5679 -.2898	1.7405 .8883	.6981 .3563				
													2.83	.1087	6.72	.2584
	0	372.3	160							-.6020 -.3161	1.577 .8280	.8823 .4632				
													4.62	.1778	8.42	.324
	0	309.3	180							-.6241 -.3484	1.308 .7299	1.0535 .5880				
													6.85	.2636	8.52	.328
	0	246.3	200							-.6183 -.3816	.9753 .6020	1.1364 .7014				
													8.45	.325	6.555	.258
	0	183.4	220							-.5892 -.4105	.6824 .4753	1.117 .7782				
													8.55	.329	4.032	.1550
	0	120.5	240							-.5547 -.4339	.4760 .3723	1.0488 .8204				
													7.54	.290	2.15	.0827
	0	57.5	260							-.5244 -.4529	.3417 .2951	.9742 .8413				
										TOTAL						
										WIRE	WALK					

TIME = 2.276 min

WORKSHEET
FORM 30-103-1 (R... 10-67) HELIOSTAT MOVEMENT DURING WIRE WA[illegible] (FROM HELIOSTAT ANGLE PROGRAM)

@ 13°/INCH DRIVE

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4 WIRE

MIRROR 011900	00 XAP	01 YAP	02 ZAP	03 Xm	04 Ym	05 Zm	06 X_s	07 Y_s	08 Z_s	$\bar{i}$ COEFF	$\bar{j}$ COEFF	$\bar{k}$ COEFF	ΔΘ BEAM	AZ TIME	ΔΦ BEAM	EL TIME
	-191.89	633.97	80	49.487	234.66	12	$-.3696 \times 10^{9}$	$.9272 \times 10^{9}$	$.1736 \times 10^{9}$	-.8761 -.4395	1.7623 .8842	.3153 .1582				
													1.14	.0438	2.056	.0791
	-172.4	569.6	100							-.9036 -.454	1.7299 .8696	.3850 .1935				
													1.544	.0594	2.740	.1054
	-152.94	505.3	120							-.9347 -.4723	1.6783 .8481	.4754 .2402				
													2.105	.0810	3.721	.1431
	-133.47	440.96	140							-.9660 -.494	1.5941 .8151	.5921 .3027				
													2.911	.112	5.055	.1944
	-114.0	376.64	160							-.9875 -.5177	1.4568 .7638	.7353 .3855				
													3.991	.1535	6.580	.2531
	-94.5	312.3	180							-.9782 -.5386	1.2466 .6864	.8875 .4887				
													5.091	.196	7.628	.2934
	-75.06	248.0	200							-.9155 -.5477	.9746 .5830	1.003 .6002				
													5.693	.2190	7.448	.286
	-55.59	183.67	220							-.8046 -.5391	.7017 .4702	1.0430 .6988				
													5.528	.2126	6.179	.238
	-36.12	119.35	240							-.6818 -.5173	.4876 .3699	1.0172 .7717				
													4.824	.1855	4.681	.180
	-16.65	55.03	260							-.5753 -.4906	.3421 .3918	.9627 .8210				
												TOTAL				

WALK TIME ≈ 1.776 MIN

1/17/80
1 OF 2

TIME REQUIRED TO MOVE IMAGES BETWEEN STANDBY AND TRACK

OBJECTIVE: DEFINE THE TIME REQUIRED TO MOVE IMAGES FROM STANDBY TO RECEIVER TRACK IF STANDBY IS DEFINED AS

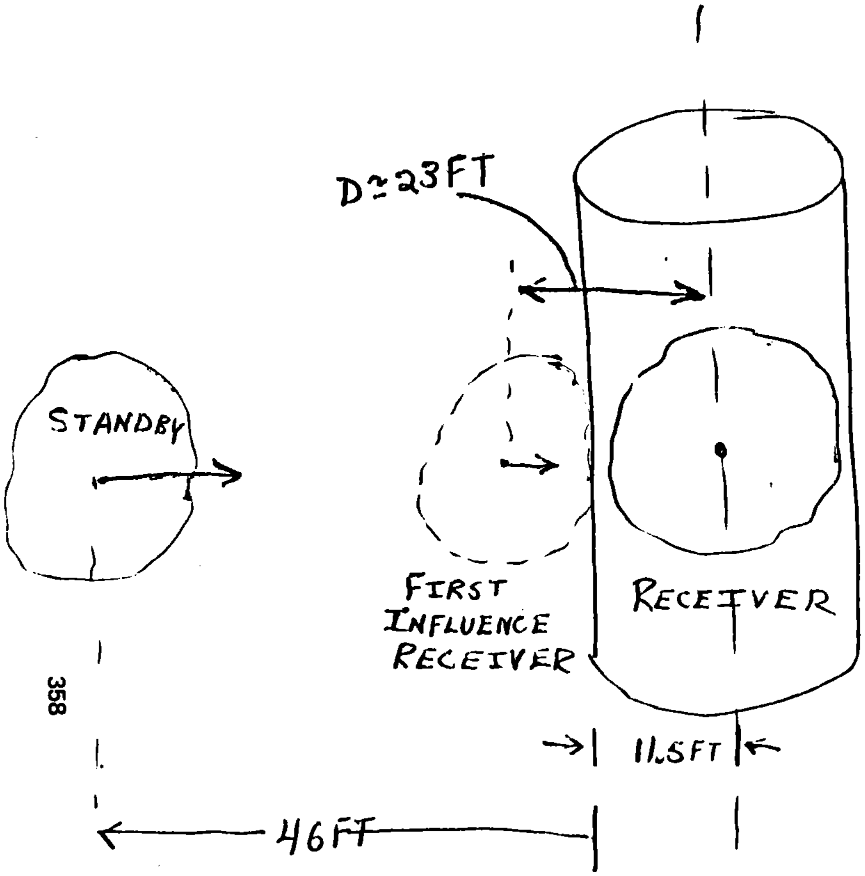
(i) 2½ RECEIVER DIAMETERS FROM THE RECEIVER CENTERLINE

(ii) 5½ RECEIVER DIAMETERS FROM THE RECEIVER CENTERLINE

(iii) 1 RECEIVER DIAMETER FROM THE RECEIVER CENTERLINE

FOR "NEAR IN" AND "FAR OUT" HELIOSTATS ON THE NORTH SIDE OF THE FIELD

1/17/80



HORIZONTAL TRAVEL DISTANCE

1. STANDBY TO REC. CENTERLINE D = 57.5FT
2. POINT OF FIRST INTERACTION TO RECEIVER CENTERLINE D = 23 FT
3. 5 DIAMETERS + TO REC CENTERLINE D = 126.5FT

- FOR CLOSE HELIOSTAT (GROUND RANGE = 239FT)

TRAVEL ANGLE FOR 1. = 13.5°

2.22 ⇒ TIME = 31 SEC @ 13°/min HELIOSTAT MOTION (* 2 - BEAM MOVEMENT)

(TIME FOR 3. = $\frac{126.5}{57}$ × 31 = 68.8 SEC.)
ANGLE 29.97° TRAVEL - BEAM

TRAVEL ANGLE FOR 2. = 5.5°

⇒ TIME = 12.7 SEC @ 13°/min (* 2 - BEAM MOTION)

- FOR DISTANT HELIOSTAT (GROUND RANGE = 1317 FT)

TRAVEL ANGLE FOR 1. = 2.5°

⇒ TIME = 5.7 SEC @ 13°/min (* 2 - BEAM MOTION)

TRAVEL ANGLE FOR 2. = 1.0°

⇒ TIME = 2.3 SEC @ 13°/min (* 2 - BEAM MOTION)

2.22
(TIME FOR 3 = $\frac{126.5}{57}$ × 5.7 = 12.65)
BE[illegible] TR[illegible] - A[illegible]E [illegible]5

2 OF 2

8/1/79
1 OF 4

Collector Interface Workshop

Action Item No 1

MDAC will document the historical changes in assumptions which resulted in the need for increasing the number of heliostats from the PDR quantity to the current quantity.

Answer:

Table 1 contains a tabular summary of the power requirements and receiver/collector field performance factors which have been developed during previous and current design analyses to reflect changes in the design point (winter 2PM vs summer 8AM), insolation, and parasitic power requirements. The data contained in the table starts with the design point and the electrical power requirement. The appropriate performance factors are listed and applied to the electrical power requirement to determine the "ideal power requirement" which is the amount of incoming sun light which would strike the heliostats assuming all heliostats are oriented normal to the sun. Table 1 then defines the total number of (STMPO) heliostats required to satisfy the "ideal power requirement" at the specified insolation levels.

Data contained in Table 2 shows the conversion in required number of heliostats when the STMPO heliostat is replaced with Martin or MDAC heliostat. In either case, the conversion is made by modifying the "equivalent STMPO heliostat" quantity by the appropriate blocking and shadowing factor and the area of the particular heliostat of interest. An "outage factor" of 32 is then added to the calculated heliostat quantity to determine the required "total heliostat" quantity.

TABLE 1 **Historical Evolution of Pilot Plant Heliostat Quantity Requirements**

	PDR (Oct, 1977)	Initial Project Review (May 2, 1979)	Scaled Analysis (May 18, 1979)	Preliminary (1) Design Review (July 30, 1979)
Design Point	Winter 2PM	Summer 8AM	Winter 2PM	Winter 2PM
Design Point Electrical Power (10 MWe Net)	11.2 MWe	11.6 MWe	11.8 MWe	11.8 MWe
Absorbed Thermal Power	32.6 MWt	33.8 MWt	34.4 MWt	34.4 MWt
Receiver Thermal Losses	4.2 MWt	4.8 MWt	4.7 MWt	4.7 MWt
Average Receiver Absorptance	(0.95)	(0.93)	(0.93)	(0.93)
Receiver Incident Power	38.7 MWt	41.5 MWt	42.04 MWt	42.04 MWt
Receiver Interception Factor	(.977)	(.976)	(.976)	(.976)
Atmospheric Attenuation Factor	(.98)	(.978)	(.978)	(.978)
Sensor Post Blocking and Shadowing Factor	(.98)	-	-	-
Field Cosine	(.801)	(.749)	(.794)	(.792)
Blocking and Shadowing	(.952)	(.958)(2)	(.902)(2)	(.898)(2)
Average Heliostat Reflectivity	(.88)	(.86)	(.86)	(.86)
Ideal Power Requirement	61.4 MWt(3)	70.9 MWt(3)	71.5 MWt(3)	72.0 MWt(3)

(1) Based on individual heliostat analysis

2 of 4

TABLE 1 Historical Evolution of Pilot Plant Heliostat Quantity Requirements (Continued)

	PDR (Oct, 1977)	Initial Project Review (May 2, 1979)	Scaled Analysis (May 18, 1979)	Preliminary (1) Design Review (July 30, 1979)
Assumed Direct Insolation	$950^{W}/m^{2}$	$898^{W}/m^{2}$	$917^{W}/m^{2}$	$917^{W}/m^{2}$
Required Glass Area	695,400 ft^{2}	850,137 ft^{2}	839,700 ft^{2}	845,100 ft^{2}
Heliostat Reflector Area	408 ft^{2}	450 ft$^{2(2)}$	450 ft$^{(2)}$	450 ft$^{2(2)}$
Equivalent Heliostats	1703	1890$^{(2)}$	1866$^{(2)}$	1878$^{(2)}$
Contingency Heliostats	57$^{(4)}$	32	32	32
Total Heliostats	1760	1922$^{(2)}$	1898$^{(2)}$	1910$^{(2)}$

(2) STMPO - defined 450 ft^{2} heliostat

(3) Rounded off values

(4) Includes non ideal effects not contained in the sizing calculations

3 OF 4

TABLE 2 Conversion from STMPO to Martin and MDAC Heliostat Quantities

	Initial Project Review (May 2, 1979)	Scaled Analysis (May 18, 1979)	Preliminary Design Review (July 30, 1979)
Equivalent STMPO Heliostats	1890 (1922-32)	1866 (1898-32)	1878 (1910-32)
Martin Heliostats (430 ft^2)			
Blocking and Shadowing Factor	.972	.915	.911
Equivalent Martin Heliostats	1950	1924	1936
Outage Factor	32	32	32
Total Heliostats	1982	1956	1968
MDAC Heliostats (479 ft^2)			
Blocking and Shadowing Factor	.945	.889	.887
Equivalent MDAC Heliostats	1800	1778	1790
Outage Factor	32	32	32
Total Heliostats	1832	1810	1822

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5/18/79
1 OF 7

DEFINITION OF FIELD PERFORMANCE FOR FIELD SIZED FOR WINTER 2 PM

(WINTER LOSS MODEL)

		PARASITIC POWER 1.6 MWe	PARASITIC POWER 1.8 MWe
	(PERFORMANCE)	(POWER)	(POWER)
GROSS ELECT		11.6 MWe	11.8 MWe
ABSORBED POWER (NET)		33.8 MWt	34.4 MWt
WINTER LOSSES		4.7 MWt	4.7 MWt
TOT. ABSORBED PWR		38.5 MWt	39.1 MWt
REC. ABSORPTION	(.93)	41.4 MWt	42.04 MWt
(INTERCEPT FACT)* (ATM ATTEN)	(.954)		
COSINE	(.794)		
BLOCK AND SHADOW	(.902)		
REFLECT	(.86)		
IDEAL POWER		70.454 MWt	71.552 MWt
INSOLATION	917 W/m^2		
GLASS AREA		76,831 m^2 (826,701 ft^2)	78028 m^2 (839600 ft^2)
No STMPO		1838 + 32 = 1870	1866 + 32 = 1898
No MDAC		1752 + 32 1784	1778 + 32 1810
No MARTIN		1894 + 32 1926	1924 + 32 1956

5/18/79
②

POWER PRODUCTION DURING BEST DAY

(BEST DAY THERMAL LOSSES)

	1.6 MW PARASITICS	$C_F = \left(\frac{76831}{78980}\right)$		1.8 MW PARASITICS	$C_F = \left(\frac{78028}{78980}\right)$
TIME	P_{INC} [UH] MW$_t$	$(P_{INC})*(CF)$ MW$_t$	P_{ABS} $[(P_{INC})(C_F)(.93) - 4.9]$	$(P_{INC} * CF)$ MW$_t$	P_{ABS} $[(P_{INC})(C_F)(.93) - 4.9]$
-6.28	16.588	16.137	10.107	16.388	10.34
-5.23	31.482	30.625	23.581	31.103	24.02
-4.18	41.260	40.137	32.427	40.763	33.01
-3.14	45.774	44.528	36.511	45.222	37.16
-2.09	49.858	48.501	40.206	49.257	40.91
-1.05	51.116	49.725	41.344	50.500	42.06
NOON	51.411	50.012	41.611	50.791	42.34
1.05	50.973	49.586	41.215	50.358	41.93
2.09	48.887	47.557	39.328	48.297	40.02
3.14	46.399	45.137	37.077	45.840	37.73
4.18	41.857	40.718	32.967	41.352	33.56
5.23	32.141	31.266	24.177	31.753	24.63
6.28	15.381	14.962	9.015	15.196	9.23

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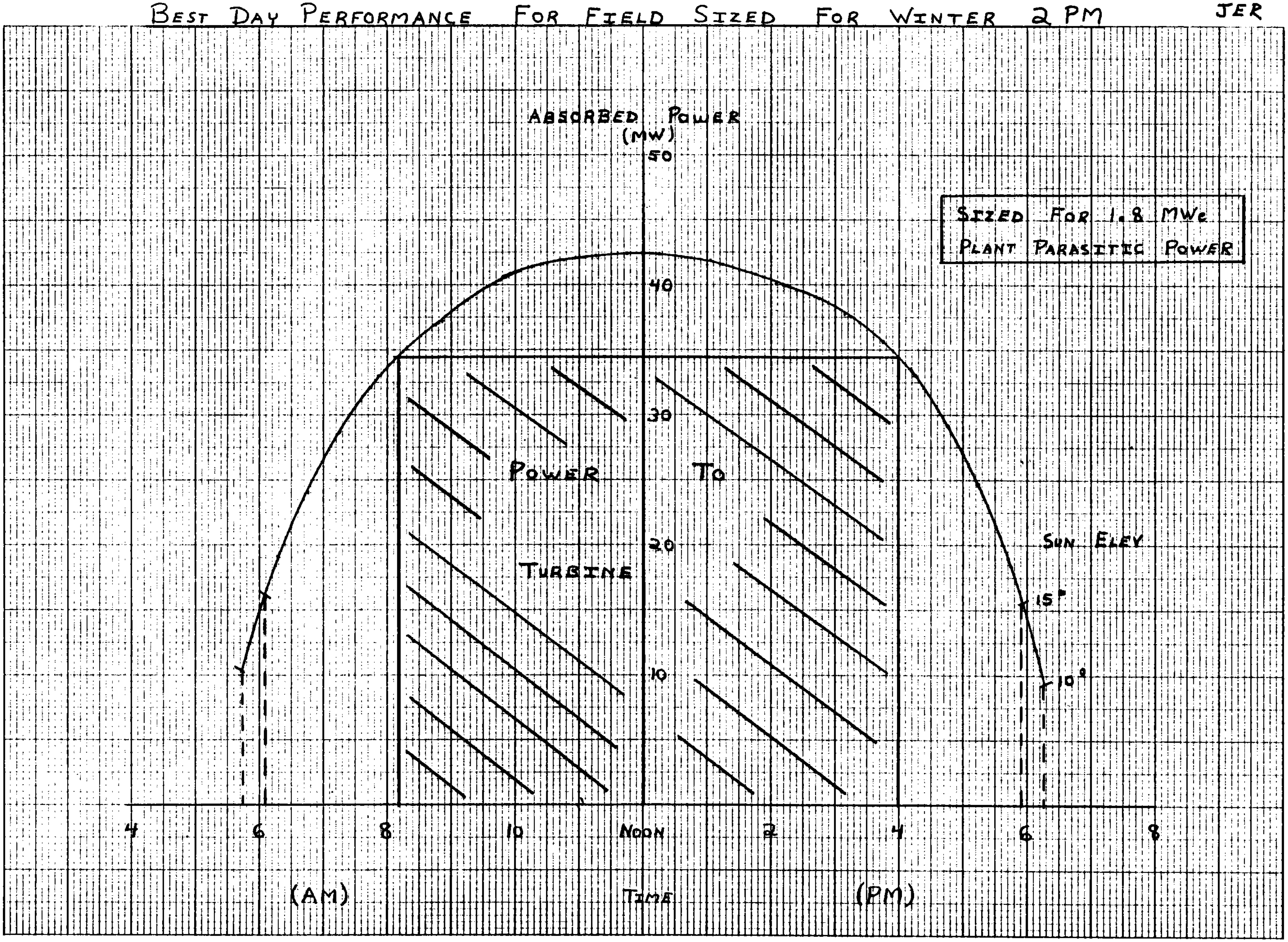
5/20/79
JER

3 OF 7

BEST DAY PERFORMANCE FOR FIELD SIZED FOR WINTER 2 PM



SIZED FOR 1.8 MWe PLANT PARASITIC POWER

5/20/79
4 OF 7

STORAGE SIZING (WINTER 2PM FIELD – SIZED FOR
1.6 MWe PLANT PARASIT

(10° SUN)

12.2 x .3
18.1 x .5
23.7 x .5
28.5 x .5
31.8 x .5
34.2 x .5
36.4 x .5
38.2 x .5
39.7 x .5
40.7 x .5
41.2 x .5
41.5 x .5
41.6 x .5 } →
41.5 x .5
41.2 x .5
40.8 x .5
40.2 x .5
39.3 x .5
38.2 x .5
37.0 x .5
35.1 x .5
32.5 x .5
29.0 x .5
24.2 x .5
18.0 x .5
11.6 x .3

423.44 MWHt

PWR TO TURB
(7.8HR)(33.8MW) = 263.64 MWH

PWR TO STOR = 159.8 MWHt

(15° SUN)

18.5 x .4

18.6 x .4

413.09 MWHt

PWR TO TURB
(7.8HR)(33.8 MW) = 263.64 MWH

PWR TO STOR = 149.45 MWH

5/20/79
5 OF 7

STORAGE SIZING (WINTER 2PM FIELD – SIZED FOR 1.8 MWe PLANT PARASITICS)

(10° SUN)	(15° SUN)
12.5 x .3	
18.4 x .5	19.1 x .4
24.1 x .5	
28.7 x .5	
32.2 x .5	
34.9 x .5	
37.0 x .5	
38.9 x .5	
40.4 x .5	
41.4 x .5	
41.9 x .5	
42.2 x .5	
42.4 x .5	→
42.3 x .5	
42.0 x .5	
41.5 x .5	
40.8 x .5	
40.0 x .5	
39.0 x .5	
37.5 x .5	
36.2 x .5	
38.0 x .5	
29.2 x .5	
24.7 x .5	
18.4 x .5	19.0 x .4
12.0 x .3	
433.40 MWHt	422.89 MWHt

PWR TO TURB =
(7.8 HR)(34.4 MW) = 268.32 MWHt

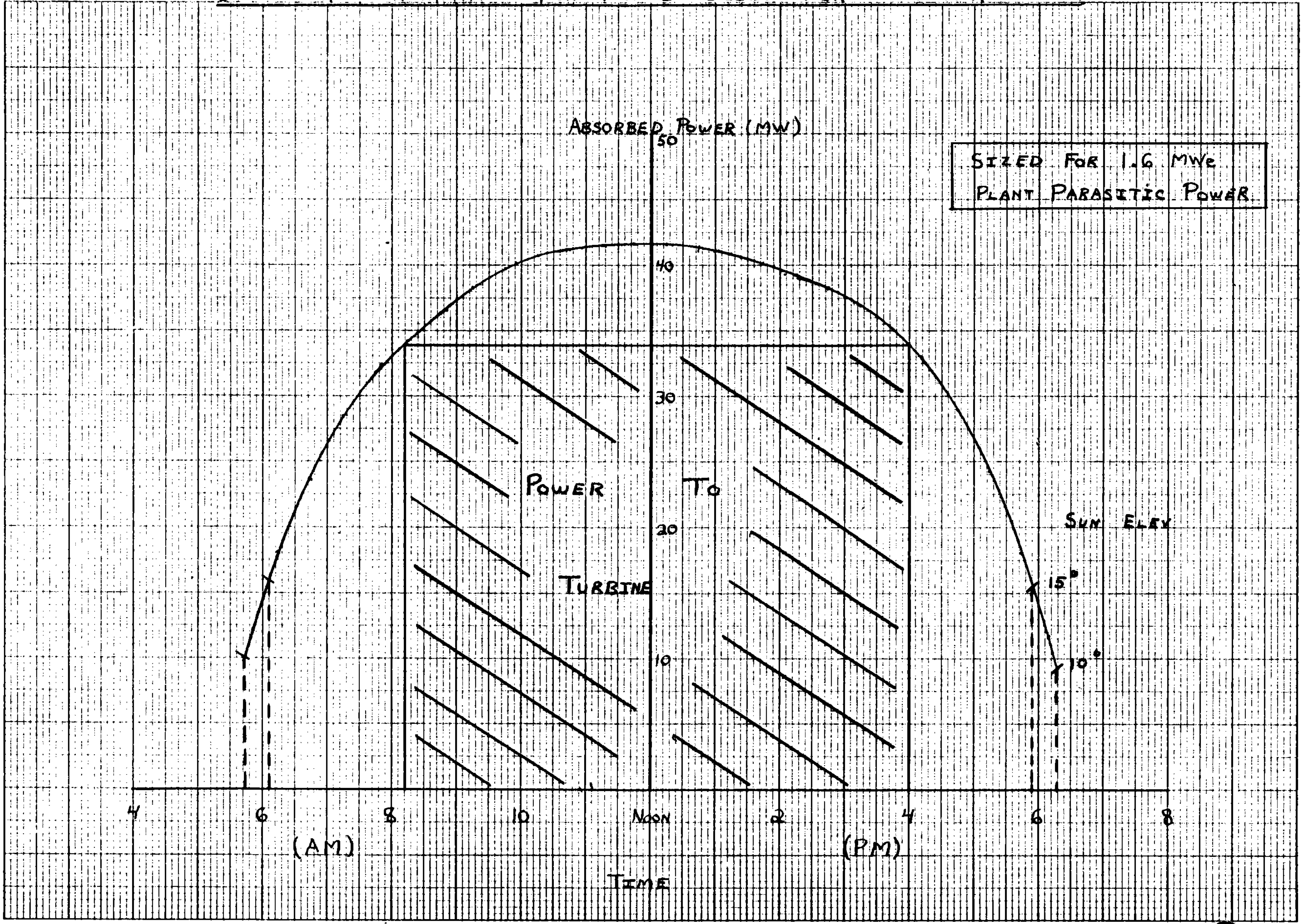
PWR TO STOR = 165.08 MWHt

PWR TO TURB =
(7.8 HR)(34.4 MW) = 268.32 MWH

PWR TO STOR = 154.57 MWHt

5/20/79
JER

BEST DAY PERFORMANCE FOR FIELD SIZED FOR WINTER 2 PM



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STORAGE SIZING SUMMARY

(BEST DAY CAPACITY FOR FIELD SIZED FOR WINTER 2PM)

	1.6 MWe PLANT PARASITICS		1.8 MWe PLANT PARASITICS	
	(10° SUN ELEV)	(15° SUN ELEV)	(10° SUN ELEV)	(15° SUN ELEV)
ENER. AVAILABLE FOR STOR.	159.8 MWH_t	149.5 MWH_t	165.1 MWH_t	154.6 MWH_t
ENERGY FOR • CONDITIONING • HEAT LOSS • ROLL AND LOAD TURB	11.8 MWH_t	11.8 MWH_t	11.8 MWH_t	11.8 MWH_t
ENERGY FOR 7.8 MWe TURBINE OPERATION	148.0 MWH_t	137.7 MWH_t	153.3 MWH_t	142.8 MWH_t
ELECTRICAL OUTPUT ($\eta_c = .2435$)	36.0 MWHe	33.5 MWHe	37.3 MWHe	34.8 MWHe
HOURS AT 7.8 MWe GROSS (7.0 MWe NET)	4.6 HR	4.3 HR	4.8 HR	4.5 HR
COLLECTOR FIELD HELIOSTAT REQ'TS	STMPO MARTIN MDAC	1870 1926 1784	STMPO MARTIN MDAC	1898 1956 1810

5/2/79
1 OF 13

COMPARISON BETWEEN SUMMER 8AM AND WINTER 2PM PERFORMANCE

	SUMMER 8 AM		WINTER 2 PM	
	PERFORMANCE	POWER	PERFORMANCE	POWER
ABSORBED POWER		33.8 MWt		33.8 MWt
ABSORB. PWR + 4.8 LOSSES		38.6 MWt		38.6 MWt
(RECEIVER ABSORPT.)	(.93)		(.93)	
(INTERCEPT) X (ATM ATTENUATION)	(.954)		(.954)	
(COSINE)	(.749)		(.7940)	
(BLOCK + SHADOW)	(.958)		(.9020)	
(REFLECT)	(.86)		(.86)	
IDEAL POWER		70.924 MWt		70.637 MWt
INSOLATION	898 W/m^2		917 W/m^2	
GLASS AREA	78980 m^2 (850,137 ft^2)		77,030 m^2 (829153 ft^2)	
No HELIO (450 FT^2)	1890		1842	
+ 32 HELIO	1922		1874	
MDAC			(.9528)(1874) = 1786	
MARTIN			(1.03097)(1874) = 1932	

5/2/79
2 of 3

COMPARISON BETWEEN SUMMER 8AM AND WINTER 2PM

PERFORMANCE

SUMMER LOSS

	SUMMER 8 AM		WINTER 2 PM	
	PERFORMANCE	POWER	PERFORMANCE	POWER
ABSORBED POWER		33.8 MWt		33.8 MWt
ABSORB. PWR + ~~4.8~~ 4.9 LOSSES		38.~~6~~7 MWt		38.6 MW
(RECEIVER ABSORPT.)	(.93)		(.93)	
(INTERCEPT) X (ATM ATTENUATION)	(.954)		(.954)	
(COSINE)	(.749)		(.7940)	
(BLOCK + SHADOW)	(.958)		(.9020)	
(REFLECT)	(.86)		(.86)	
IDEAL POWER		71.108 ~~70.924~~ MWt		70.637 MW
INSOLATION	898 W/m²		917 W/m²	
GLASS AREA	78980 m² (850,137 ft²)		77,030 m² (829153 ft²)	
No HELIO (450 FT²)	1894 ~~1890~~		1842	
+32 HELIO	1922 1926		1874	
MDAC	1926 (.9529)	1836		
MA[illegible]	19[illegible] (1.03097)	1986		

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COMPARISON BETWEEN SUMMER 8AM AND WINTER 2PM PERFORMANCE

WINTER LOSS

	SUMMER 8AM		WINTER 2 PM	
	PERFORMANCE	POWER	PERFORMANCE	POWER
ABSORBED POWER		33.8 MWt		33.8 MWt
ABSORB. PWR + ~~4.8~~ 4.7 LOSSES		38.6 MWt		38.5 ~~38.6~~ MWt
(RECEIVER ABSORPT.)	(.93)		(.93)	
(INTERCEPT) X (ATM ATTENUATION)	(.954)		(.954)	
(COSINE)	(.749)		(.7940)	
(BLOCK + SHADOW)	(.958)		(.9020)	
(REFLECT)	(.86)		(.86)	
IDEAL POWER		70.924 MWt		70.454 ~~70.637~~ MWt
INSOLATION	898 w/m²		917 w/m²	
GLASS AREA	78980 m² (850,137 ft²)		77,030 m² (829153 ft²)	
No HELIO (450 FT²)	1890		1838 ~~1842~~	
+32 HELIO	1922		~~1874~~ 1870	
MDAC			1870(.9528)	17[illegible] 8 2
MARTIN			1870(1.03[illegible])	192[illegible]

5/2/79
4 OF 13

SUMMER AND WINTER WINDS
(AVE VALUES)

$$\overline{V} = \frac{\Sigma V_i P_i}{\Sigma P_i}$$

V_i - VELOCITY
P_i - PROBABILITY

JUNE	DEC
.0429 x .9 m/SEC	.0929 x .9 m/SEC
.0767 x 2.6 m/SEC	.1034 x 2.6 m/SEC
.2007 x 4.4 m/SEC	.1366 x 4.4 m/SEC
.2147 x 6.95 m/SEC	.0487 x 6.95 m/SEC
.1331 x 9.8 m/SEC	.0119 x 9.8 m/SEC
.0538 x 13.4 m/SEC	.0085 x 13.4 m/SEC
.0032 x 18.25 m/SEC	.0008 x 18.25 m/SEC
$\Sigma P_i = .7251$	$\Sigma P_i = .4028$
$\Sigma V_i P_i = 4.697$	$\Sigma V_i P_i = 1.537$
$\overline{V} = \frac{4.697}{.7251} = 6.48$ m/SEC	$\overline{V} = \frac{1.537}{.4028} = 3.82$ m/SEC
$\overline{V} = 14.5$ mph	$\overline{V} = 8.5$ mph
$\overline{T} = 87°F$	$\overline{T} = 55°F$
$V_{REC} = 6.48\left(\frac{80}{10}\right)^{.15}$	$V_{REC} = 3.82\left(\frac{80}{10}\right)^{.15}$
$V_R = 8.85$ m/sec → 19.8 mph	$V_R = 5.22$ m/sec → 11.7 mph

5/2/79
5 OF 13

REF LOSS TEMP = 780°F   AREA FACTOR = 1.0976

WINTER LOSS

WIND SCALE FACTOR $= \frac{11.7}{10.93} = 1.070$

TEMP FACTOR $\frac{780-55}{780-73} = 1.025$

$$\text{LOSS} = 3.2(1.0976) + [.5^{(1.025)^{1/3}} + .5(1.070)^{.8}(1.025)]\,(1.0976)$$

$$3.512 + 1.147$$

$$= 4.66 \text{ MWt}$$

SUMMER LOSS

WIND FACTOR $= \frac{19.8}{10.93} = 1.812$

TEMP FACTOR $= \frac{780-87}{780-73} = .9802$

$$\text{LOSS} = 3.2(1.0976) + [.5(.9802)^{1/3} + .5(1.812)^{.8}(.9802)]\,(1.0976$$

$$3.512 + 1.411$$

$$= 4.92 \text{ MWt}$$

5/3/79
6 OF 13
REVISED
5/20/79

	10° SUN LIMIT	15° SUN LIMIT	
ENERGY AVAIL. FOR STORAGE	165.1 MWHt	156.2 MWHt	(REVISED)
ENERGY FOR · CONDITIONING · HEAT LOSS · ROLL & LOAD TURB	11.8 MWHt	11.8 MWHt	
ENERGY FOR 7.8MWe OPERATION	153.3 MWHt	144.4 MWHt	(REVISED)
TURBINE HEAT RATE 14,014 BTU/KWH $\eta_c = .2435$			
ELECTRICAL OUTPUT	37.3 MWHe	35.2 MWHt	(REVISED)
HOURS AT 7.8MWe GROSS (7 MWe NET)	4.8 HR	4.5 HR	(REVISED)

(BASED ON SYSTEM SIZED FOR 8 HOUR SUMMER OPERATION AT 10 MWe NET)

ANNUAL AVERAGE LOSS

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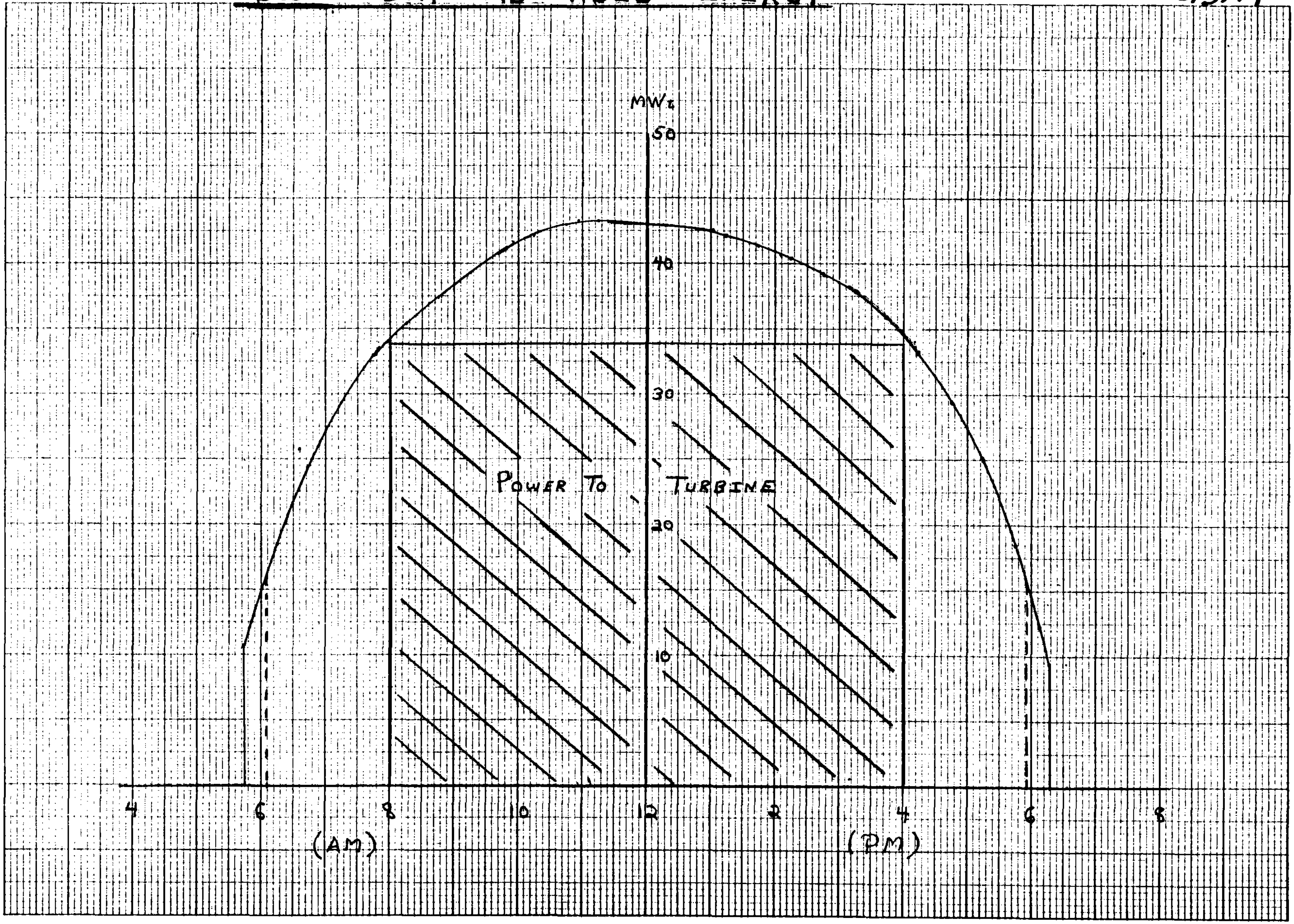
5/3/79

BEST DAY ABSORBED ENERGY



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REVISED
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THERMAL STORAGE SIZING

DAY 93	($P_{inc}/950$)	P_{INC}	P_{ABS} [P_{INC} ÷ .73 - 4.8]
NOON	.0520	51.376	42.98
1.05	.0514	50.937	42.57
2.09	.0502	48.845	40.63
3.14	.0488	46.409	38.36
4.18	.0461	41.813	34.09
5.23	.0395	32.153	25.10
6.28	.0286	15.358	9.48
-1.05		51.116	42.74
-2.09		49.858	41.57
-3.14		45.774	37.77
-4.18		41.260	33.57
-5.23		31.482	24.48
-6.28		16.588	10.63

(10° SUN)	(15°) SUN $\sum$(1/2 HR INCREM.)
6 12x.5	39.2
18.5 15.2	37.8
24.5	36.0
29.3	33.2
33.0	29.5
35.4	25.1
37.5	~~18.5~~ 15.2
39.3	6.1 ~~12.2x.5~~
41.0	871 ÷ 2 =
42.2	$\boxed{\text{435.5 MWHt UNDER CURVE}}$ 426 MWHt
43.0	
43.2	
43.0	
→ 43.0	
42.7	
42.1	
41.4	
40.5	

$\boxed{\text{ENERGY UNDER TURBINE CURVE} \quad 33.8 \times 8 = 270.4 \text{ MWHt}}$

ΔENERGY FOR EXTENDED OPER.

156.2

STORAGE CAPACITY = 165.1 MWHt

4/79
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	10° SUN LIMIT	15° SUN LIMIT
ENERGY AVAIL FOR STORAGE	109.3 MWH_t	97.8 MWH_t
ENERGY FOR · CONDITIONING · HEAT LOSS · ROLL + LOAD TURB	11.0 MWH_t	11.0 MWH_t
ENERGY FOR 7.8 MWe OPERATION	98.3 MWH_t	86.8 MWH_t

$\eta_{CYCLE} = .2435$

ELECTRICAL OUTPUT	23.94 MWHe	21.14 MWHe
HOURS AT 7.8 MWe GROSS (7 MWe NET)	3.1 HR	2.7 HR

(BASED ON SYSTEM SIZED FOR 4 HOUR WINTER OPERATION AT 10 MWe NET) – ANNUAL AVERAGE LOSS MODEL

5/4/79
10 OF 13

THERMAL STORAGE SIZED FOR 4 HOUR WINTER DAY

INSOLATION	TIME	INCID PWR (MWt)	(1874/1922) SCALED INCIDENT PWR (MWt)	[.93 - 4.8] ABSORBED POWER (MWt)
967	NOON	48.482	47.27	39.16
964	.64	48.016	46.82	38.74
953	1.28	46.547	45.38	37.41
924	1.92	43.447	42.36	34.60
		2.00 → 42.765		
873	2.56	37.921	36.97	29.58
793	3.20	30.154	29.40	22.54
625	3.85	19.784	19.29	13.14
962	-.64	47.916	46.72	38.65
953	-1.28	46.547	45.38	37.41
925	-1.92	43.494	42.41	34.64
784	-2.56	38.399	37.44	30.02
803	-3.20	30.534	29.77	22.89
686	-3.85	21.715	21.17	14.89

5/4/79
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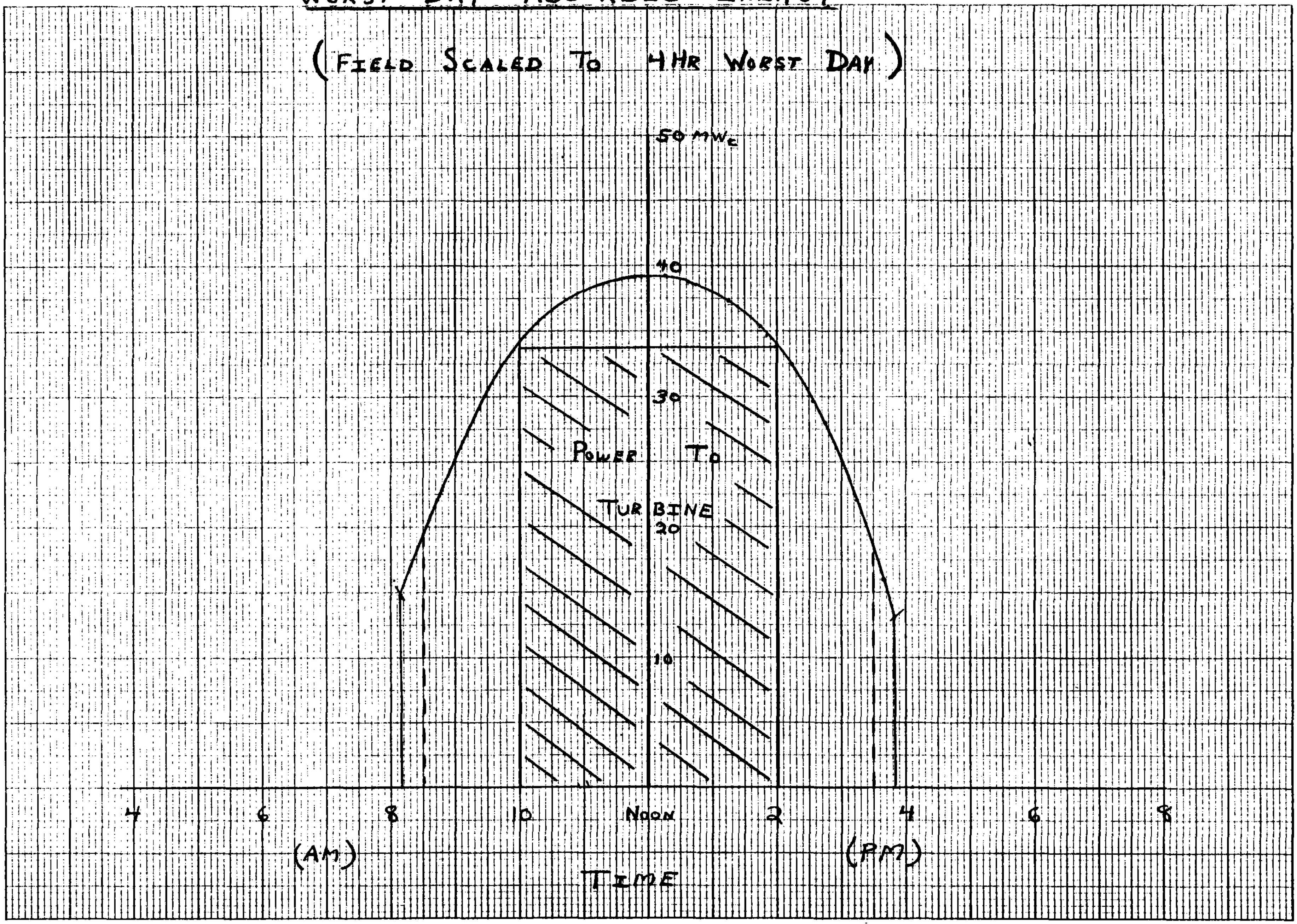
WORST DAY ABSORBED ENERGY

(FIELD SCALED TO 4 HR WORST DAY)



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THERMAL STORAGE SIZING

(SIZED FOR 4 HOUR WORST DAY OPERATION)

ΣP_{ABSORB}

11.1
22.3
27.8
32.5
35.5
37.5
38.5
39.1
39.2
38.5
37.2
35.4
32.5
28.0
22.0
11.8

15° SUN (22.3 – 22.0)
10° SUN (11.1 – 11.8)

466
4?1.1

15° SUN

$\frac{466}{2} = 233\ MWH_t$

10° SUN

$\frac{489.1}{2} = 244.5\ MWH_t$

TOTAL COLLECTION

TURBINE DEMAND

33.8 X 4HR = 135.2 MWH

ENERGY FOR STORAGE

(15°) 233 - 135.2 = 97.8 MWH_t

(10°) 244.5 - 135.2 = 109.3 MWH_t

5/4/79
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NUMBER OF HELIOSTATS

CONDITION	STMPO	MARTIN	MDAC
SUMMER 8AM			
• AVE ENVIRON (1)	1922	1982	1832
• AVE JUNE ENVIR (2)	1926	1986	1836
WINTER 2PM			
• AVE ENVIRON (1)	1874	1932	1786
• AVE DEC. ENVIR. (3)	1870	1928	1782

(1) 11.7 mph 73°F ANNUAL AVE

(2) 14.5 mph 87°F SUMMER DAY AVE

(3) 8.5 mph 55°F WINTER DAY AVE

MISCELLANEOUS PLANT CALCULATIONS

8/16/80
1 OF 6

ESTIMATED BLEED STEAM CONDITIONS ENTERING CONDENSER

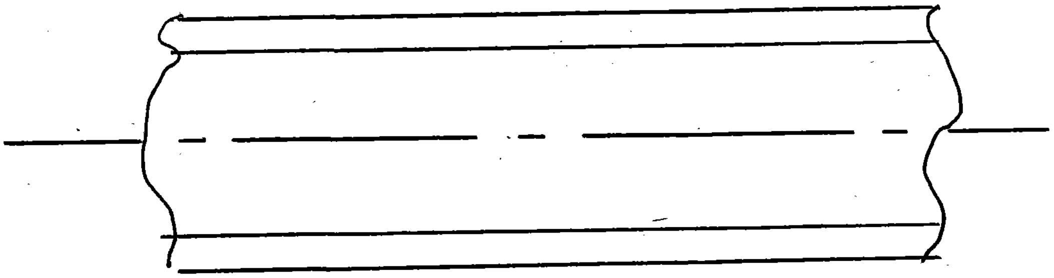
1. PROBLEM: DEFINE THE STEAM TEMPERATURE ENTERING THE CONDENSER FROM

(1) BLEED FLOW FROM RECEIVER FLASH TANK
(ASSUMED 300 LB/HR INITIALLY @ 960°F,
1500 psia → h = 1465 BTU/LB)

(2) FLOW LEAKAGE THROUGH PV-1001
150 LB/HR INITIALLY @ 950°F
1465 psia → h = 1465 BTU/LB

WHICH EXPANDS TO CONDENSER PRESSURE
2.5 IN HG h = 1465 BTU/LB → T ≈ 870°F

2. HEAT LOSS THROUGH STEAM DUMP PIPE



10" PIPE
2½" INSULATION

ASSUME ALL FLOW IS
INTRODUCED AT OR
NEAR THE DESUPERHEATER

8/16/80
2 OF 6

REVIEW OF HEAT LOSS THROUGH STEAM DUMP LINE

$Q = (UA)\Delta T$

$$UA = \frac{1}{\left[\frac{1}{(h_{STEAM})\pi D_i L} + \frac{\ln(R_2/R_1)}{k\,2\pi L} + \frac{1}{(h_{amb})(\pi)D_{OUTSIDE}(L)}\right]}$$

ASSUME

$h_{STEAM} = 1.0$ BTU/HR-FT^2-°F (REF $0.85 \rightarrow 1.12$ BTU/HR-FT^2-°F STEVE McCORMICK CALC

NEGLECT TEMP DROP ACROSS PIPE ($k_{pipe} \rightarrow$ LARGE)

D_i = INSIDE PIPE DIAMETER = 0.835 FT

$D_{OUTSIDE}$ = OUTSIDE INSULATION DIAMETER = 15.75 IN
= 1.3125 FT

R_1 = INSIDE INSULATION DIAMETER = 5.01 IN

R_2 = $D_{OUTSIDE}/2$ = 7.875 IN

$h_{amb} = 1.45$ BTU/HR-FT^2-°F

$k = 0.04$ BTU/HR-FT-°F

$$UA = \frac{1}{\left[\frac{1}{(1.0)(\pi)(.835)(73)} + \frac{\ln\left(\frac{7.875}{5.01}\right)}{(.04)(2\pi)(73)} + \frac{1}{(1.45)(\pi)(1.3125)(73)}\right]}$$

$$UA = \frac{1}{5.222\times10^{-3} + 2.465\times10^{-2} + 2.29\times10^{-3}}$$

00 01 02

$UA = 31.09$ BTU/HR-°F

8/16/80
3 OF 6

REFERENCE PIPING DISTANCE

2½" INSULATION PORTION FROM STATION ⑷⑹⓪ TO ⑸②⑸

LENGTH

2' 6"
6' 6"
6' 3"
2' 6"
10' 6"
1' 6"
6' 9"
1' 6"
12' 0"
8' 6"
21' 6"
2' 0"
5' 0"
6' 0"
2' 0"

95' 0"

INTERFACE 22 FT UPSTREAM OF CONDENSER INTERFACE

PIPE LENGTH TO INTERFACE

95-22 FT = 73 FT

$$Nu_D = Re_D \, Pr^{1/3} \, f/8$$

$$Re_D = \frac{\rho V D}{\mu}$$

$\rho = .00133 \ LB/FT^3$

$D = .835 \ FT$

$\mu = 1.64 \times 10^{-5} \frac{(LB)}{(SEC)(FT)}$

$$V = \frac{\dot{m}}{\rho A} = \frac{450 \ LB/HR}{(.00133)(.574)(3600)}$$

$V = 164 \ FT/SEC$

$$Re_D = \frac{(.00133)(164)(.835)}{1.64 \times 10^{-5}} = 11106$$

$f = .018$ FROM CRANE

$$h = \frac{k}{D} \, Re \, P_r^{1/3} \, \frac{f}{8}$$

$$= \left(\frac{9.2 \times 10^{-3}}{.835}\right)(11106)\left(\overset{1}{\cancel{P_r}}\right)^{1/3} \frac{.018}{8}$$

$h = .275 \ BTU/HR\text{-}FT^2\text{-}{}^\circ F$

OUTSIDE CONVECTION

5 mph WIND = 7.33 FT/sec

$\rho = 0.0765 \ LB/FT^3$

$\mu = 0.046 \frac{LB}{FT\,HR} = 1.278 \times 10^{-5} \frac{LB}{FT\,SEC}$

$D_o = 1.3125 \ FT$

$$\frac{D_o G}{\mu_f} = \frac{(1.3125 \ FT)(0.0765 \ LB/FT^3)(7.33 \ FT/SEC)}{1.278 \times 10^{-5} \ LB/FT\text{-}SEC}$$

$$= 5.76 \times 10^4$$

$$\frac{h_m D_o}{k} = 121$$

$$h_m = \frac{k}{D}(121)$$

$$= (121)\left(\frac{.0157}{1.3125}\right) = 1.45 \frac{BTU}{HR\text{-}FT^2}$$

8/16/80
4/ DF

$Q_{LOSS} = UA\,\Delta T$

$= (31.09)(870-110) \quad = 2.362 \times 10^4$ BTU/HR $\quad (\bar{T} = 870°$

$= (31.09)(820-110) \quad = 2.207 \times 10^4$ BTU/HR $\quad (\bar{T} = 820°$

$= (31.09)(770-110) \quad = 2.052 \times 10^4$ BTU/HR $\quad (\bar{T} = 770°$

$= (31.09)(720-110) \quad = 1.896 \times 10^4$ BTU/HR $\quad (\bar{T} = 720°F$

$= (31.09)(670-110) \quad = 1.741 \times 10^4$ BTU/HR $\quad (\bar{T} = 670°F$

$= (31.09)(620-110) \quad = 1.586 \times 10^4$ BTU/HR $\quad (\bar{T} = 620°F)$

$= (31.09)(840-110) \quad = 2.269 \times 10^4$ BTU/HR $\quad (\bar{T} = 840°$

$Q_{STEAM} = \dot{m}\, C_p\, \Delta T$

$$= (450\ ^{LB}/_{HR})(0.5\ ^{BTU}/_{LB\text{-}°F})(T_{IN} - T_{OUT}) \rightarrow (T_{IN} - 2T_{AVE} + T_{IN}) \rightarrow 2(T_{IN} - T_{AVE})$$

Q_{STEAM}	$\bar{\bar{T}}$
0 BTU/HR	870 °F
2.25×10^4	820 °F
4.5×10^4	770 °F
1.35×10^4	840 °F

8/16/80
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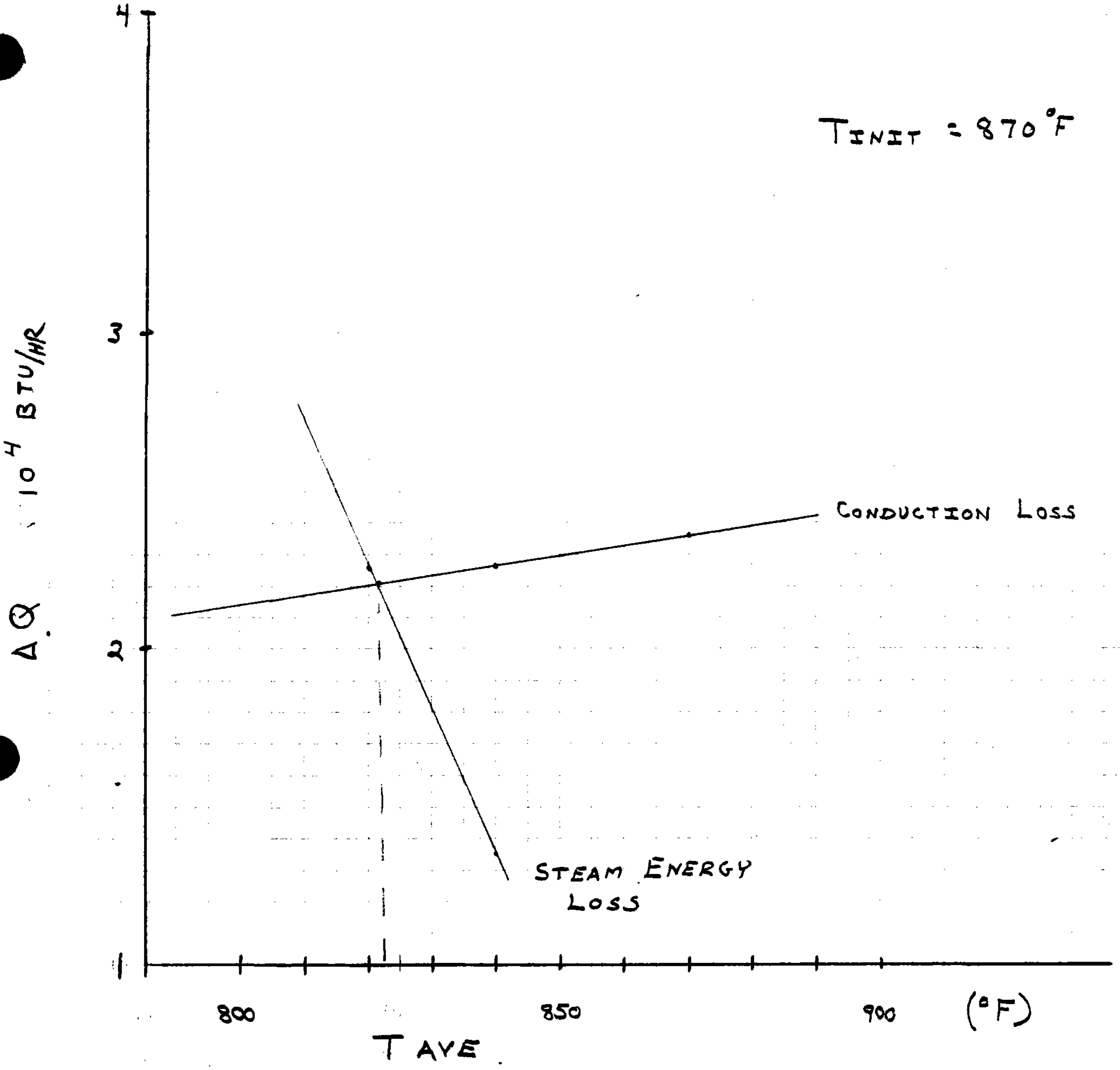


$\therefore$ $\underline{T_{AVE} = 822\,°F}$ ⟶ STEAM AT JOINT POINT
= 774 °F
@ INTERFACE ⟨60⟩

$Q_{LOSS} = 2.21 \times 10^4 \; BTU/HR$

AVE PIPE TEMP

$$UA = \frac{1}{\left[\frac{1}{h_{STEAM}\, \pi\, D_i\, L}\right]} = \frac{1}{\frac{1}{(1.0)\pi(.835)(73)}} = 191.5 \; BTU/_{HR\text{-}°F}$$

$$\Delta T = \frac{Q}{UA} = \frac{2.21 \times 10^4 \; BTU/HR}{191.5 \; BTU/_{HR\text{-}°F}} = 115\,°F \quad \text{FILM TEMP DROP}$$

8/16/80
6 OF 6

PIPE TEMP AT AVE POINT = 822-115 = 707 °F

PIPE TEMP AT INTERFACE ⟨60⟩ LOCATION = 774-115 °F = 659°

7/7/80
1 OF 11

DAN

HERE IS THE INFORMATION YOU REQUESTED FOR THE AEROSPACE PLANT PERFORMANCE COMPUTER PROGRAM. IT COVERS ALL OF THE PARAMETERS YOU MENTIONED ON THE PHONE. MOST OF THESE WERE FAIRLY OBVIOUS WITH THE EXCEPTION OF ITEM No 5 "ENERGY STORAGE SYSTEM STARTUP REQUIREMENT". IF YOU HAVE QUESTIONS, GIVE ME A CALL.

John Raetz

7/5/80
2 OF 11

INPUTS FOR AEROSPACE PILOT PLANT PERFORMANCE COMPUTER PROGRAM

1. TOTAL HELIOSTAT REFLECTOR AREA

$$(430\ FT^2)(1818)(1-.0123) = \boxed{772125\ FT^2}$$

1.23% AREA LOSS DUE TO EDGE SEALS

2. RADIATION AND CONVECTION LOSS

$\boxed{4.7\ MW_t}$

ASSUMPTIONS:

1. AMBIENT TEMP = 55°F
2. WIND SPEED = 8.5 mph

} AVERAGE WINTER CONDITION

3. MAIN STEAM DOWNCOMER PIPE

- $\boxed{L \simeq 478\ FT}$ (LENGTH FROM RECEIVER MANIFOLD TO TURBINE INLET)
- $\boxed{OD = 6.625\ IN \quad ID = 4.897\ IN}$ (6 IN DOUBLE EXTRA STRONG PIPE)
- THERMAL LOSS

  $\boxed{0.1\ MW_t}$

7/5/80
3 OF 11

- PUMPING POWER

(SEE FIGURE 1)

4. ADMISSION STEAM PIPING

- $\boxed{155.87 \text{ FT}}$ (TURBINE TO SUPERHEATER E-307)

  $\boxed{129.86 \text{ FT}}$ (TURBINE TO SUPERHEATER E-308)

- $\boxed{OD = 6.625 \text{ IN} \quad ID = 5.761 \text{ IN}}$

  (6 IN SCH 40 PIPE)

- $\boxed{LOSS = .015 \text{ MW}_T}$

NOTE: THE FOLLOWING DESIGN REVISION IS IN PROGRESS

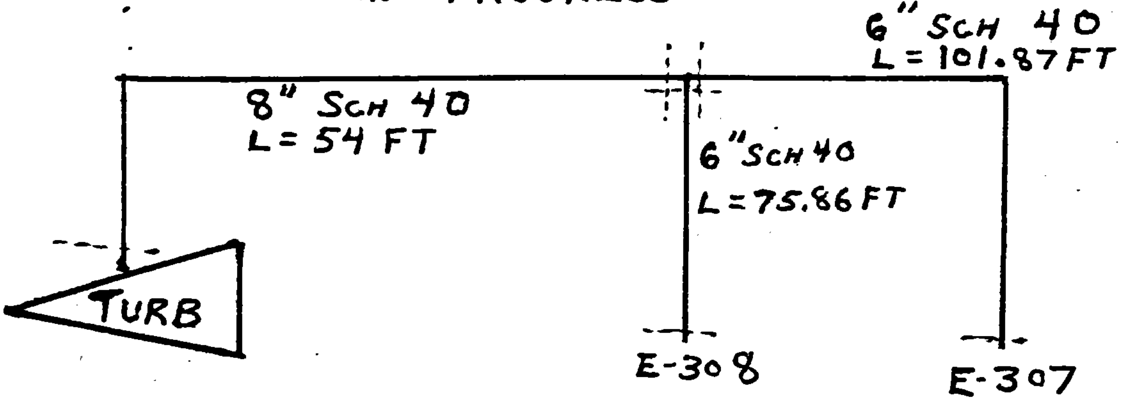
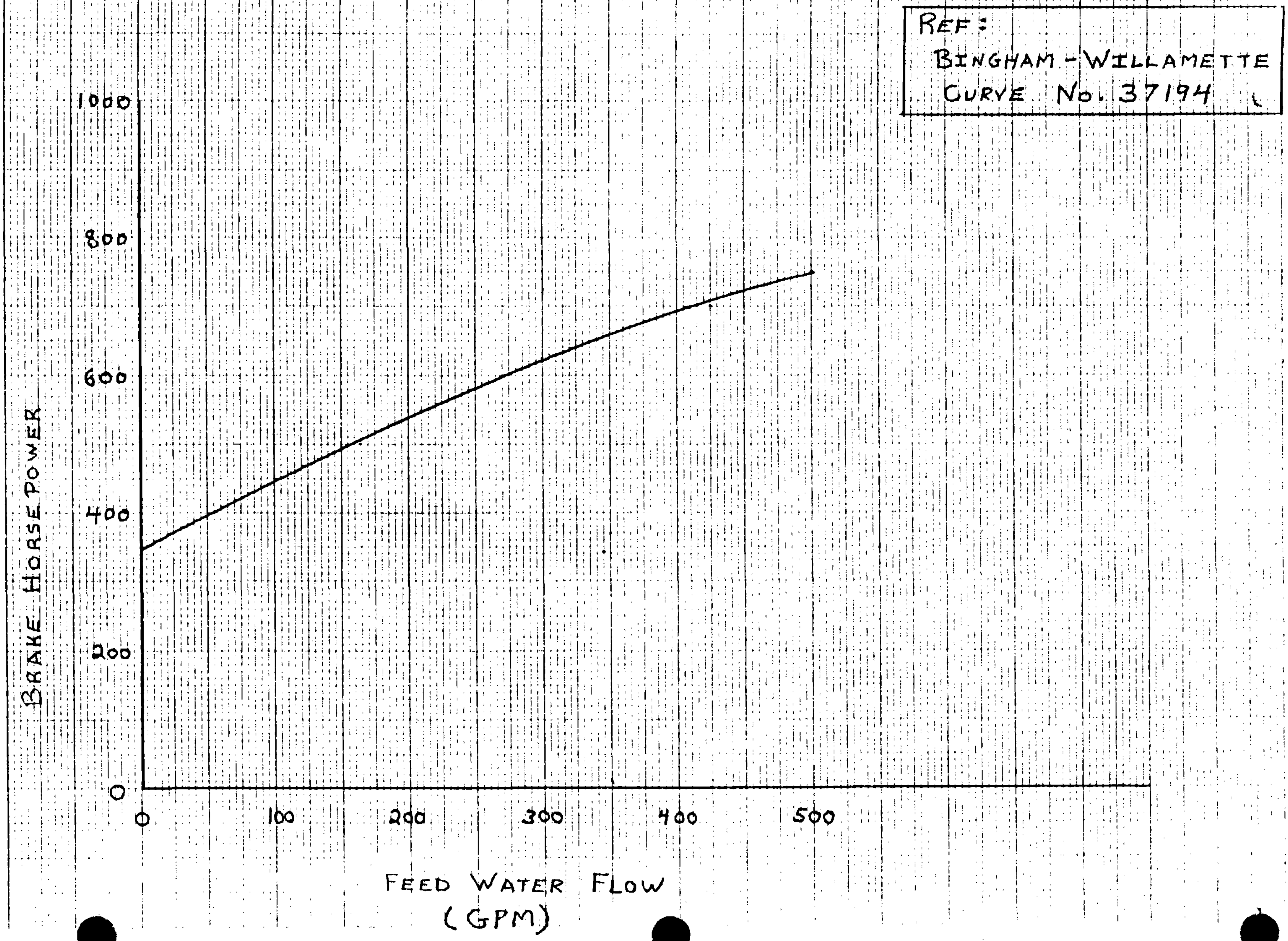


FIG 1. RECEIVER FEED PUMP POWER REQUIREMENTS



7/5/80
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5. ENERGY STORAGE SYSTEM

- STARTUP REQUIREMENT
  (NOT SURE WHAT THIS IS!)

ASSUME IT IS THERMAL STORAGE ENERGY REQUIRED TO START THE TURBINE FROM ADMISSION STEAM

15 MWH_t^* (WARM TURBINE)
7.2 MWH_t^* (HOT TURBINE)

* ESTIMATED VALUES — NO ADMISSION STEAM STARTUP GUIDELINES AND PROCEDURE HAVE YET BEEN SUPPLIED BY GE.

- THERMAL LOSS

THERMAL STORAGE TANK

2% ENERGY LOSS PER 20 HR HOLD

CHARGING OIL LOOP

0.5% POWER LOSS DURING CHARGING LOOP OPERATING PERIODS (APPLIES TO FULL LOAD)

EXTRACTION OIL LOOP

0.5% POWER LOSS DURING EXTRACTION LOOP OPERATING PERIODS (APPLIES TO FULL LOAD)

7/5/80
6 OF 11

6. EPGS

- TURBINE RATING (GENERATOR OUTPUT)

12.5 MWe
13.4 MWe MAX OUTPUT

- MINIMUM OPERATING POWER

2 MWe GENERATOR OUTPUT

(ESTIMATED VALUE FOR CONTINUOUS DUTY)

- GROSS CYCLE EFFICIENCY

$\boxed{35.19\%}$ @ 12.5 MWe OUTPUT

RECEIVER STEAM ONLY
(112,140 LB/HR)

$\boxed{25.36\%}$ @ 8.001 MWe OUTPUT

ADMISSION STEAM ONLY
(105,000 LB/HR)

$\boxed{30.48\%}$ @ 10.358 MWe OUTPUT

RECEIVER + ADMISSION STEAM
57,500 LB/HR RECEIVER STEAM
52,500 LB/HR ADMISSION STEAM

REF: GE STEAM TURBINE PROPOSAL
(SCE TRANSMITAL LETTER 9/26/79)

7/5/80
7 OF 11

- PARASITIC POWER ESTIMATE

  SEE TABLE 1

  NOTE : TABLE 1 <u>INCLUDES</u> THE RECEIVER FEED PUMP + ALL OTHER PARASITIC LOADS. BE SURE NOT TO DOUBLE COUNT THE FEED PUMP SINCE IT WAS ALREADY PRESENTED IN FIGURE 1.

  PARASITIC LOAD ESTIMATES ARE FOR "FULL POWER" OPERATION WITHIN EACH OPERATING MODE. AT PART POWER, SOME EQUIPMENT MAY BE SHUT DOWN.

7. COLLECTOR FIELD / RECEIVER

- COSINE
  (SEE TABLE 2)

- BLOCKING AND SHADOWING
  (SEE TABLE 3)

TABLE 1

PLANT PARA 'TIC LOAD ESTIMATE (KW) 1 '29/79

	MODE 1	2	3	4	5	6	7	8
COLLECTOR SYSTEM*	54	54	54	54	54	—	54	—
MCC "A" & MCC "L"								
SCE ROTATING EQUIP.	1097	1097	1220	1220	1097	630	1220	139
SFDI, CONTROL, DAS & EQUIP. ROOMS	40	40	40	40	40	40	40	40
WAREHOUSE ‡	22	22	22	22	22	22	22	2.8
SCE CONTROL BLDG, AUX BAY A/C, LIGHTING, OTHER.	100	100	100	100	100	100	100	100
SCE ADMINIST. BLDG	90	90	90	90	90	90	90	30
MCC "B" (TSS)	13	337	337	661	337	337	661	38.3
MCC "C" (WATER TR.)	149.7	149.7	149.7	149.7	149.7	149.7	149.7	85.0
PPA (RECEIVER)	25.6	25.6	25.6	25.6	25.6	20.0	25.6	44.0
OTHER **	100	100	100	100	100	60	100	50
TOTALS	1691	2015	2138	2462	2015	1449	2462	529

* MDAC FIELD @ .85 P.F. (AVG)
OR MMC FIELD @ .92 P.F.

** [illegible]HER INCLUDES: (SPECIAL DAS INST [illegible]80), BCS, WEATHER STATION, I FORGETS, 6KW

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TABLE 2. COLLECTOR FIELD COSINE

APPROX CALENDAR DAY

```
                      UANNUAL SUMMARY OF COSINES , UNIVERSITY OF HOUSTON
                      U     HOUR =*   0.       1.05     2.09     3.14     4.18     5.23     6.28
(JUNE 21)              DAY =  93      0.8400   0.8339   0.8158   0.7865   0.7471   0.6996   0.6466
                      U     HOUR =    0.       1.02     2.04     3.06     4.07     5.09     6.11
(MAY 21/JULY 21)       DAY = 124      0.8429   0.8370   0.8195   0.7910   0.7526   0.7061   0.6538
                      U     HOUR =    0.       0.95     1.90     2.85     3.81     4.76     5.71
(APR 21/AUG 21)        DAY = 155      0.8477   0.8424   0.8264   0.8004   0.7652   0.7220   0.6727
                      U     HOUR =    0.       0.86     1.72     2.59     3.45     4.31     5.17
(MAR 21/SEPT 21)       DAY = 186      0.8484   0.8439   0.8305   0.8085   0.7785   0.7415   0.6987
                      U     HOUR =    0.       0.77     1.53     2.30     3.06     3.83     4.60
(FEB 21/OCT 21)        DAY = 216      0.8427   0.8392   0.8287   0.8115   0.7879   0.7585   0.7241
                      U     HOUR =    0.       0.68     1.36     2.04     2.71     3.39     4.07
(JAN 21/NOV 21)        DAY = 246      0.8343   0.8316   0.8236   0.8105   0.7925   0.7699   0.7431
                      U     HOUR =    0.       0.64     1.28     1.92     2.56     3.20     3.85
(DEC 21)               DAY = 276      0.8303   0.8279   0.8209   0.8094   0.7936   0.7737   0.7500
```

TABLE 3. COLLECTOR FIELD BLOCKING AND SHADOWING

```
U     HOUR =*   0.       1.05     2.09     3.14     4.18     5.23     6.28
 DAY =  93      0.9909   0.9852   0.9822   0.9885   0.9849   0.9174   0.7507
U     HOUR =    0.       1.02     2.04     3.06     4.07     5.09     6.11
 DAY = 124      0.9874   0.9843   0.9827   0.9887   0.9836   0.9135   0.7498
U     HOUR =    0.       0.95     1.90     2.85     3.81     4.76     5.71
 DAY = 155      0.9836   0.9832   0.9852   0.9904   0.9816   0.9054   0.7418
U     HOUR =    0.       0.86     1.72     2.59     3.45     4.31     5.17
 DAY = 186      0.9864   0.9867   0.9893   0.9912   0.9695   0.8879   0.7321
U     HOUR =    0.       0.77     1.53     2.30     3.06     3.83     4.60
 DAY = 216      0.9912   0.9917   0.9912   0.9811   0.9460   0.8607   0.7208
U     HOUR =    0.       0.68     1.36     2.04     2.71     3.39     4.07
 DAY = 246      0.9831   0.9825   0.9733   0.9554   0.9075   0.8226   0.7203
U     HOUR =    0.       0.64     1.28     1.92     2.56     3.20     3.85
 DAY = 276      0.9717   0.9703   0.9602   0.9385   0.8898   0.8114   0.7201
```

* "HOURS" MEASURED FROM NOON (SYMMETRIC MORNING AND AFTERNOON)

7/5/80
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- RECEIVER SHADOW

$\boxed{0.67\ \%}$ OF HELIOSTAT AREA SHADOWED BY RECEIVER AND TOWER (ANNUAL AVERAGE VALUE, MIDDAY FROM EQUINOX THRU SUMMER, THE RECEIVER SHADOW FACTOR = 0)

- EDGE LOSSES

$\boxed{0.}$ (NO EDGE LOSS)

WOULD BE NON ZERO ONLY FOR SINGLE AXIS TRACKING COLLECTORS SUCH AS PARABOLIC CYLINDERS

- HELIOSTAT REFLECTIVITY

$\boxed{0.89}$ CLEAN

- ATMOSPHERIC LOSS FRACTION

$\boxed{3\ \%}$ ANNUAL AVERAGE LOSS

- RECEIVER INTERCEPTION FACTOR

$\boxed{0.976}$ (FRACTION OF REDIRECTED SUN LIGHT ACTUALLY STRIKING THE RECEIVER)

7/5/80
11 OF 11

- SECONDARY CONCENTRATOR EFFICIENCY

100 %	(NO SECONDARY CONCENTRATOR)

8. RECEIVER SURFACE

- TRANSMISSIVITY

100 %	(NO TRANSPARENT COVER OVER RECEIVER)

- ABSORPTIVITY

95 %	(PYROMARK ABSORPTIVE COATING)

1/14/80
1 OF 14

PLACEMENT OF MAIN STEAM PRESSURE CONTROL POINT

OBJECTIVE: DEFINE THE PROPER LOCATION FOR THE MAIN STEAM PRESSURE CONTROL POINT SUCH THAT ≥1465 psia CAN BE MAINTAINED AT THE INLETS TO THE TURBINE AND THERMAL STORAGE CHARGING CONTROL VALVE. ALSO DEFINE THE MAXIMUM PRESSURE TO BE EXPERIENCED AT THE TURBINE AND THERMAL STORAGE CHARGING INLET CONTROL VALVE DURING LOW FLOW CONDITIONS

CASES CONSIDERED:

(i) PRESSURE CONTROL POINT IMMEDIATELY UPSTREAM OF THE TURBINE INLET

(ii) PRESSURE CONTROL POINT IMMEDIATELY UPSTREAM OF THE THERMAL STORAGE CHARGING INLET VALVE (UV-3102)

(iii)* PRESSURE CONTROL POINT AT SPLIT POINT WHERE TURBINE, THERMAL STORAGE CHARGE, AND STEAM DUMP FLOWS SEPARATE
(140 FT UPSTREAM OF TURBINE)
(160 FT UPSTREAM OF TS CHARGING CONTROL VALVE)

* SELECTED DESIGN APPROACH

STEAM PIPING CALC

1/14/80
2 OF 14

1. SPLIT TO TURBINE INLET

LOCATION	LENGTH	BEND		
175				
		B	(45°)	
	10.88 ft			
180				
		B	(45°)	
	1.77 ft			
182				
	11.20 ft			
		B	(90°)	
185				
	9.56 ft			
		B	(90)	
190				
	3.00 ft			
195				
205				
	2.00 ft			
210				
	2.00 ft			(MOV-MS-2-2)
215				
	4.00 ft			
220				
	19.00 ft			
		B	(90°)	
235				
	14.42 ft			
		B	(90°)	
240				
	7.00 ft			
		B	(90°)	
250				
	4.50 ft			
255				
	20.00 ft			
260				
		B	(90°)	
	4.50 ft			
270				
		B	(90°)	
	8.00 Ft			
285				
	2.00 FT			(MSSV)
287				
	12.00 FT			
		B	(90°)	
295				
	4.00 FT			

SUMMARY SPLIT TO TURBINE

1/14/80
3 OF 14

TOTAL LENGTH = 139.83 FT (4 FT FOR VALVES)

RT ANGLE BENDS = 8

45° ANGLE BENDS = 2

FROM PAGE 5 → $\Delta P_{FR} = 17.82$ psi

$\Delta P_{K} = 22.68$ psi

$\Delta P_{TOTAL} = 40.50$ psi

@ ~950 °F 1465 psia (1500 psia)

$\overline{V} = .515\ FT^3/LB$

$\dot{w} = 115{,}000\ LB/HR$

1/14/80
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2. SPLIT TO THERMAL STORAGE CHARGE CONTROL VALVE

LOCATION	LENGTH	BEND	
175			
	1.5		
		B (45°)	
200			
	6.21		
		B (45°)	
205			
	14.36		
		B (90°)	
210			
	9.56		
		B (90°)	
215			
	3.00		
220			
315	~~2.00~~		
	2.00		
320			
	2.00		MOV-MS-3-1
325			
	23.00		
345			
		B (90°)	
	14.42		
		B (90°)	
350			
	7.00		
		B (90°)	
360			
	39.92		
		B (90°)	
380			
	3.06		
		B (90°)	
385			
	20.00		
		B (90°)	
390			
	10.89		
		B (90°)	
395			
	4.00		

400 (1 FT PAST INTERFACE 1I)

1/14/80
5 OF 14

SUMMARY SPLIT TO TS CHARGE

TOTAL LENGTH = 160.92FT (2 FT FOR VALVE MOV-MS-3-1

RT ANGLE BENDS = 9

45° ANGLE BENDS = 2

DATA : ID = 4.897 IN

$$\Delta P_{FR\ (PIPE)} = \frac{(3.4\times10^{-6})(f)(L)(\dot{w})^2(\bar{V})}{d^5}$$

$$\Delta P_K = \frac{(2.8\times10^{-7})(\bar{V})(\dot{w})^2(K)}{d^4}$$

K FACTOR	To TURBINE	To TS
	8 – RT ANG @ .75 = 6	9 – RT ANG @ .75 = 6.75
	2 – 45° ANG @ .42 = .84	2 – 45° ANG @ .42 = .84
	(NEGLECT VALVE)	(NEGLECT VALVE)
	TOTAL = 6.84	TOTAL = 7.59

TURBINE LEG REF

$\bar{V}$ = .515 FT^3/LB

$\Delta P = \Delta P_{FR} + \Delta P_K$

f = .0155

$\dot{w}$ = 115,000 LB/HR

$$\Delta P_{FR} = \frac{(3.4\times10^{-6})(.0155)(139.83FT)(115,000)^2(.515)}{(4.897)^5}$$

$$= \underline{17.82\ psia}$$

$$\Delta P_K = \frac{(2.8\times10^{-7})(.515)(115\,000)^2(6.84)}{(4.897)^4}$$

$$= \underline{22.68\ psia}$$

$$\boxed{\Delta P_{TOTAL} = 40.50\ psia\ \text{TOTAL}}$$

$$\bar{K}_1 = \frac{(\Delta P_{TOTAL})}{\dot{w}^2\ \bar{V}} = \frac{40.5\,psia}{(115\,000)^2\ (.515)} = 5.946\times10^{-9}$$

1/14/80
7 OF 14

TS CHARGE LEG

$\bar{V} = .342 \ \mathrm{FT^3/LB}$ 130,000 LB/HR

$$\Delta P_{FR} = \frac{(3.4\times10^{-6})(.0155)(160.92\,\mathrm{ft})(130000)^2(.342)}{(4.897)^5}$$

$$= \underline{17.40 \ \mathrm{psia}}$$

$$\Delta P_K = \frac{(2.8\times10^{-7})(.342)(130{,}000)^2(7.59)}{(4.897)^4}$$

$$\Delta P_K = \underline{21.36 \ \mathrm{psia}}$$

$$\Delta P_{TOTAL} = \underline{38.76 \ \mathrm{psia}}$$

$$\bar{K}_2 = \frac{\Delta P_{TOT}}{\dot{\omega}^2 \bar{V}} = \frac{38.76 \ \mathrm{psia}}{(130{,}000)^2(.342)} = 6.706\times10^{-9}$$

$P_{REF} = P_T + \bar{K}_1 \dot{\omega}_1^2 \bar{V}$ TURBINE LEG

$P_{REF} \quad P_{TS} + \bar{K}_2 \dot{\omega}_2^2 \bar{V}$ TS CHARGE LEG

$\bar{K}_1$ = RCL00 $\bar{K}_2$ − RCL01 $\bar{V}$ − RCL02

$\dot{\omega}_1$ = RCL03 $\dot{\omega}_2$ − RCL04 $P_{CONTROL\,(TURB)}$ − RCL05 (1465 psia)

```
LBL          =              RCL
 A           +               0    0
RCL          RCL             4    3
 0   0       0               X²
 0   1       5               *
 *           =               RCL
RCL          HLT             0
 0   0          → P_R        2
 3   4       −               =
 X²          RCL             HLT
 *            0   0             → P_TS
RCL           1   0
 0           *
 2
```

CONTROL P
AT TS
INLET

1/14/80
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CONTROL AT TURBINE INLET (P=1465psia)

$\dot{w}_{TOT}$	$\dot{w}_1$	$\dot{w}_2$	P_R	P_{TS}
135,000	115000	20000	1505 psia	1504 psia
	105,000	30000	1498.7	1495.6
	85,000	50,000	1487.1	1478.5
	65,000	70000	1477.9	1461.0
	45,000	90000	1471.2	1443.2
	30,000	105000	1467.7	1429.7
115,000	95,000	20000	1492.6	1491.3
	85,000	30,000	1487.1	1484.0
	65,000	50,000	1477.9	1469.3
	45,000	70,000	1471.2	1454.3
	25,000	90,000	1466.9	1438.9
100,000	80 000	20 000	1484.6	1483.2
	70000	30000	1480.0	1476.9
	50000	50000	1472.7	1464.0
	30000	70000	1467.8	1450.8
80,000	60000	20000	1476.0	1474.6
	50000	30000	1472.7	1469.5
	30000	50000	1467.8	1459.1
36,800	5000	31,800	1465.1	1461.6
	31,800	5000	1468.1	1468.0
50 000	30,000	20000	1467.8	1466.4
	20,000	30000	1466.2	1463.1

1/14/80
9 OF 14

CONTROL AT THERMAL STORAGE INLET (P=1465 psia)

$\dot{W}_{TOT}$	$\dot{W}_1$	$\dot{W}_2$	P_R	P_{TURB}
135000	115000	20000	1466.4 psia	1425.9 psia
	105,000	30000	1468.1	1434.3
	85,000	50,000	1473.6	1451.5
	65,000	70,000	1481.9	1468.9
	45 000	90,000	1493.0	1486.8
	30,000	105,000	1503.1	1500.3
115,000	95000	20000	1466.4	1438.7 psia
	85,000	30,000	1468.1	1446.0
	65,000	50,000	1473.6	1460.7
	45,000	70,000	1481.9	1475.7
	25,000	90,000	1492.9	1491.0
100,000	80000	20000	1466.4	1446.8
	70000	30000	1468.1	1453.1
	50000	50000	1473.6	1466.0
	30000	70000	1481.9	1479.2
80000	60000	20000	1466.4	1455.4
	50000	30000	1468.1	1460.5
	30000	50000	1473.6	1470.9
36800	5000	31800	1468.5	1468.4
	31800	5000	1465.1	1462.0
50000	30000	20000	1466.4	1463.6
	20000	30000	1468.1	1466.9

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CONTROL PRESSURE AT STEAM SPLIT (P_{SPLIT} = 1505 psia)

```
LBL
B
RCL  } SPLIT
0    } CONTROL
5    }   PRESS
-
RCL
0
0
*
RCL
0
3
x²
*
RCL
0
2
=
HLT  PTURB
RCL
0
5
-
RCL
0
1
*
RCL
0
4
x²
*
RCL
0
2
=
HLT  PTS
```

$\dot{W}_{TOT}$	$\dot{W}_1$	$\dot{W}_2$	P_{TURB}	P_{TS}
135000	115000	20000	1464.5 psia	1503.6 p
	105,000	30,000	1471.2	1501.9 psia
	85,000	50,000	1482.9	1496.4
	65,000	70,000	1492.1	1488.1
	45,000	90,000	1498.7	1477.0
	30000	105,000	1502.2	1466.9
115000	95000	20000	1477.4	1503.6
	85000	30000	1482.8	1501.9
	65000	50000	1492.1	1496.4
	45000	70000	1498.8	1488.1
	25000	90000	1503.1	1477.
100000	80000	20000	1485.4	1503.6
	70000	30000	1490.0	1501.9
	50000	50000	1497.3	1496.4
	30000	70000	1502.2	1488.1
80000	60000	20000	1494.0	1503.6
	50000	30000	1497.3	1501.9
	30000	50000	1502.2	1496.4
36,800	5000	31800	1504.9	1501.5
	31800	5000	1501.9	1504.9
50,000	30000	20000	1502.2	1503.
	20000	30000	1503.8	1501.9

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CONTROL PRESSURE AT SPLIT (SLIDING PRESSURE CONTROL)

$\dot{W}_{TOT}$	$\dot{W}_1$	$\dot{W}_2$	P_{TURB}	P_{TS}
135000 (P=1505)	(SEE DATA PAGE 9)			
115000	95000	20000	1467	1493.6
(P=1495)	85000	30000	1472.9	1491.9
	65000	50000	1482.	1486.4
	45000	70000	1488.7	1478.1
	25000	90000	1493.1	1467.0
100,000	80000	20000	1465.4	1483.6
(P=1485)	70000	30000	1470.	1481.9
	50000	50000	1477.3	1476.4
	30000	70000	1482.2	1468.1
80000 (P=1476)	60000	20000	1465.0	1474.6
	50000	30000	1468.3	1472.9
	30000	50000	1473.2	1467.4
36800 (P=1469)	5000	31800	1468.9	1465.5
	31800	5000	1465.9	1468.9
50000 (P=1470)	30000	20000	1467.2	1468.6
	20000	30000	1468.8	1466.9

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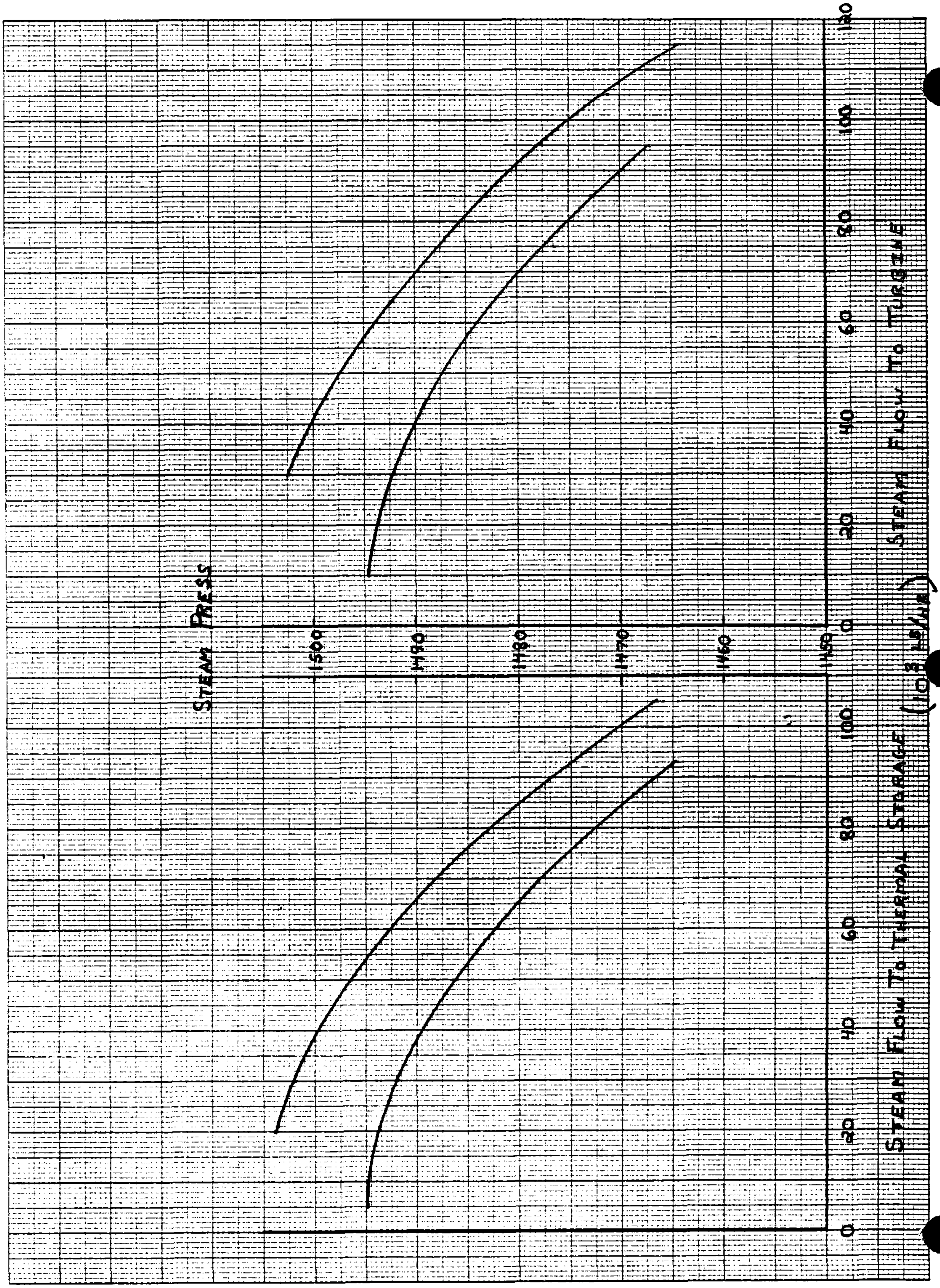
STEAM PRESS
1500
1490
1480
1470
1460
1450
0
20
40
60
80
100
120
STEAM FLOW TO TURBINE
STEAM FLOW TO THERMAL STORAGE (10^3 LB/HR)

6/10/80
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ΔP CALCULATION SPRAY POINT TO T3 INLET

130,000 LB/HR DERATED STEAM

$\rho = 2.985$ LB/FT³

6" XXS A = .1308 FT²

$\dot{m} = \rho A V \rightarrow V = \frac{\dot{m}}{\rho A} = \frac{130,000}{(2.985)(.1308)(3600)}$

$V = 92.5$ FT/SEC MAX

@ 130,000 LB/HR

$$\Delta P = \underbrace{f \frac{L}{D} \frac{V^2}{2g}}_{\text{LINE}} + \underbrace{K \frac{V^2}{2g}}_{\text{FITTING}}$$

SEE PAGE 6 FOR ΔP DERATED STEAM

$$\Delta P = 35.76 \left(\frac{w}{130,000}\right)^2$$

w	ΔP	P
130,000	35.76	1466.47 psia
100,000	22.93	1482.1
75,000	12.90	1492.1
50,000	5.73	1497.3
25,000	1.43	1503.6

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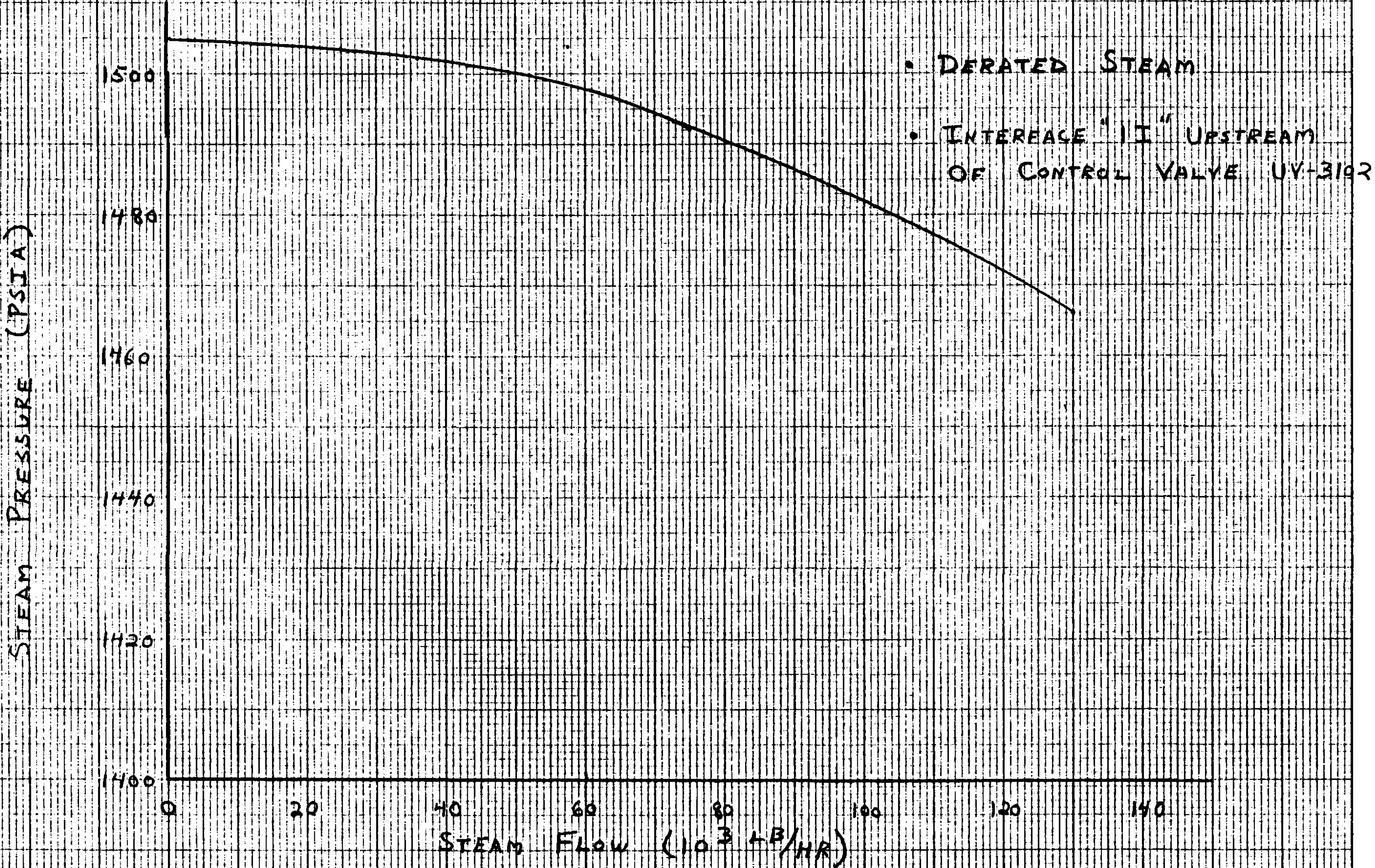
6/10/80

THERMAL STORAGE CHARGING INLET PRESSURE



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9/22/79
1 OF 6

PILOT PLANT ANNUAL ENERGY ESTIMATES

OBJECTIVE: DEVELOP ESTIMATES OF ELECTRICAL ENERGY PRODUCTION FOR SELECTED DAYS AND ON AN ANNUAL BASIS. ESTIMATE STATUS OF THERMAL STORAGE CHARGE AFTER COLLECTOR FIELD OPERATION ON TYPICAL DAYS.

DAILY OPERATING SCENARIO

- STORE MORNING RAMP UNTIL A CAPABILITY TO PRODUCE 10 MWe EXISTS
- STORE AFTERNOON DOWN RAMP WHEN POWER OUTPUT FALLS BELOW 10 MWe
- STORE DAILY EXCESS ABOVE THAT REQUIRED TO PRODUCE 10 MWe
- OPERATE THE TURBINE AT 10 MWe FROM RECEIVER STEAM WHEN AVAILABLE POWER EXCEEDS THE 10 MWe DEMAND RATE
- POWER THE TURBINE FROM ADMISSION STEAM DURING ALL OTHER PERIODS

9/22/79
2 OF 6

FIELD
POWER
INTEGRATION

WINTER DAY

THERMAL POWER
$10^\circ \le El$
(MWH_t)

48 { 17
31

37.2
39.5
39.4
37.2
} 10 AM - 2 PM 153.3 MWH

47.1 { 30.7
16.4

95.1 MWH_t

248.4 MWH_t

Δ = 15.7 MWH_t

34.4 MW. x 4 HR = 137.6 MWH_t

SCENARIO

RUN @ 10 MWe NET FOR 4 HOURS — 137.6 MWH_t

STORE EXCESS — 15.7 MWH_t

STORE MORNING t<10AM — 48 MWH_t

STORE AFTERNOON t>2PM — 47.1 MWH_t

Σ STORED ENERGY = 110.8 MWH_t

η_{gross} = .245 @ 7.8 MWe

η_{net} = .219 @ 7.0 MWe net

P_{THERM} = 32 MW_t

TURBINE STARTUP PENALTY ~8 MWH

NET STORED ENERGY 102.8 MWH

HOURS = 3.21 HRS x.95 = 3.0

STOP COLLECTION AT 3.85 PM

SCENARIO

STORE MORNING 48 MWH
STORE EXCESS 15.7 MWH
63.7 MWH

SUPPLEMENT MODE 3 (10-7 AFTER 2PM) (16.5 MW)
STARTUP PENALTY (8)

NET 39.2 MWH

HOURS @ 7 MW = 1.2 HRS

9/22/79
3 OF 6

FIELD POWER INTEGRATION

SUMMER DAY

THERMAL POWER
$10^\circ \leq El$
(MWH_t)

$$59.2\,MWH \left\{ \begin{array}{l} 3.25 \\ 21.2 \\ 34.7 \end{array} \right.$$

$$\left. \begin{array}{l} 33.0 \\ 40 \\ 41.8 \\ 42.3 \\ 42.1 \\ 41.3 \\ 39.7 \\ 36.5 \end{array} \right\} 316.7\,MWH_t$$

$$55.9\,MWH \left\{ \begin{array}{l} 31.5 \\ 21.4 \\ 3 \end{array} \right.$$

431.8 MWH_t

$34.4 \times 7.85 = 270\,MWH_t$

$\Delta = 46.7\,MWH_t$

STOP COLLECTION AT 6.28 HRS

SCENARIO

RUN @ 10 MWe NET FOR 7.85 HRS —	270 MWH_t
STORE EXCESS —	46.7 MWH
STORE MORNING $t < 8$ AM —	59.2 MWH_t
STORE EVENING $t > 4$ PM —	55.9 MWH_t

Σ STORED ENERGY = 161.8 MWH_t

$$\eta_{net} = \frac{10}{34.4} = .291$$

TURBINE STARTUP PENALTY ~ 8 MWH_t

NET STORED ENERGY = 153.8 MWH_t
HOURS = 4.8 HRS × .95 = 4.6

SCENARIO

STORE MORNING —	59.2 MWH
STORE EXCESS —	46.7 MWH
	105.9 MWH
SUPPLEMENT (MODE 3) 10 – 7 AFTER 4 PM	(21.5 MWH)
STARTUP PENALTY	(8)

NET 79.4 MWH
HOURS @ 7 MWe 2.5 HRS

9/22/79
4 OF 6

EQUINOX

TIME	$(72MW)\left(\frac{\cos N}{\cos O}\right)\left(\frac{I_{NEW}}{I_{OLD}}\right)\left(\frac{B+S\ NEW}{B+S\ OLD}\right) =$	INCID MWt	ABSORB $(I * .93 - 4.8)$ MWt
-5.17	$42.04\left(\frac{.6938}{.792}\right)\left(\frac{621}{917}\right)\left(\frac{.7113}{.898}\right)$	19.75	13.57
-4.31	$42.04\left(\frac{.7346}{.792}\right)\left(\frac{783}{917}\right)\left(\frac{.8842}{.898}\right)$	32.78	25.69
-3.45	$42.04\left(\frac{.7699}{.792}\right)\left(\frac{875}{917}\right)\left(\frac{.971}{.898}\right)$	42.17	34.41
-2.59	$42.04\left(\frac{.7984}{.792}\right)\left(\frac{926}{917}\right)\left(\frac{.988}{.898}\right)$	47.08	38.99
-1.72	$42.04\left(\frac{.8194}{.792}\right)\left(\frac{954}{917}\right)\left(\frac{.9865}{.898}\right)$	49.71	41.43
-0.86	$42.04\left(\frac{.8258}{.792}\right)\left(\frac{971}{917}\right)\left(\frac{.9836}{.898}\right)$	50.84	42.48
Noon	$42.04\left(\frac{.8365}{.792}\right)\left(\frac{973}{917}\right)\left(\frac{.9823}{.898}\right)$	51.54	43.13
0.86	SYMMETRIC	50.84	42.48
1.72		49.71	41.43
2.59		47.08	38.99
3.45		42.17	34.41
4.31		32.78	25.69
5.17	(——)	19.75	13.57

/22/79
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EQUINOX (SYMMETRIC ABOUT NOON)

(COUNTING FROM NOON)

ABS PWR MWHt)

$$\left.\begin{array}{l}43.1\\42.5\\39.5\\36\times.45\end{array}\right\}\begin{array}{l}141.3\text{ MWH}\times 2=\\282.6\text{ MWH}\\6.9\text{ HRS}\end{array}\longrightarrow \Delta = 45.2\text{ MWH}$$

SURPLUS ↑ →

$$\left.\begin{array}{l}32.5\times.55\\24\\15\times.2\end{array}\right\}\begin{array}{l}44.9\times 2=\\89.8\text{ MWHt}\end{array}$$

34.4 x 6.9 HRS = 237.4 MWH

RUN PLANT 10MW FOR 6.9 HRS — 237 MWHt

STORE EXCESS — 45.2 MWHt

STOR MORNING — 44.9 MWHt

STOR EVENING — 44.9 MWHt

Σ STORED ENERGY: 135 MWH

− 8 MWHt TURBINE STARTUP

NET STORED ENERGY = 127 MWH
HRS = 3.97

9/22/7
6 OF 6

ANNUAL SUMMARY

	HOURS 10 MW	HOURS 7 MW
SUMMER	7.8	4.8
EQUINOX	6.9	4.0
WINTER	4	3.2

$$\frac{S+2E+W}{4}$$

$$\frac{7.8+2(6.9)+4}{4}$$

$$= 6.4\ HRS$$

3.6 EQUIVALENT

$$\frac{4.8+2(4)+3.2}{4}$$

$$= 4\ HRS$$

*.95 REDUCTION FOR OTHER PARASITIC STEAM REQUIREMENTS

RESULT ANNUAL VALUE

6.4 HR @ 10 MWe

3.8 HR @ 7 MWe

A3-204-SJS-EP-484
June 7, 1979

MEMORANDUM

Subject: OFF DESIGN TURBINE STEAM CONDITIONS

To: R. G. Riedesel and J. E. Raetz

From: S. J. Scotti

Copies to: G. C. Coleman, P. I. Kawano, M. H. Lobell, D. W. Pearson
J. E. Riel, W. P. Olson

This memorandum documents a modification of the "MDAC Solar Thermal Heat and Mass Balance Program" to analyze the 10 MW Solar Pilot Plant for cases in which the thermodynamic states at the turbine throttle valve and admission port are not the nominal design states. Also, data is presented to indicate the dependence of output power on several of these "off design" steam conditions for various combinations of throttle and admission flow rate. Several general results follow:

1) Power output increases fairly linearly with temperature (either throttle or admission).

2) Pressure variations have a minor effect on output power.

3) Throttle temperature has the greatest effect on output power with a coefficient of about .116 watt/°F-lbm.

4) Admission temperature has a lesser effect on output power with a .099 watt/°F-lbm coefficient.

A description of the program modifications and the case summary data sheets are included in an attachment to this memorandum.

S. J. Scotti

S. J. Scotti

Modification of Program for "Off Design" Steam Conditions

The Heat and Mass Balance program has been modified by adding a block of code which corrects the turbine expansion line end point for "off design" steam conditions at the throttle and admission ports. Both high and low pressure section end points are corrected. Also, a density dependent correction is applied to the windage loss term that is present when operating with admission flow only. The details of the modifications are treated in General Electric communication LTSD4159C-14, "Approximate Performance Corrections for Variant Steam Conditions".

Results of "Off Design" Cases

Tables 1 to 4 list output power as a function of flow rates for "off design" throttle temperature, throttle pressure, admission temperature, admission pressure, respectively. Included in these tables are the nominal output power and the output power for steam conditions below and above nominal conditions.

In summary, the temperature dependence of the output power (in watts) can be approximately expressed as the linear combination.

$$DP_T = \text{WTHR}\ (\text{TTHR}-950.0)\ .116 + \text{WADM}\ (\text{TADM}-525.0)\ .099$$

where the throttle and admission flow rates (WTHR and WADM) are in lbm/hr, and the throttle and admission temperatures (TTHR and TADM) are in °F. Table 5 gives an indication of the accuracy of this expression.

The pressure dependences are smaller but more difficult to model. For a throttle pressure varying $\pm$ 100 psi from nominal, the output power varies less than $\pm$ .03 MW with the lower pressures giving the higher output power. For an admission pressure varying $\pm$ 50 psi from nominal, the output power varies less than $\pm$ .09 MW with lower pressures giving higher output power only when the total flowrate (admission plus throttle) was less than about 100000 lbm/hr.

The three cases listed in Table 1 for throttle flow only are plotted in Figure 1. These curves give an illustration of the magnitude of the change in output power that can result from "off design" temperatures.

TABLE 1

VARIATION OF OUTPUT POWER WITH "OFF-DESIGN" THROTTLE TEMPERATURE

WTHR(lb/hr)	WADM(lb/hr)	P-(MWe)	P(MWe)	P+(MWe)
114635	0	11.21	12.52	13.82
102000	0	9.99	11.18	12.35
90000	0	8.81	9.87	10.89
60000	0	5.58	6.31	7.01
30000	0	2.32	2.69	3.04
90000	5000	9.19	10.21	11.25
90000	15000	9.90	10.95	11.98
90000	25000	10.64	11.67	12.71
60000	5000	6.18	6.90	7.61
60000	20000	-	7.96	8.68
60000	40000	8.79	9.50	10.20
60000	54000	9.85	10.54	11.24
30000	5000	2.78	3.16	3.51
30000	20000	4.09	4.45	4.82
30000	40000	5.84	6.21	6.56
30000	60000	-	7.68	8.03
30000	85000	9.27	9.63	9.97

Notes:

1) P Computed for design conditions
Throttle Temperature = 950°F
Throttle Pressure = 1465°psia
Admission Temperature = 525°F
Admission Pressure = 384.7 psia

2) P- Computed for same conditions as 1)
except Throttle Temperature = 850°F

3) P+ Computed for same conditions as 1)
except Throttle Temperature = 1050°F

TABLE 2

VARIATION OF OUTPUT POWER WITH "OFF-DESIGN" THROTTLE PRESSURE

WTHR(lb/hr)	WADM(lb/hr)	P-(MWe)	P(MWe)	P+(MWe)
114635	0	12.52	12.52	12.51
102000	0	11.19	11.18	11.16
90000	0	9.90	9.87	9.84
60000	0	6.34	6.31	6.28
30000	0	2.71	2.69	2.67
90000	5000	10.23	10.21	10.18
90000	15000	10.96	10.95	10.92
90000	25000	11.69	11.67	11.64
60000	5000	6.92	6.90	6.87
60000	20000	-	7.96	-
60000	40000	9.52	9.50	9.48
60000	54000	10.55	10.54	10.52
30000	5000	3.18	3.16	3.14
30000	20000	4.47	4.45	4.43
30000	40000	6.22	6.21	6.19
30000	60000	7.69	7.68	7.66
30000	85000	9.65	9.63	9.62

Notes:

1) P Computed for design conditions

2) P- Computed for same conditions as 1) except Throttle Pressure = 1365 psia

3) P+ Computed for same conditions as 1) except Throttle Pressure = 1565 psia

TABLE 3

VARIATION OF OUTPUT POWER WITH "OFF-DESIGN" ADMISSION TEMPERATURE

WTHR(lb/hr)	WADM(lb/hr)	P-(MWe)	P(MWe)	P+(MWe)
0	30000	1.47	1.62	1.76
0	45000	2.75	2.99	3.20
0	60000	4.03	4.36	4.65
0	90000	-	6.74	7.19
0	110000	7.84	8.39	8.90
90000	5000	10.18	10.21	10.23
90000	15000	10.87	10.95	11.01
90000	25000	11.54	11.67	11.79
60000	5000	6.90	6.90	6.95
60000	20000	-	7.96	-
60000	40000	9.31	9.50	9.69
60000	54000	10.30	10.54	10.80
30000	5000	3.14	3.16	3.19
30000	20000	4.38	4.45	4.57
30000	40000	6.04	6.21	6.42
30000	60000	-	7.68	7.96
30000	85000	9.22	9.63	9.99

Notes:

1) P Computed for design conditions

2) P- Computed for same conditions as 1)
except Admission Temperature = 475°F

3) P+ Computed for same conditions as 1)
except Admission Temperature = 575°F

TABLE 4

VARIATION OF OUTPUT POWER WITH "OFF-DESIGN" ADMISSION PRESSURE

WTHR(lb/hr)	WADM(lb/hr)	P-(MWe)	P(MWe)	P+(MWe)
0	30000	1.69	1.62	1.56
0	45000	3.06	2.99	2.92
0	60000	4.42	4.36	4.30
0	90000	6.78	6.74	6.70
0	110000	8.37	8.39	8.37
90000	5000	10.24	10.21	10.17
90000	15000	10.95	10.95	10.92
90000	25000	11.61	11.67	11.67
60000	5000	6.99	6.90	6.86
60000	20000	-	7.96	-
60000	40000	9.50	9.50	9.49
60000	54000	10.47	10.54	10.56
30000	5000	3.24	3.16	3.11
30000	20000	4.54	4.45	4.41
30000	40000	6.29	6.21	6.19
30000	60000	7.69	7.68	7.66
30000	85000	9.59	9.63	9.65

Notes:

1) P Computed for design conditions

2) P- Computed for same conditions as 1) except Admission Pressure = 334.7 psia

3) P+ Computed for same conditions as 1) except Admission Pressure = 434.7 psia

TABLE 5

CHECK CASES FOR EQUATION (1)

WTHR(lb/hr)	WADM(lb/hr)	DP_{TE}(MWe)	DP_T(MWe)	%ERROR
90000	5000	1.06	1.07	0.9
90000	15000	1.10	1.12	1.8
90000	25000	1.16	1.17	0.9
60000	5000	.76	.72	5.3
60000	20000	.82	.80	2.5
60000	40000	.89	.89	0.0
60000	54000	.97	.96	1.0
30000	5000	.38	.37	2.6
30000	20000	.49	.45	8.2
30000	40000	.57	.55	3.5
30000	60000	.63	.65	3.2
30000	85000	.72	.77	6.9

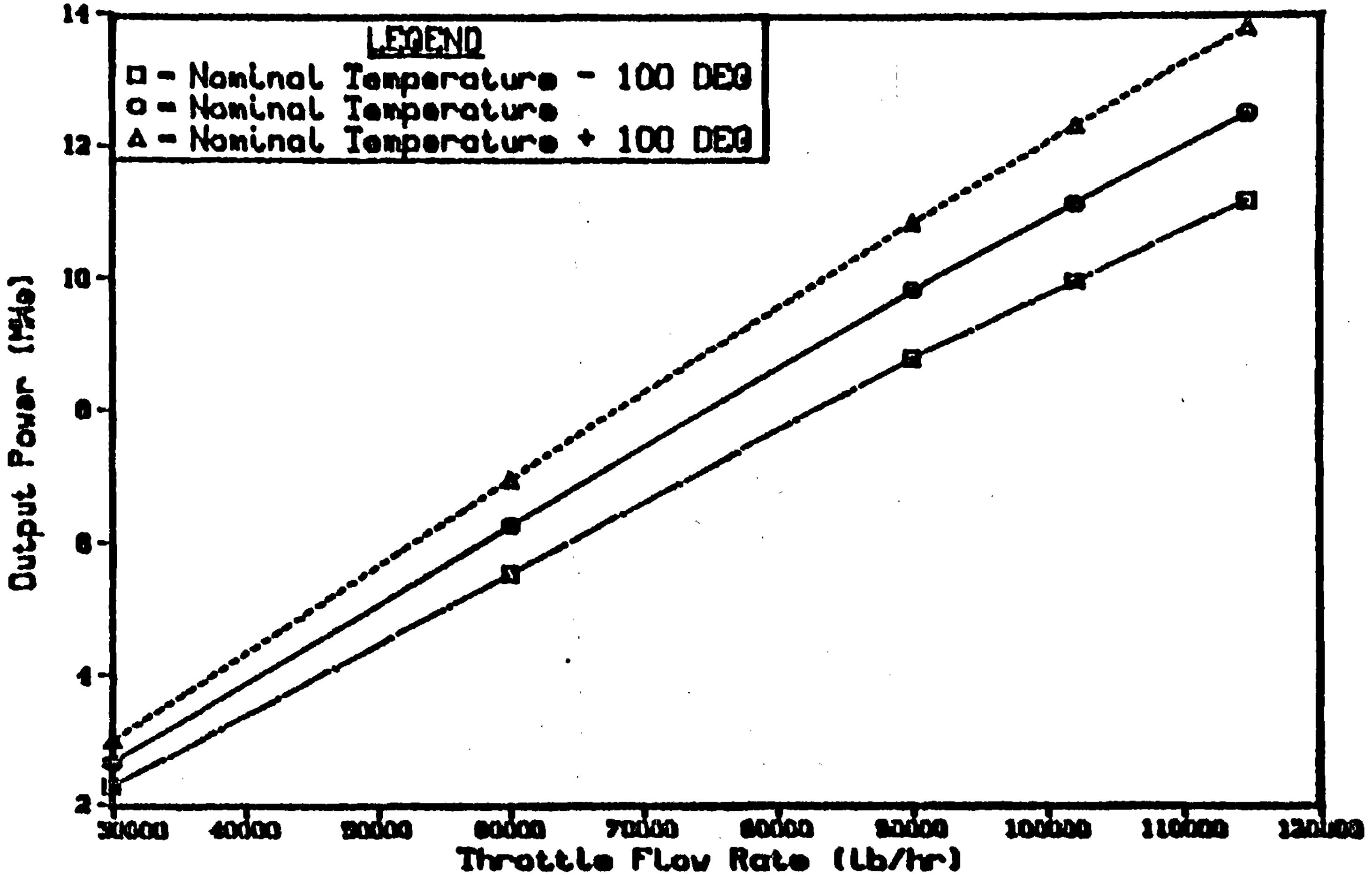
Notes:

1) The off design conditions used were Throttle Temperature = 1050°F
Admission Temperature = 575°F
Pressures were design condition pressures

2) DP_{T_E} were computed "exactly" using the Heat and Mass Balance Program and are equal to off design output power minus design output power.

3) DP_T were computed using equation (1)

Figure 1 -- OUTPUT POWER VS THROTTLE FLOW RATE



A3-228-JER-EP-249
April 3, 1979

MEMORANDUM

Subject: SYSTEM BLANKETING AND SEALING STEAM REQUIREMENTS

To: R.G. Riedesel

From: J.E. Raetz

Copies to: G.C. Coleman, H.H. Eby, C.M. Finch, K.R. Knox, M.H. Lobell, R.J. Perkins

The blanketing and sealing steam requirements influence the design and component selection of both the thermal storage subsystem and the auxiliary electric boiler. The steam conditions which must be produced from either of these two sources must match the temperature, pressure (saturated steam), and flow-rate requirements as established by the conditioned components. These include (1) the receiver during subfreezing periods, (2) turbine steam seals during non operating periods, (3) the deaerator and high pressure feedwater heaters, and (4) other steam pipes, components, and heat exchangers located throughout the system.

The maximum blanketing steam pressure (and temperature) is established on the basis of heat exchanger blanketing requirements for the thermal storage heat exchangers (both charging and discharging). During non operating periods, it is desirable to maintain a high pressure on the water/steam side of the heat exchangers to minimize the potential for oil leakage into the feedwater circuit. Estimates carried out during the PDR indicated that pressure differentials of 2-3 atmospheres would be sufficient to minimize the potential for such leakage.

The PDR design assumed that this differential pressure would be provided on a nightly basis by a source of GN_2. An option which is recommended for the pilot plant design is to provide this pressure from the blanketing steam which would be available on an as required basis throughout the night. Since no GN_2 would be introduced into the system, the daily problem of removing the GN_2 by a combination of local venting and vacuum removal from the condenser would be eliminated. The GN_2 pressurization option would still be used for prolong periods of shutdown when condenser vacuum is broken and the balance of the system is changed with GN_2.

The blanketing steam pressure requirement must be sufficient to provide the 2-3 atmosphere pressure differential over the Caloria side pressure which is set by the sum of the ullage and hydrostatic pressures in the thermal storage tank (TSU). Since a combined ullage and hydrostatic pressure of 30-35 psia is anticipated, a blanketing steam pressure of 75 psia is recommended.

The potential impact of using 75 psia blanketing steam pressure on other components was reviewed with Al McKenzie of Stearns Roger. Al indicated that the turbine seals and deaerator normally require 5 psig steam. Since these pressures are controlled by inlet pressure regulating stations, there is no problem operating with a 75 psia upstream inlet pressure. He pointed out that during startup, the blanketing and sealing steam pressure is supplied from the receiver or thermal storage at a substantially higher upstream pressure than the 75 psia value. Al also pointed out that no problem exists in matching an auxiliary electric boiler to the 75 psia steam condition. Other high pressure hardware (H.P. heaters, douncomers, etc.) will have no problem accepting the 75 psia blanketing steam since they normally experience higher pressure during operation. The 75 psia steam should also enhance system startup because of the higher component temperature maintained during nighttime periods in comparison to the level produced by the more conventional 5 psig blanketing steam.

The detailed blanketing steam generation process is shown in figure 1 (pinch point diagram). The figure shows the steam generation line and indicates the high temperature and low temperature (range of values) extremes for the Caloria. The exact low temperature condition must be defined by Rocketdyne during their detailed design since it will influence the location of the intermediate extraction manifold, the Caloria flowrate, and the minimum Caloria temperature which will subsequently enter the charging heat exchanger when charging operation first resumes.

Preliminary estimates of blanketing and sealing steam quantity requirements are contained in the following tabulation.

Receiver freeze protection	2.3×10^6 BTU/HR	(1)	$\times$ 8HR = 18.4×10^6
Turbine seal steam	1.0×10^6 BTU/HR	(2)	$\times 16 = 17.04 \times 10^6$
Deaerator and HP heater	15×10^3 BTU/HR	(3)	
Other pipes, components, and heat exchangers	50×10^3 BTU/HR	(4)	
			35.44×10^6 BT

A3-228-JER-EP-249
April 3, 1979

These values are currently being reevaluated to reflect the latest design and operating information. Due to the conservative assumptions regarding receiver freeze protection, the necessary thermal power shall be provided for an 8 hour period. The last three items in the tabulation shall be provided for an assumed 16 hour thermal conditioning period.

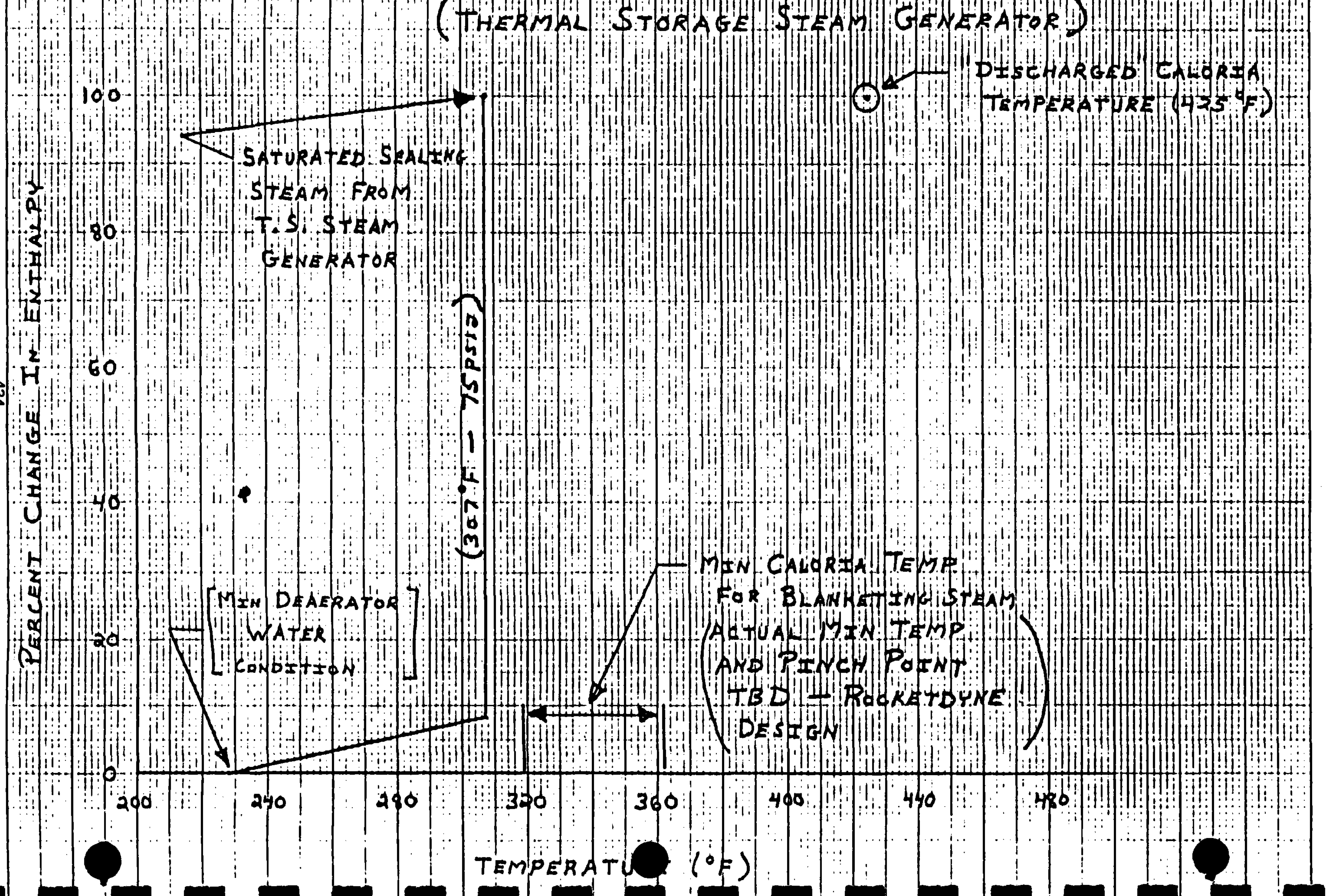
(1) Scaled from PDR receiver—9°F ambient temp, 40 mph wind
(2) PDR value (may be substantially less if other than GE turbine selected)
(3) PDR value
(4) Assumed value-currently being evaluated

J E Raetz

JE Raetz

FIG 1 PINCH POINT DIAGRAM FOR SEALING STEAM

(THERMAL STORAGE STEAM GENERATOR)



AUXILIARY BOILER

TURBINE SEALS 1000 LB/HR — 1×10^6 BTU/HR

H P (PDR) HEATERS 10 LB/HR — 10×10^3 BTU/HR

DEAERATOR (PDR) BLANKETING 15 LB/HR — 15×10^3 BTU/HR

OTHER PIPES AND COMPONENTS 2×10^5 BTU/HR

TOTAL 1.225×10^6 BTU/HR

$$\text{ELECTRIC POWER CAPACITY} = \frac{1.225 \times 10^6}{3.413 \times 10^6\ (.9)} = 399\ KW_e$$

STMPO 201

Department of Energy
San Francisco Operations Office
1333 Broadway
Oakland, California 94612

Reply To: DOE Solar One Project Office
P.O. Box 366
Daggett, CA 92327

OCT 19 1984

Mr. Robert L. Gervais
Solar One Project Office
McDonnell Douglas Astronautics Corp.
P.O. Box 366
Daggett, CA 92327

Subject: Contractor Clearance of Contract DE-AC03-79SF10499
Solar One Reports for DOE/TIC Inclusion.

Dear Bob:

Enclosed are copies of covers and title pages of nine reports prepared by McDonnell Douglas Astronautics Corporation for the Solar One Project under the above referenced contract. In preparation for delivery of these documents to DOE/TIC, I have prepared a SAN form 70 "Request for Patent Clearance" and a DOE form RA-426 "Recommendations for Announcement and Distribution of Documents" for each document.

Please have the appropriate MDAC personnel complete and sign these forms. As agreed, SAN form 70 should be forwarded to SAN/OPC by your office with copies of the completed SAN form 70 and the transmittal letter being sent to me. The completed DOE form RA-426 should be sent directly back to me.

The documents covered by this letter are:

Primary Document No.	Secondary No.	Brief Title
DOE/SF/10499-T108	STMPO 193	PSS Final Design Calculations (Book 18 of 26)
DOE/SF/10499-T109	STMPO 194	PSS Final Design Calculations (Book 19 of 26)
DOE/SF/10499-T110	STMPO 195	PSS Final Design Calculations (Book 20 of 26)
DOE/SF/10499-T111	STMPO 196	PSS Final Design Calculations (Book 21 of 26)
DOE/SF/10499-T112	STMPO 197	PSS Final Design Calculations (Book 22 of 26)

DOE/SF/10499-T113	STMPO 198	PSS Final Design Calculations (Book 23 of 26)
DOE/SF/10499-T114	STMPO 199	PSS Final Design Calculations (Book 24 of 26)
DOE/SF/10499-T115	STMPO 200	PSS Final Design Calculations (Book 25 of 26)
DOE/SF/10499-T116	STMPO 201	PSS Final Design Calculations (Book 26 of 26)

If you should have any questions or concerns please do not hesitate to contact me by telephone at, (619) 254-2672.

Sincerely,

S.D. Elliott, Jr., Director
DOE Solar One Project Office

SDE/aks
Project File: CCC010.RNO(SA3:)

Encl: Nine Document Covers W/forms 70 and RA-426

cc: Roger Gaither, SAN/OPC
W.D. Matheny, DOE/TIC
Mike Lopez, DOE/SAN (FGS)
Mary Soderstrum, B&McD

DEPARTMENT OF ENERGY
SAN FRANCISCO OPERATIONS OFFICE

CONTRACTOR REQUEST FOR PATENT CLEARANCE FOR RELEASE OF UNCLASSIFIED DOCUMENT

Prime Contract No.
DE-AC03-79SF10499

Subcontract No.
(N/A)

Report No. (STMPO 201)
DOE/SF/10499-T116

Date of Report
September 1980

Name & Phone No. of DOE Technical Representative
S.D. Elliott, Jr.
(619) 254-2672

TO:
Roger S. Gaither, Asst. Chief for Prosecution
Office of Patent Counsel/Livermore Office
P.O. Box 808, L-376
Livermore, California 94550

FROM:
McDonnell Douglas Corporation
3855 Lakewood Blvd.
Long Beach, CA 90846

1. Document Title: Plant Support Subsystem Final Design Calculations (Book 26 of 26)

2. Type of Document: ☒ Technical Report, ☐ Conference Paper, ☐ Journal Article, ☐ Abstract or Summary, ☐ Copy of Oral Presentation, ☐ Other (please specify): ________

3. In order to meet a publication schedule or submission deadline, patent clearance by (Routine) would be desired.

SENDER IS TO CHECK BOX #4 OR #5 BELOW.

☐ 4. I have reviewed (or have had reviewed by technically knowledgeable personnel) this document for possible inventive subject matter (Subject Inventions) and that no inventions or discoveries (Subject Inventions) are deemed to be disclosed in this document except as stated below:

a. Attention should be directed to pages ________ of this document.

b. This document describes matter relating to an invention:

i. Contractor Invention Docket No. ________.
ii. A disclosure of the invention was submitted to DOE on ________ (date)
iii. A disclosure of the invention will be submitted shortly ________ (approximate date)
iv. A waiver of DOE's patent rights to the contractor:
☐ has been granted, ☐ has been applied for; or ☐ will be applied for ________ (date)

☐ 5. This document is being submitted, but no review has been made of this document for possible inventive subject matter.

6. Remarks: Provide copy of clearance to: Solar One Project Office
P.O. Box 366, Daggett, CA 92327

Reviewing/Submitting Official: Name (Print/Type) ________
Title ________
Signature ________ Date ________

TO: INITIATOR OF REQUEST

FROM: ASSISTANT CHIEF FOR PROSECUTION
Office of Patent Counsel/Livermore Office

☐ No patent objection to above-identified release.

☐ Please defer release until advised by this office.

Signed ________ Date Mailed ________

DOE Form RA-426
(10/80)

U.S. DEPARTMENT OF ENERGY

OMB NO. 038-R0190

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See Instructions on Reverse Side

1. DOE Report No. DOE/SF/10499-T116 (STMPO 201)	2. Contract No. DE-AC03-79SF10499	3. Subject Category No. UC-62, 62c, 62d

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Plant Support Subsystem Final Design Calculations (Book 26 of 26)

5. Type of Document ("x" one)
☒ a. Scientific and technical report
☐ b. Conference paper: Title of conference ______

______ Date of conference ______

Exact location of conference ______ Sponsoring organization ______
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S.D. Elliott, Jr., Director, DOE Solar One Project Office

Organization
P.O. Box 366, Daggett, CA 92327 (619) 254-2672

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DOE/SF/10499-T116
STMPO 201
SAN/0499-50
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10 MWe Solar Thermal
Central Receiver Pilot Plant

SOLAR FACILITIES DESIGN INTEGRATION

PSS FINAL DESIGN CALCULATIONS
BOOK 26 OF 26--MDAC GENERAL ANALYSIS AND BACKGROUND DATA (RADL ITEM 7-8)

September 1980

WORK PERFORMED UNDER CONTRACT
DE-AC03-79SF10499

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY
5301 BOLSA AVENUE
HUNTINGTON BEACH' CA 92647

U.S. Department of Energy

MCDONNELL DOUGLAS CORPORATION

Solar Energy

DOE/SF/10499-T116

STMPO 201
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Central Receiver Pilot Plant
Solar Facilities Design Integration

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September 1980

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY
5301 BOLSA AVENUE
HUNTINGTON BEACH, CA 92647

PREPARED FOR THE
U.S. DEPARTMENT OF ENERGY
SOLAR ENERGY
UNDER CONTRACT DE-AC-03-79SF10499

H009-M-941

DOE Form RA-426
(10/80)

U.S. DEPARTMENT OF ENERGY

OMB NO. 038-R0190

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S.D. Elliott, Jr., Director, DOE Solar One Project Office
Organization
P.O. Box 366, Daggett, CA 92327 (619) 254-2672

Signature	Date

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DEPARTMENT OF ENERGY
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CONTRACTOR REQUEST FOR PATENT CLEARANCE
FOR RELEASE OF UNCLASSIFIED DOCUMENT

Prime Contract No. DE-AC03-79SF10499

Subcontract No. (N/A)

Report No. (STMPO 201) DOE/SF/10499-T116

Date of Report September 1980

Name & Phone No. of DOE Technical Representative S.D. Elliott, Jr. (619) 254-2672

TO: Roger S. Gaither, Asst. Chief for Prosecution
Office of Patent Counsel/Livermore Office
P.O. Box 808, L-376
Livermore, California 94550

FROM:
McDonnell Douglas Corporation
3855 Lakewood Blvd.
Long Beach, CA 90846

1. Document Title: Plant Support Subsystem Final Design Calculations (Book 26 of 26)

2. Type of Document: ☒ Technical Report, ☐ Conference Paper, ☐ Journal Article, ☐ Abstract or Summary, ☐ Copy of Oral Presentation, ☐ Other (please specify): ______

3. In order to meet a publication schedule or submission deadline, patent clearance by (Routine) would be desired.

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Title Asst. Chief Patent Counsel, MDC (MS 122-23)
Signature ______ Date 6 Nov 84

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Office of Patent Counsel/Livermore Office

☐ No patent objection to above-identified release.

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Signed ______ Date Mailed ______