SANDERS ASSOCIATES, INC.
ENERGY SYSTEMS CENTER

NASA-CR-194268

23 AUGUST 1979

JPL NO. 9950 – 860

HIGH TEMPERATURE SOLAR THERMAL RECEIVER PARAMETRIC ANALYSIS - TASK 1

CONTRACT NO. 955454
7JUNE 1979

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(NASA-CR-194268) HIGH TEMPERATURE SOLAR THERMAL RECEIVER PARAMETRIC ANALYSIS, TASK 1 (Sanders Associates) 37 p

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1 of 37

SANDERS ASSOCIATES, INC.
ENERGY SYSTEMS CENTER

AGENDA

TASK 1 - STATEMENT OF WORK

CONCEPTS

APPLICATIONS

RECEIVER PARAMETERS

WINDOW DESIGN

WINDOW ANALYSIS

MATERIALS CONSIDERATIONS

REGIMES OF OPERATION

RECOMMENDATION

STATEMENT OF WORK (BALANCE OF PROGRAM)

08219-4

TABLE 1

Concept	Description	Window	Temperature Inlet	Temperature Outlet	Pressure Atm	Power	Storage	Weight	Risks	Cost	Rating
A	Matrix	Yes	1800	2000-3000	2-8	25-150	No	180	Low	1	1
A'	Matrix	Yes	1800	2000-3000	2-8	25-150	Yes	306	Low	2	2
B	Extended Surface Bell Jar	No	2500	2000-3000	?	?	No	131	High	4	5
C	Extended Surface Radial Fins	Yes	1800	2000-3000	2-8	25-150	Intrinsic	337	Low	3	3
D	Tubed	No	2500	2000-3000	2-8		Intrinsic	287	Intrinsic	5	4

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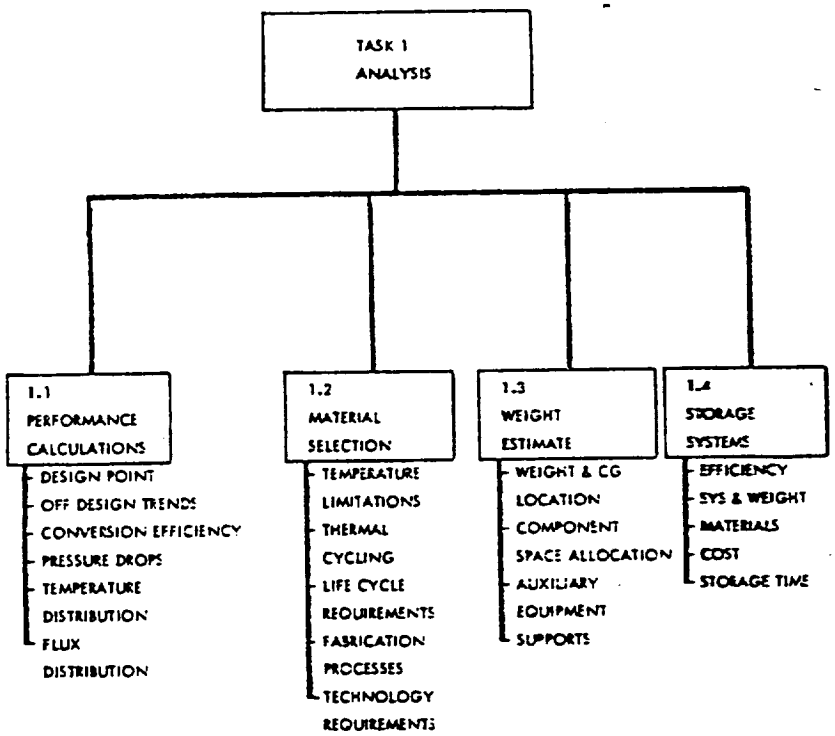
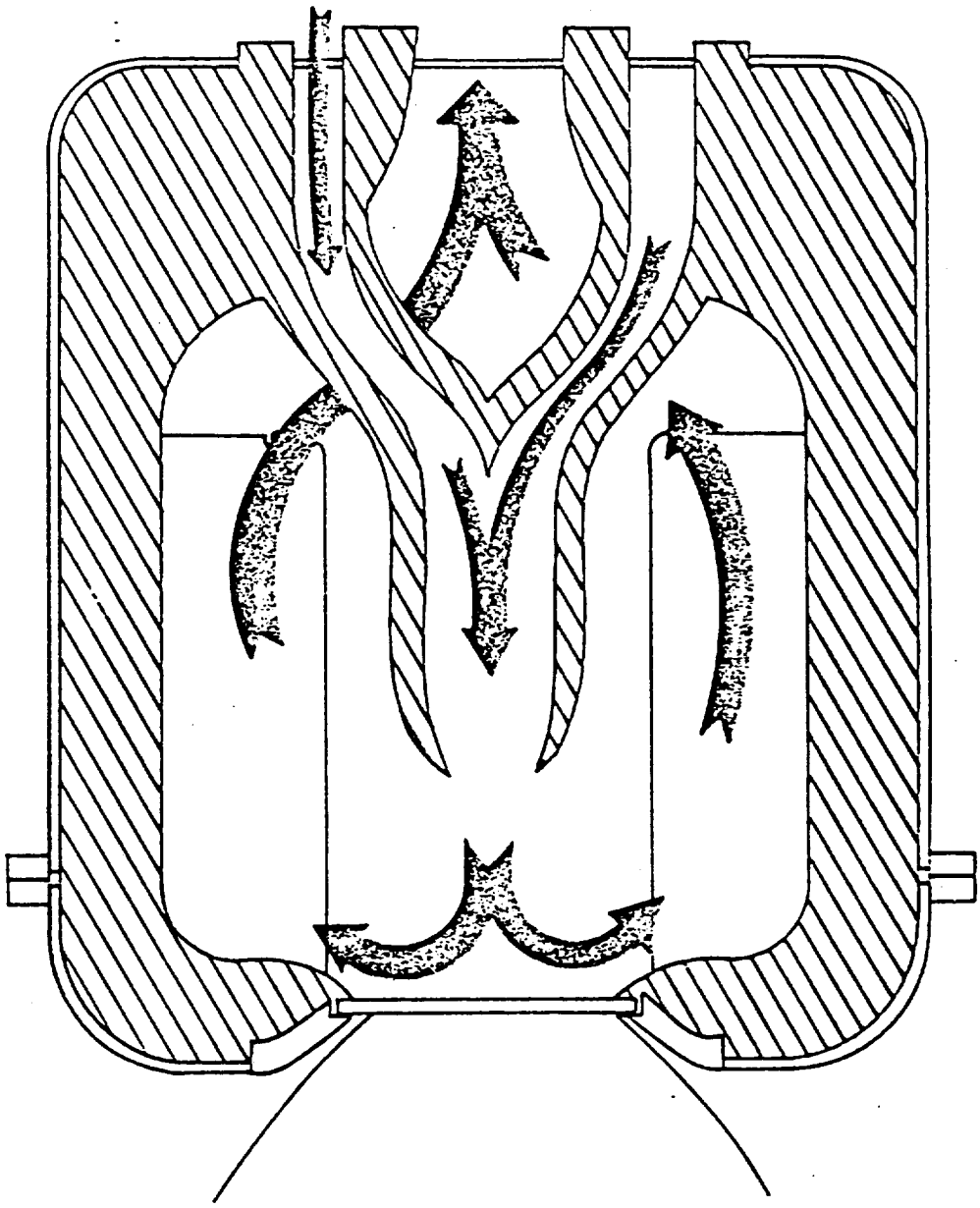

TASK 1
ANALYSIS
1.1
PERFORMANCE
CALCULATIONS
DESIGN POINT
OFF DESIGN TRENDS
CONVERSION EFFICIENCY
PRESSURE DROPS
TEMPERATURE
DISTRIBUTION
FLUX
DISTRIBUTION
1.2
MATERIAL
SELECTION
TEMPERATURE
LIMITATIONS
THERMAL
CYCLING
LIFE CYCLE
REQUIREMENTS
FABRICATION
PROCESSES
TECHNOLOGY
REQUIREMENTS
1.3
WEIGHT
ESTIMATE
WEIGHT & CG
LOCATION
COMPONENT
SPACE ALLOCATION
AUXILIARY
EQUIPMENT
SUPPORTS
1.4
STORAGE
SYSTEMS
EFFICIENCY
SYS & WEIGHT
MATERIALS
COST
STORAGE TIME

9950-860

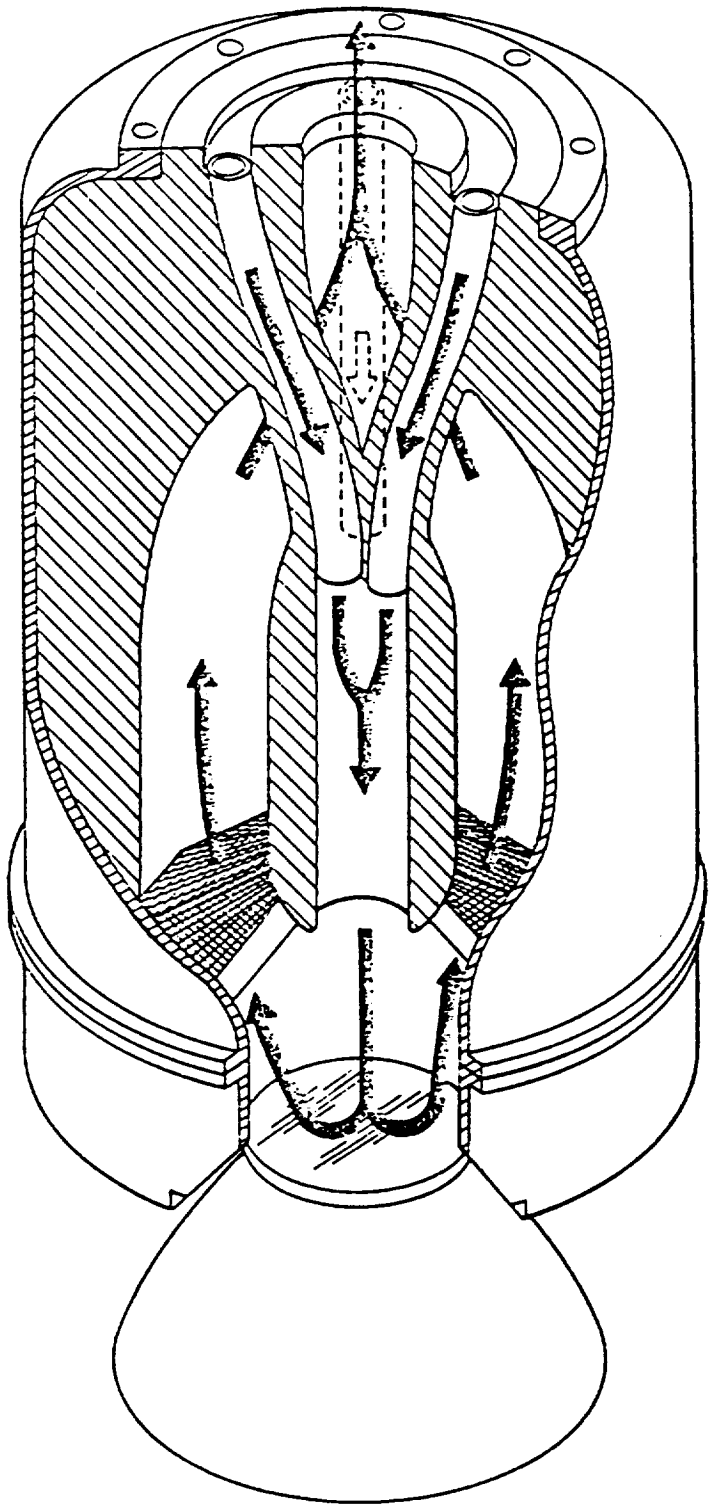


PRESSURIZED MATRIX

HIGH TEMPERATURE SOLAR THERMAL RECEIVER

ENGINEERING SKETCH

9950-860

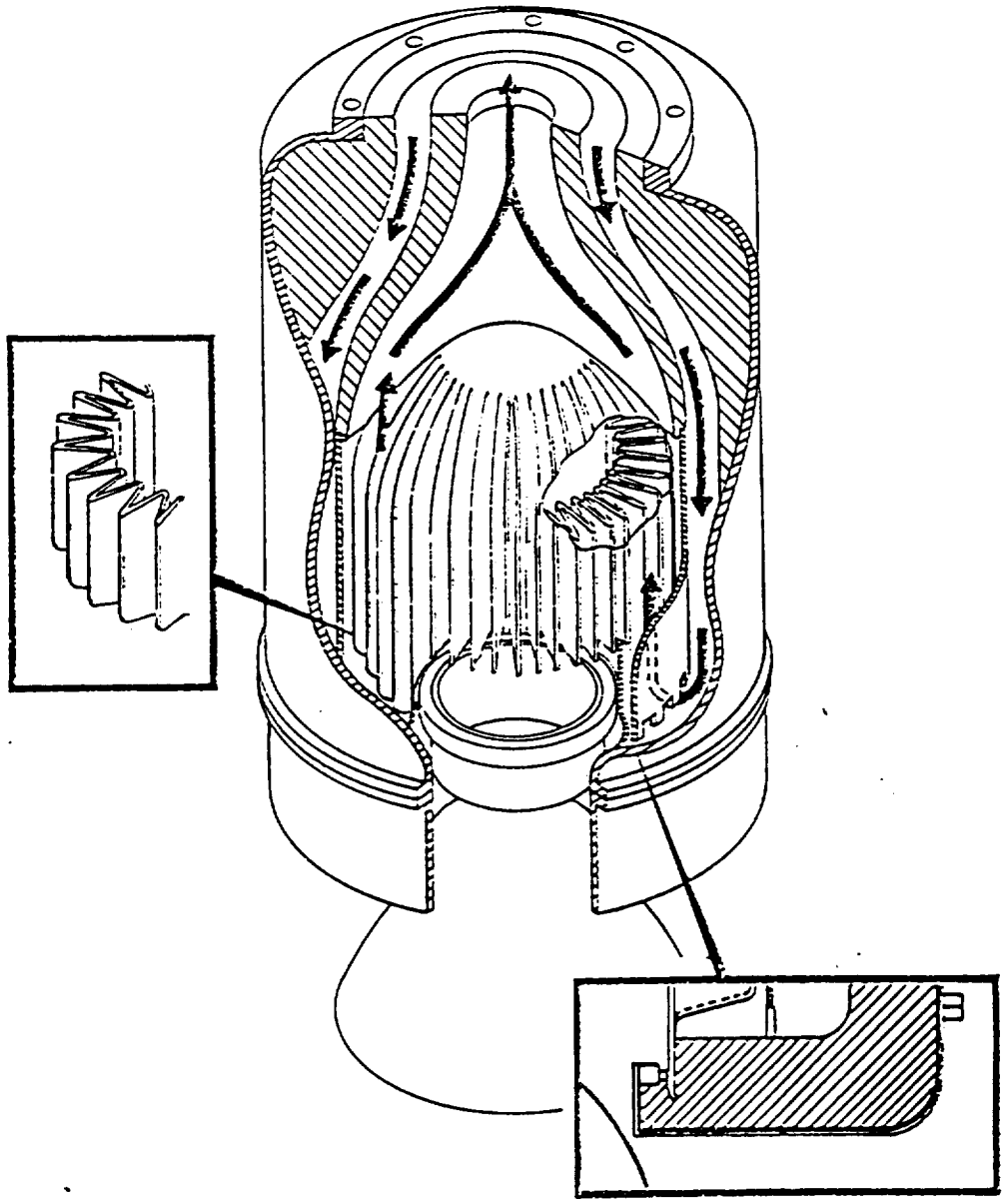


PRESSURIZED MATRIX

HIGH TEMPERATURE SOLAR THERMAL RECEIVER

PLATE A

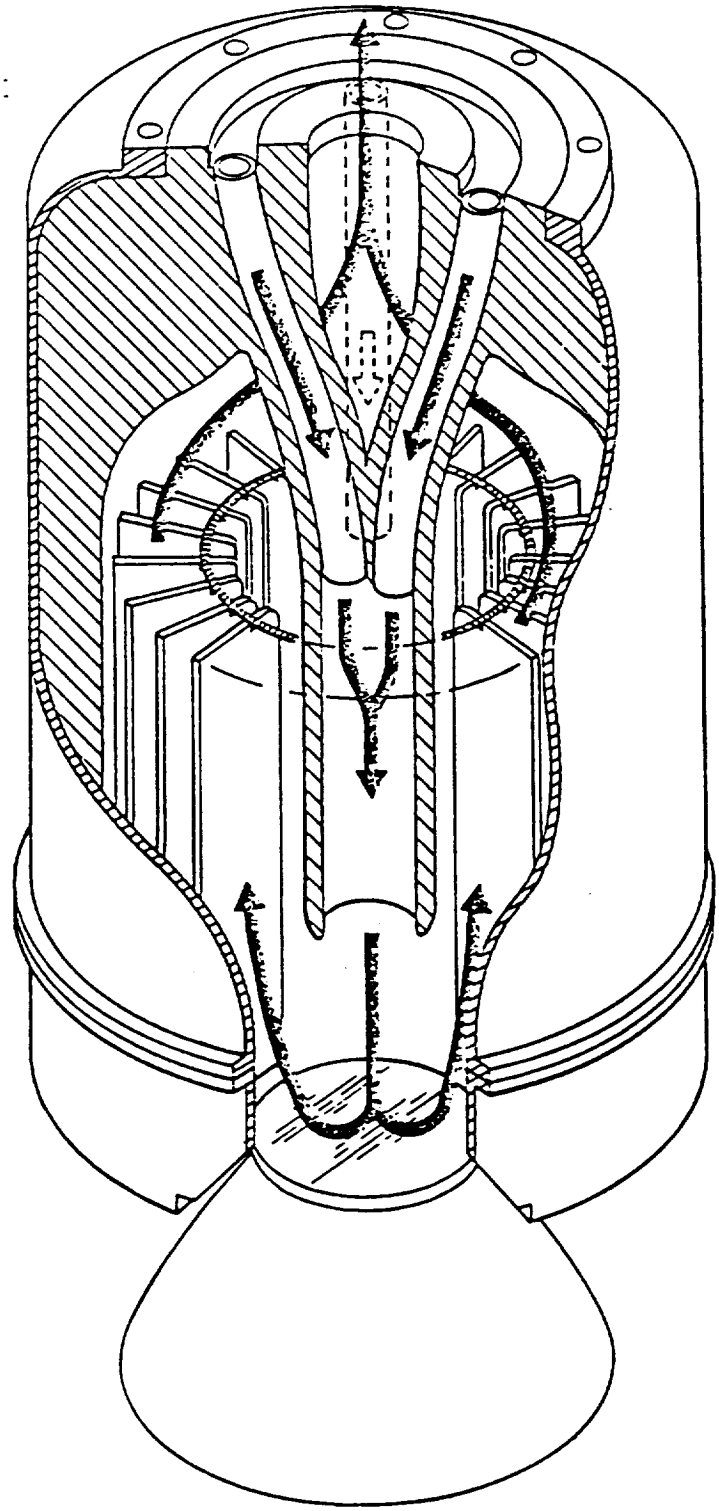
9950-860



OPEN EXTENDED SURFACE RECEIVER

PLATE B

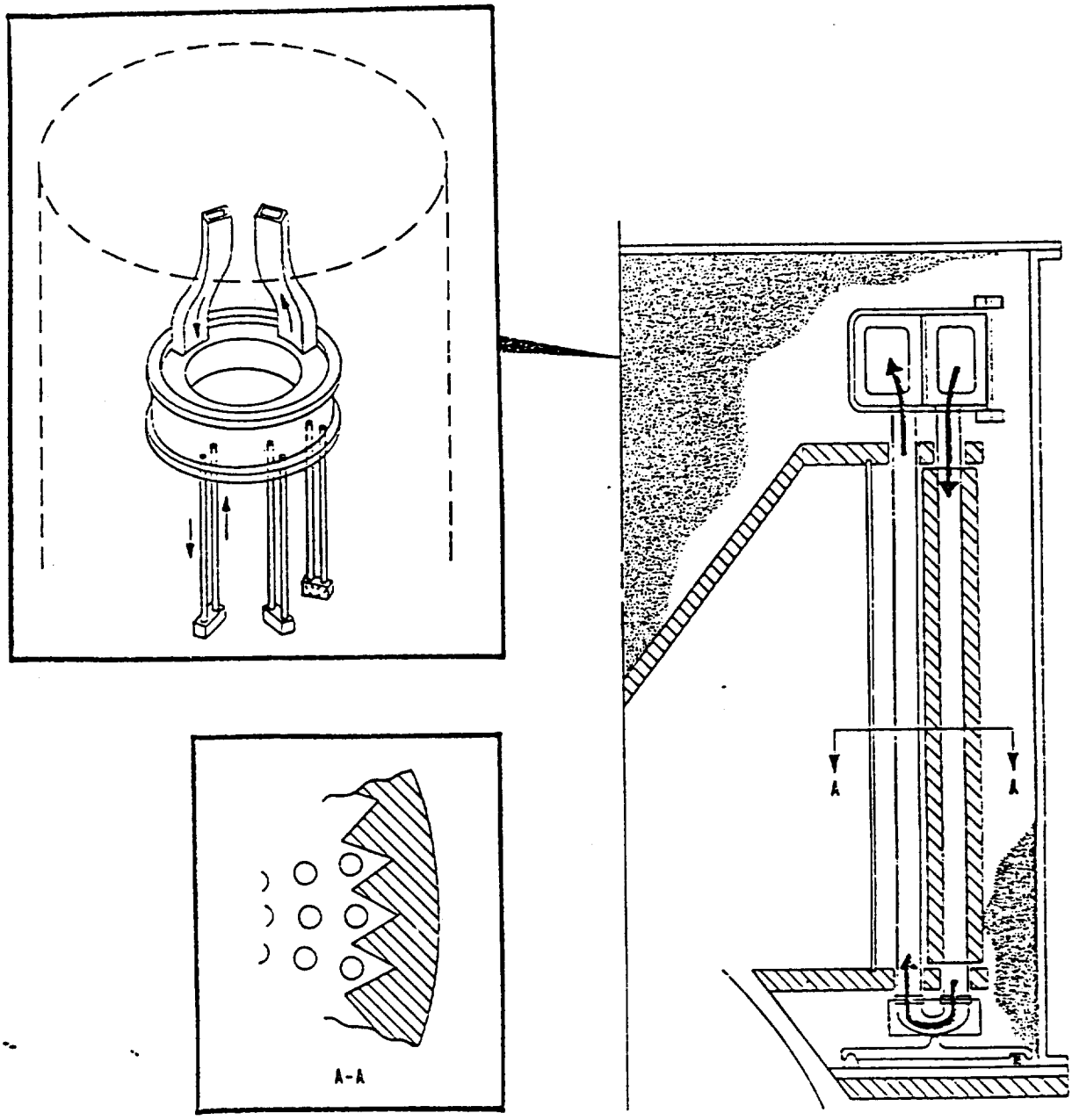
9950-860



WINDOWED EXTENDED SURFACE RECEIVER

PLATE C

9950-860



TUBED CAVITY RECEIVER

PLATE D

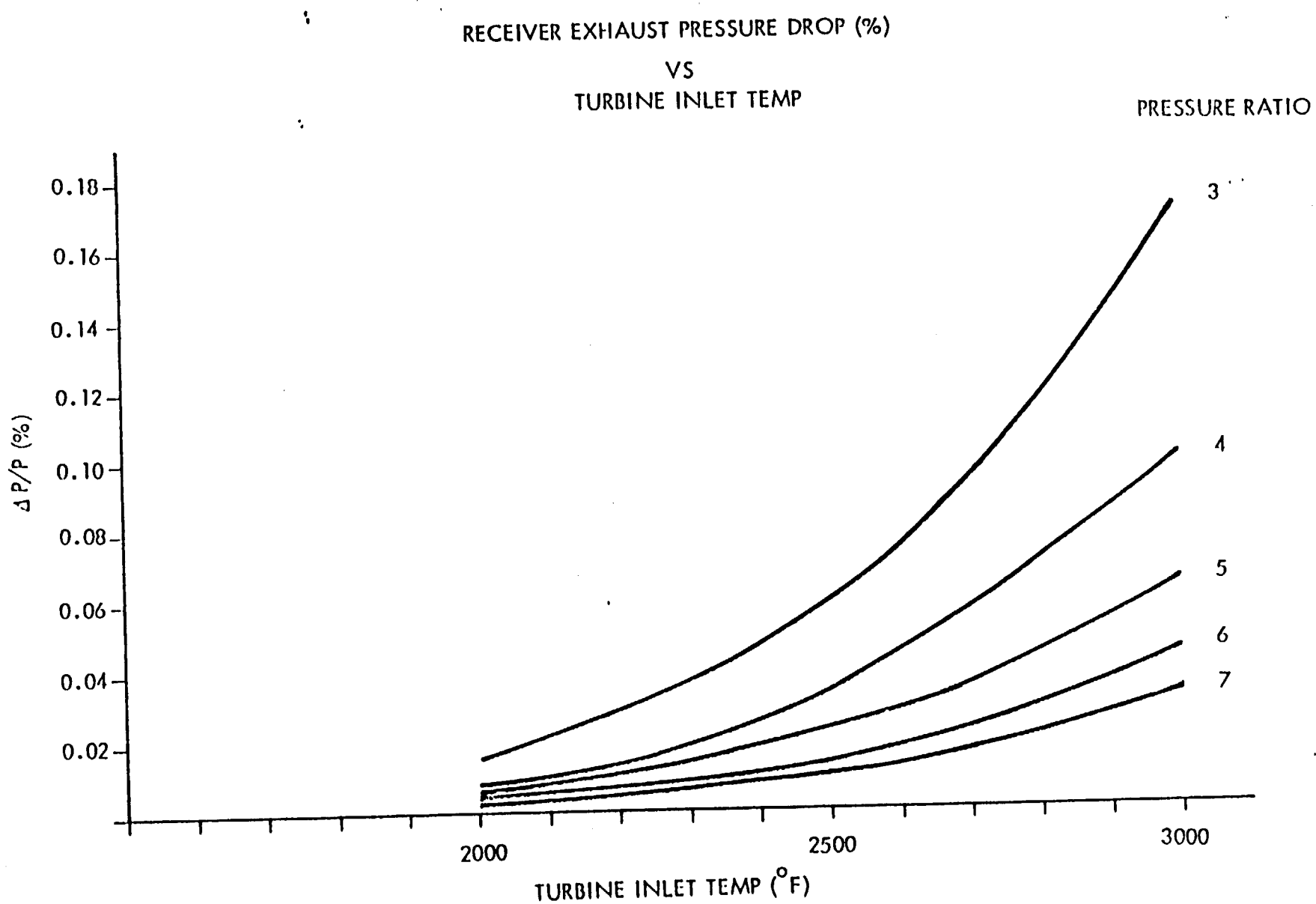

RECEIVER EXHAUST PRESSURE DROP (%)
VS
TURBINE INLET TEMP
PRESSURE RATIO
3
4
5
6
7
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
ΔP/P (%)
2000
2500
3000
TURBINE INLET TEMP (°F)

Figure 1.

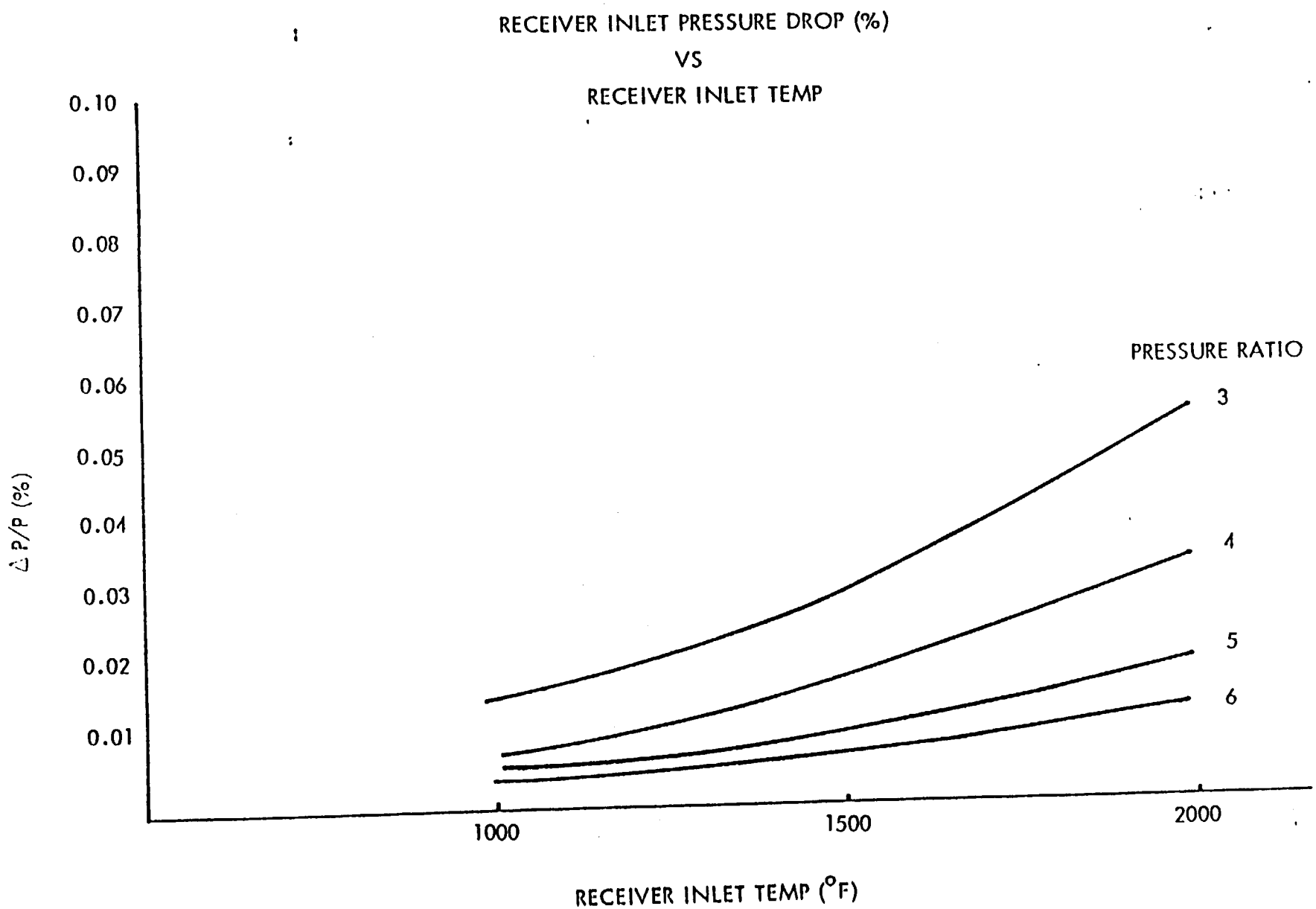
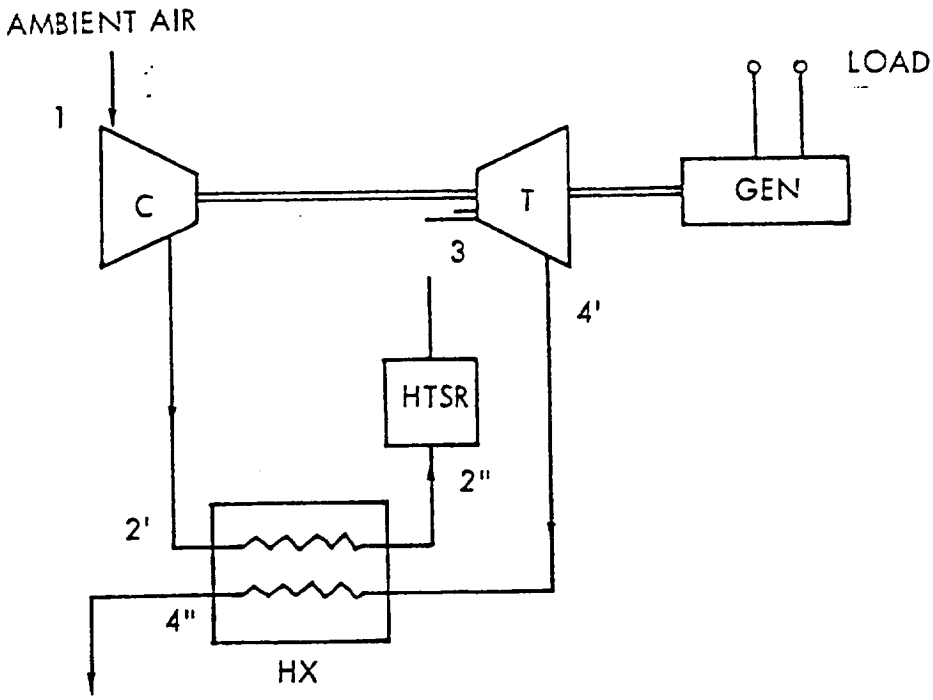

RECEIVER INLET PRESSURE DROP (%)
VS
RECEIVER INLET TEMP
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
ΔP/P (%)
PRESSURE RATIO
3
4
5
6
1000
1500
2000
RECEIVER INLET TEMP (°F)

Figure 2.

9950-860



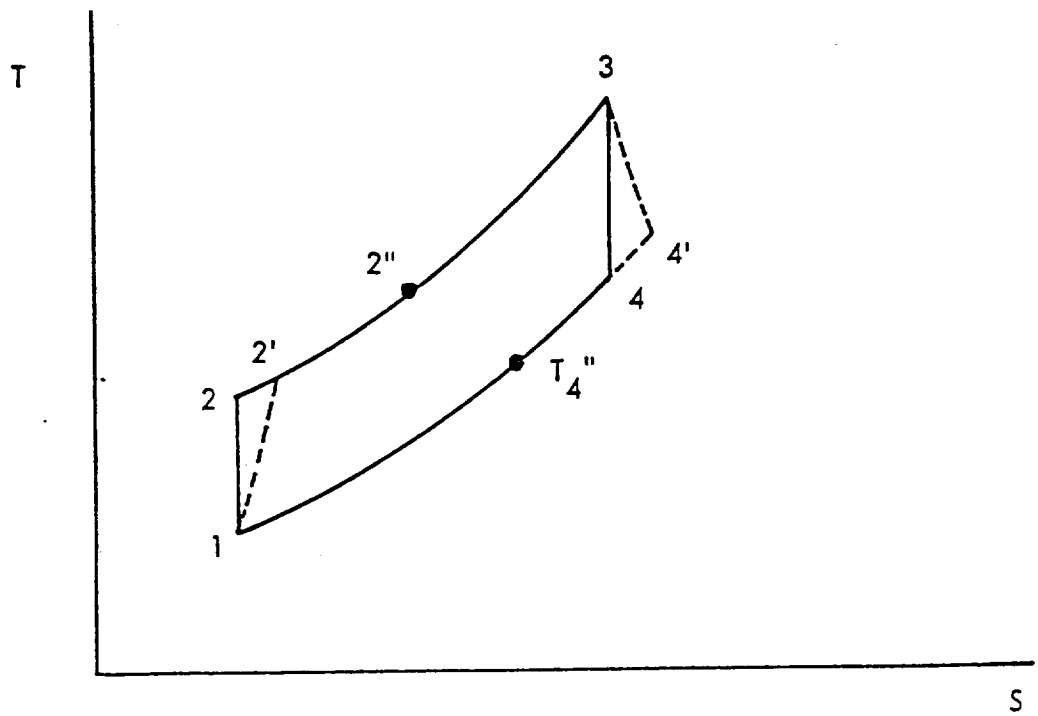


Figure 3.

TABLE 2. BRAYTON PERFORMANCE DATA

T_1 (°F)		PR=2			PR=3			PR=4			PR=5			PR=6			PR=7			PR=8		
		0	0.5	0.9	0	0.5	0.9	0	0.5	0.9	0	0.5	0.9	0	0.5	0.9	0	0.5	0.9	0	0.5	0.9
2000.	T_2"	266	978	1560	366	945	1417	445	929	1324	509	921	1257	563	917	1205	614	916	1163	658	917	1128
	η %	.87	16	36.3	15.2	22.9	40.7	18.5	26.3	40.9	20.7	28.1	40.2	22.3	29	39.1	23.4	29.5	37.8	24.3	29.7	36.5
2200.	T_2"	268	1070	1724	368	1030	1571	446	1010	1470	511	999	1398	567	993	1341	616	990	1296	659	989	1258
	η	9.8	16.1	37.4	15.4	23.4	42.6	18.9	27.1	43.4	21.2	29.2	43	22.9	30.4	42.1	24.2	31.2	41.2	25.2	31.6	40.1
2400.	T_2"	269	1165	1896	370	1118	1729	448	1094	1621	513	1080	1543	568	1071	1482	617	1066	1433	661	1064	1302
	η	9.5	15.7	37.5	15.3	23.4	43.7	18.8	27.3	45	21.3	29.7	45	23.1	31.2	44.5	24.5	32.1	43.7	25.6	32.8	42.9
2600.	T_2"	271	1249	2048	371	1200	1876	449	1171	1760	514	1154	1677	570	1144	1612	619	1137	1560	662	1132	1516
	η	10	16.5	39.3	15.7	24.1	45.7	19.3	28.2	47.2	21.9	31.7	47.3	23.8	32.4	47	25.3	33.5	46.4	26.4	34.2	45.7
2800.	T_2"	273	1324	2183	373	1281	2022	451	1244	1891	515	1223	1801	571	1211	1733	620	1202	1678	664	1197	1632
	η	11.1	18.3	42.9	15.9	24.5	47	20.1	29.4	49.6	22.7	32	49.8	24.7	33.7	49.6	26.2	34.9	49.1	27.4	350	48.5
3000.	T_2"	274	1401	2522	37.4	1342	2132	452	1321	2031	517	1289	1926	572	1274	1847	621	1264	1789	665	1257	1741
	η	11.9	19.5	45.5	17.6	26.8	50.5	20.2	29.7	50.7	23.7	33.4	52.2	25.7	35.2	52	27.2	36.4	51.6	28.5	37.4	51.1

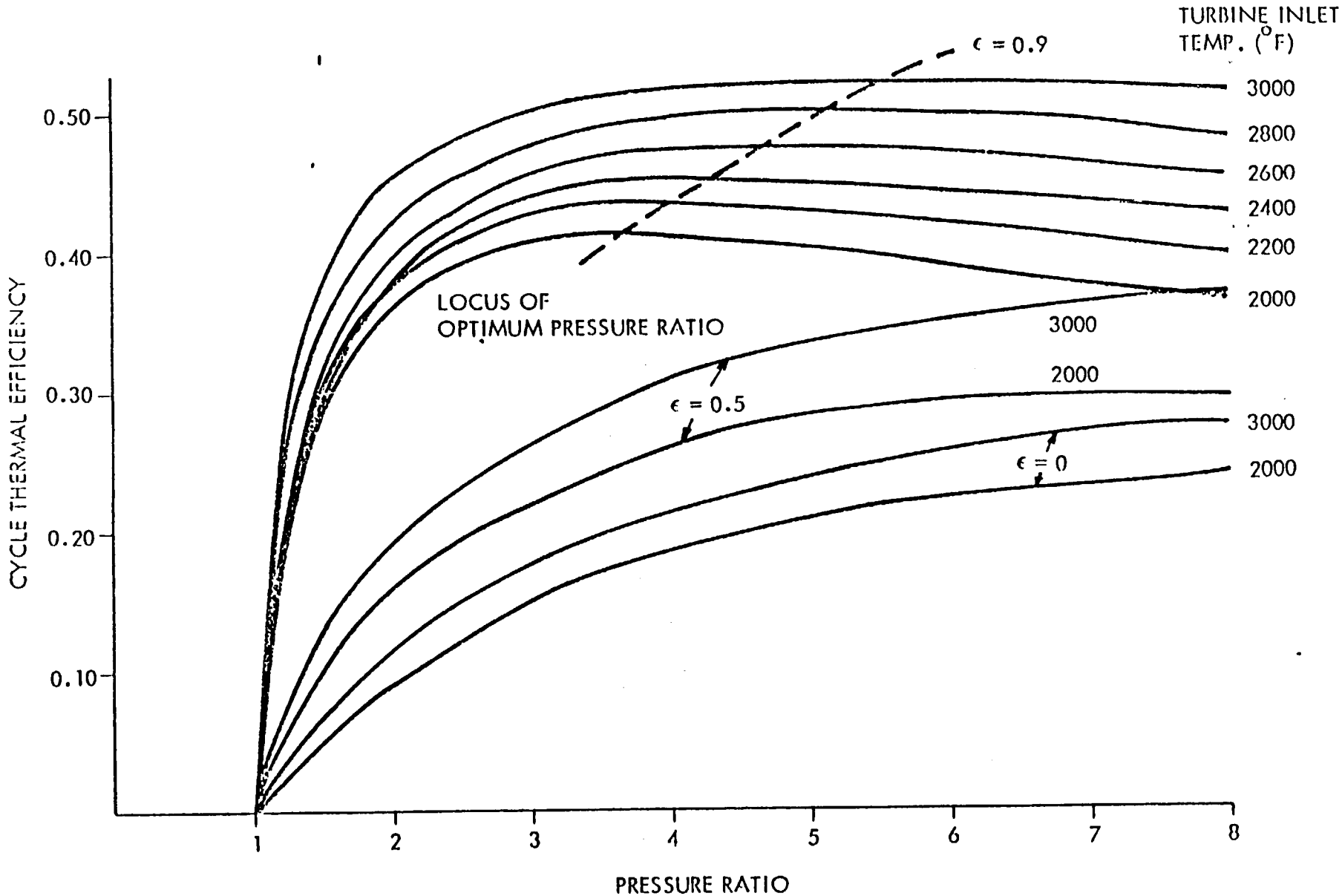


Figure 4. Cycle Efficiency versus Pressure Ratio

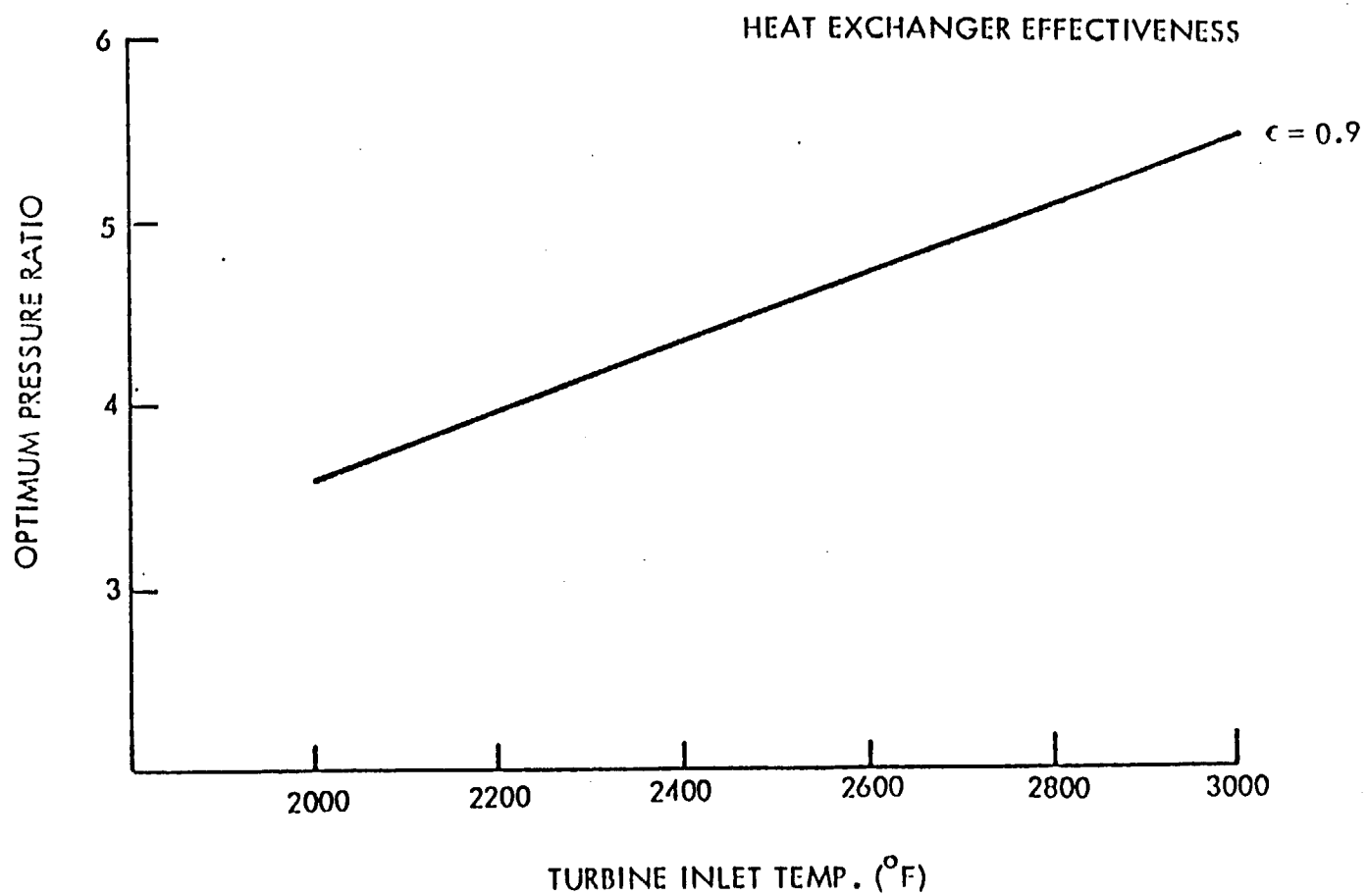


Figure 5. Optimum Pressure Ratio versus Turbine Inlet Temperature

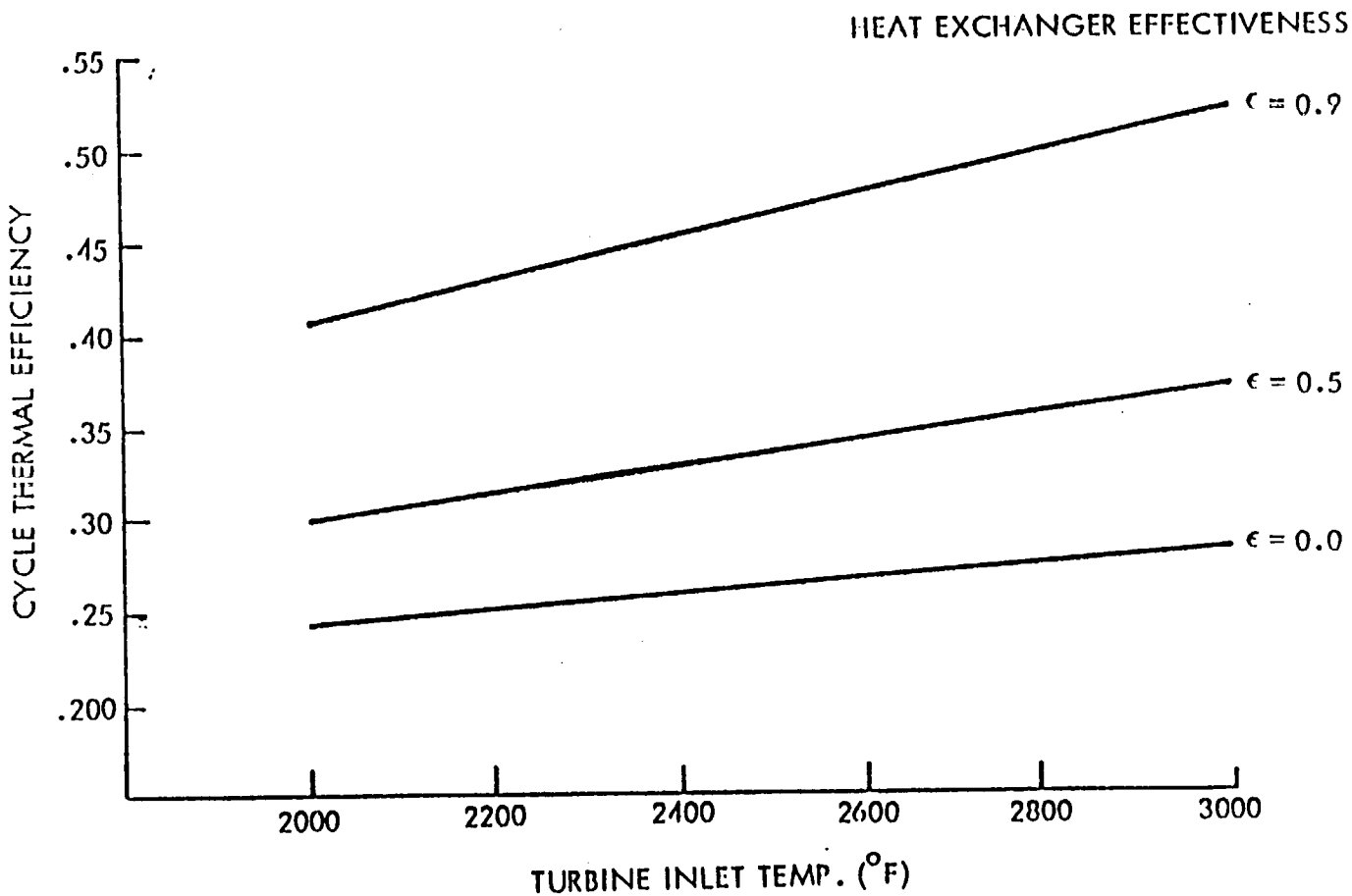


Figure 6. Cycle Efficiency at the Optimum Pressure Ratio versus Turbine Inlet Temperature

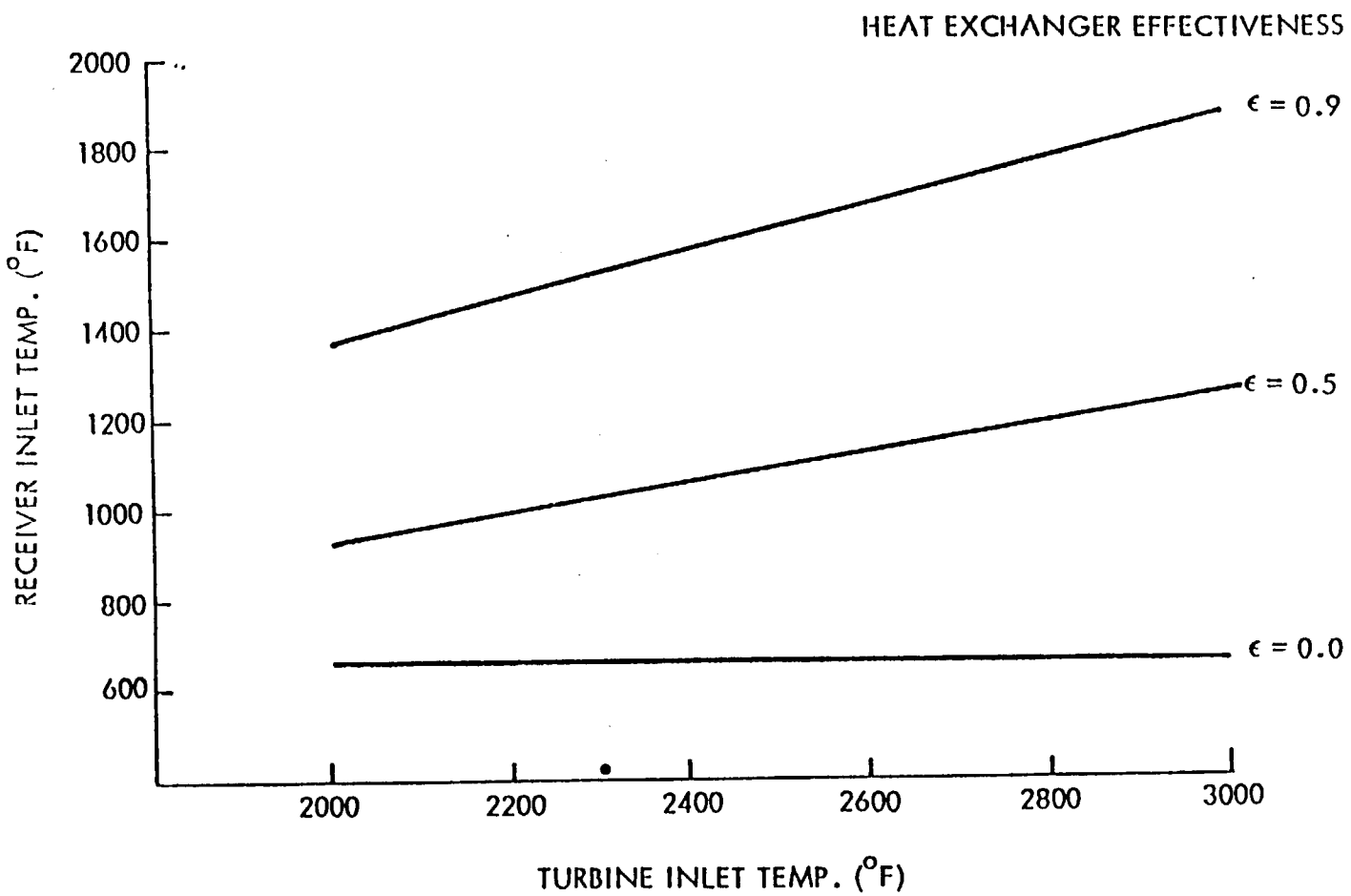


Figure 7. Receiver Inlet Temperature At the Optimum Pressure Ratio versus Turbine Inlet Temperature

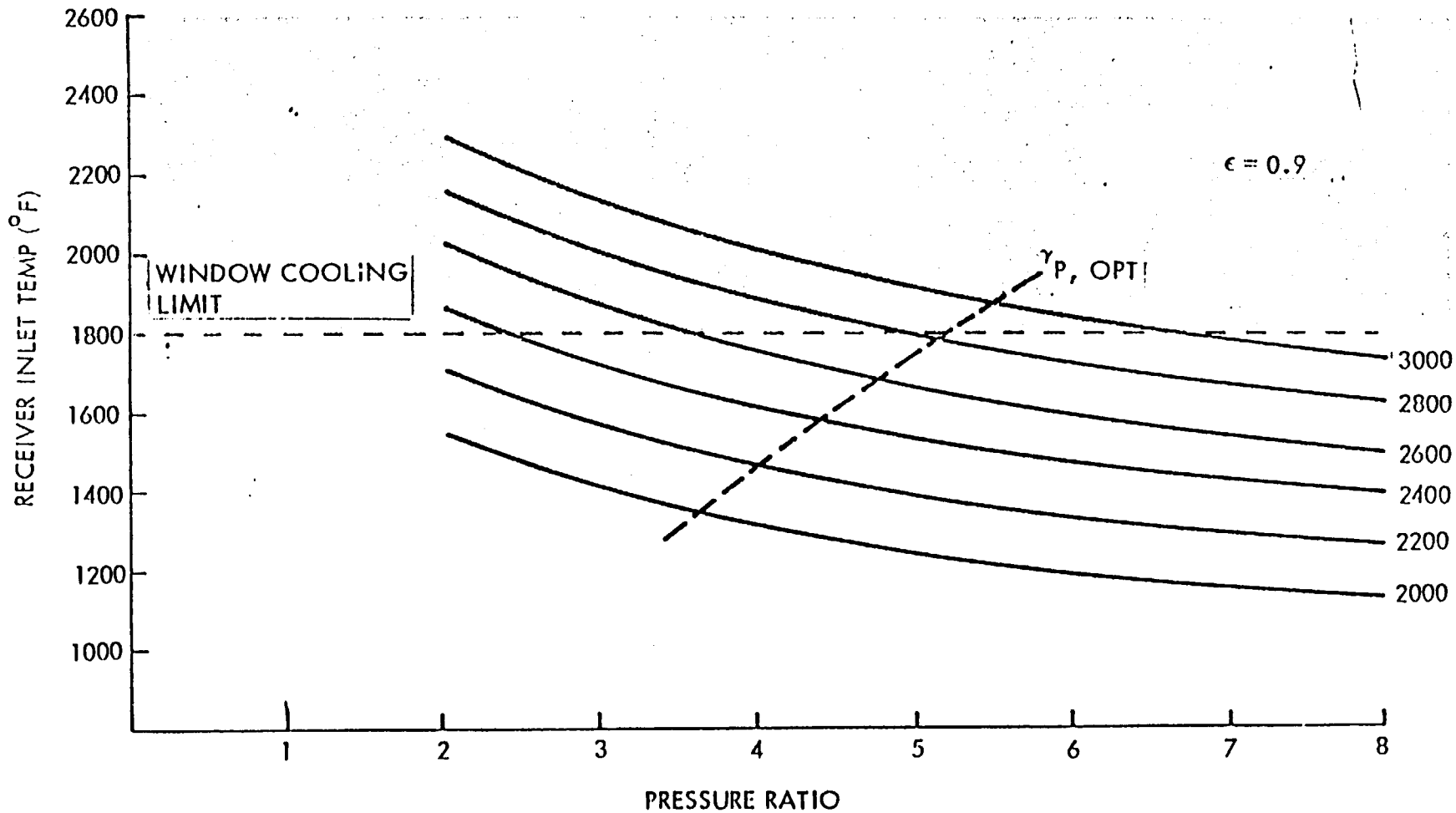


Figure 8. Receiver Inlet Temperature versus Pressure Ratio and Turbine Inlet Temperature

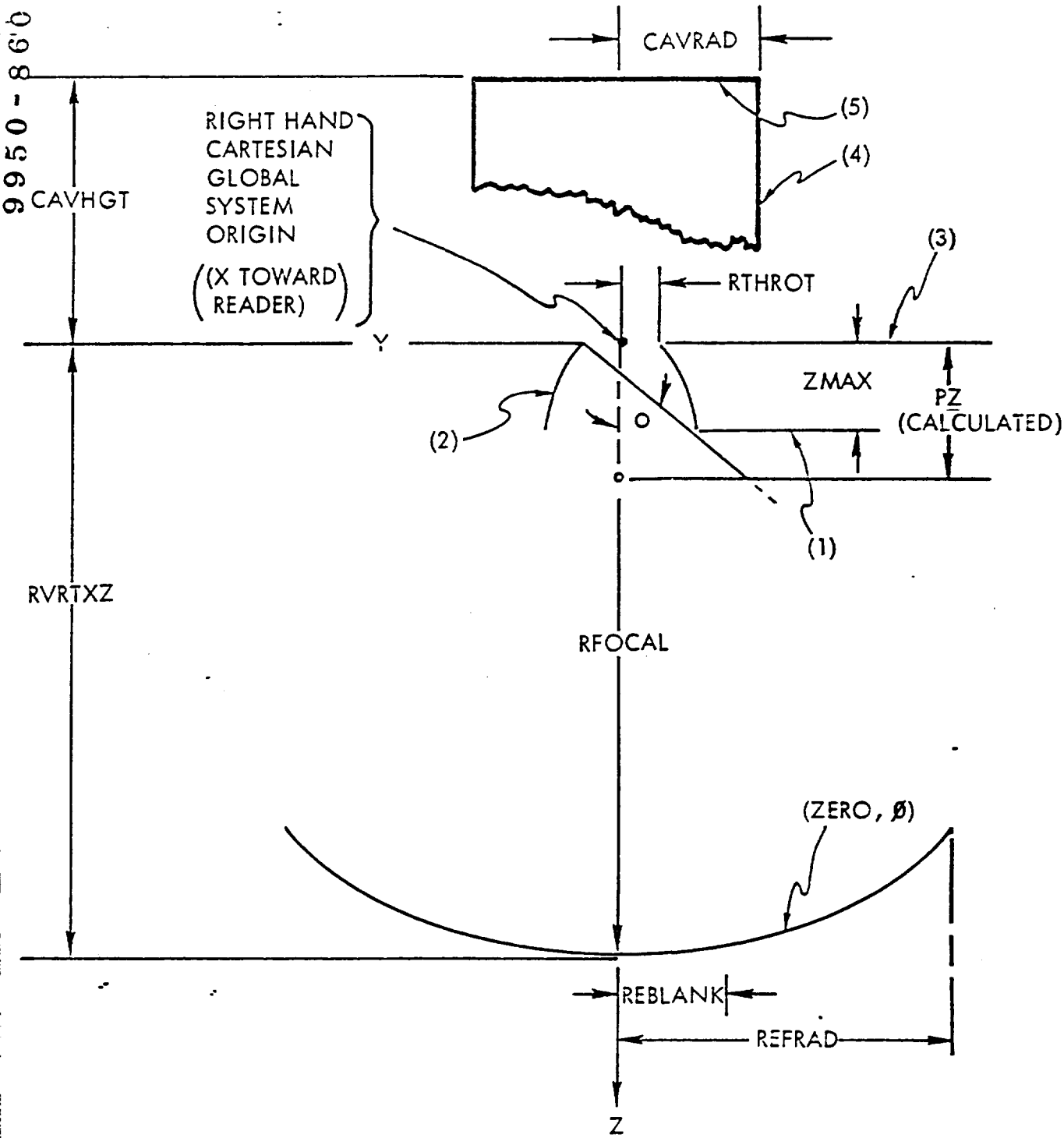


Figure 9.

9950-86b

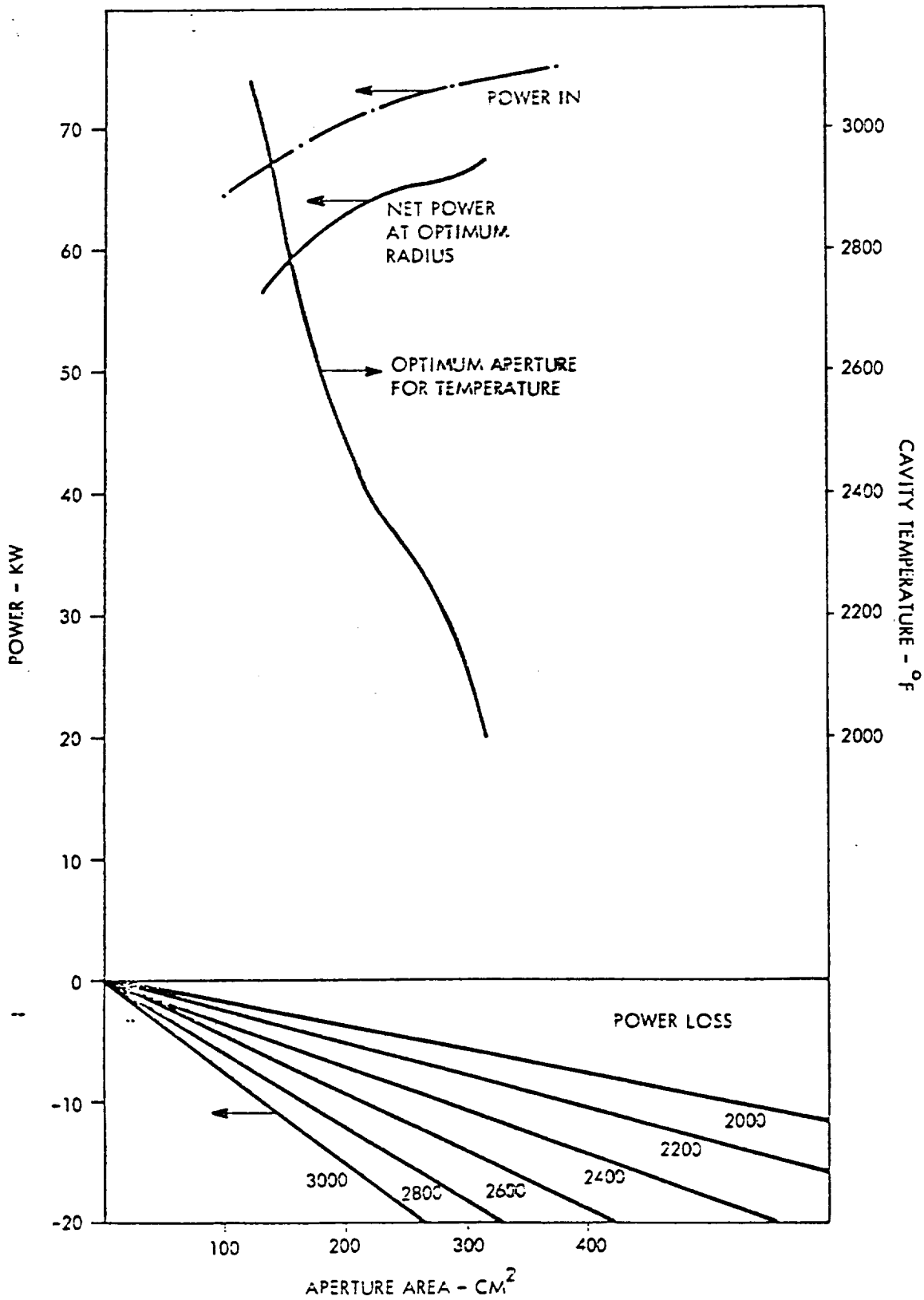


Figure 10. Open Receiver

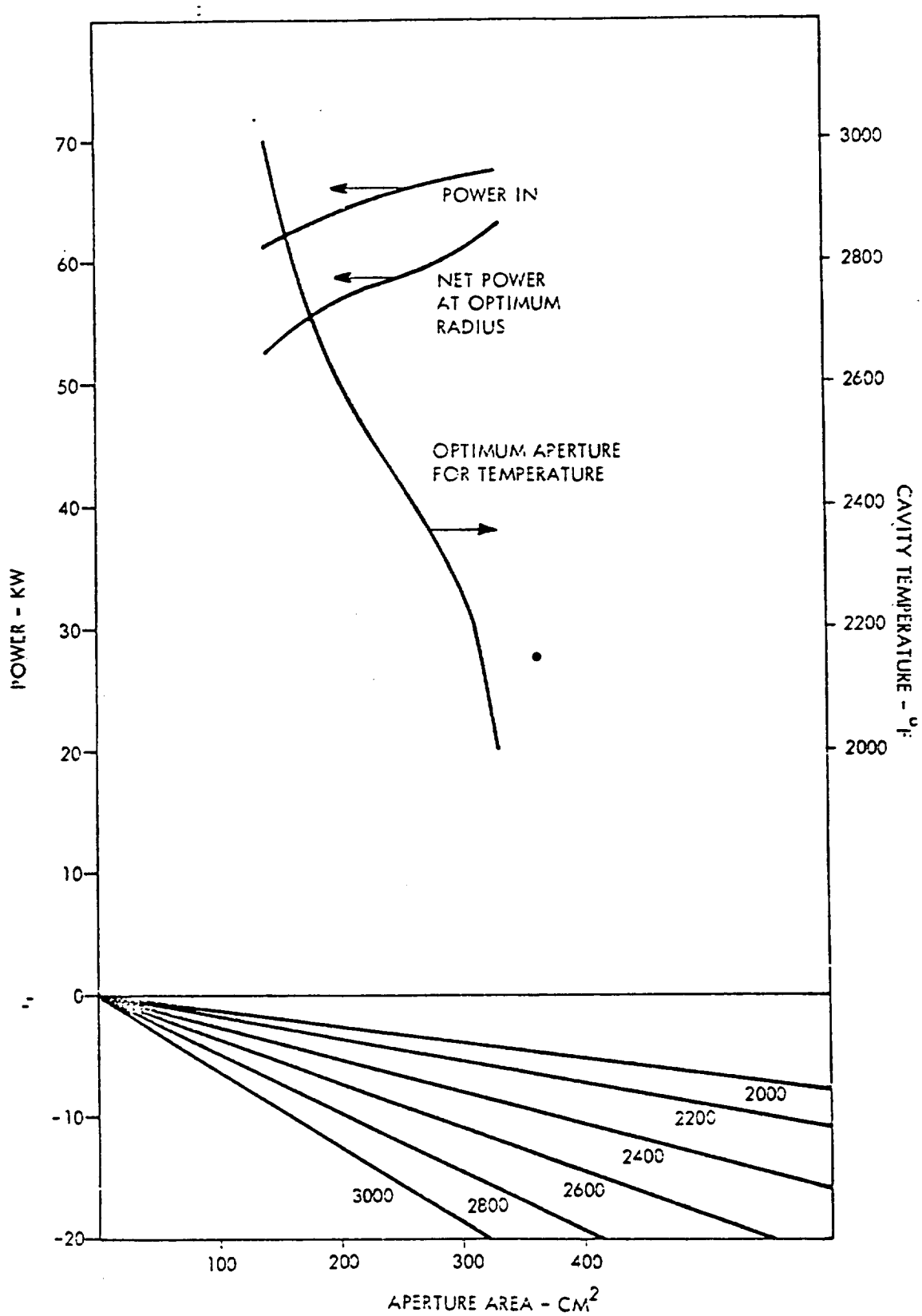


Figure 11. Windowed Receiver

9950-860

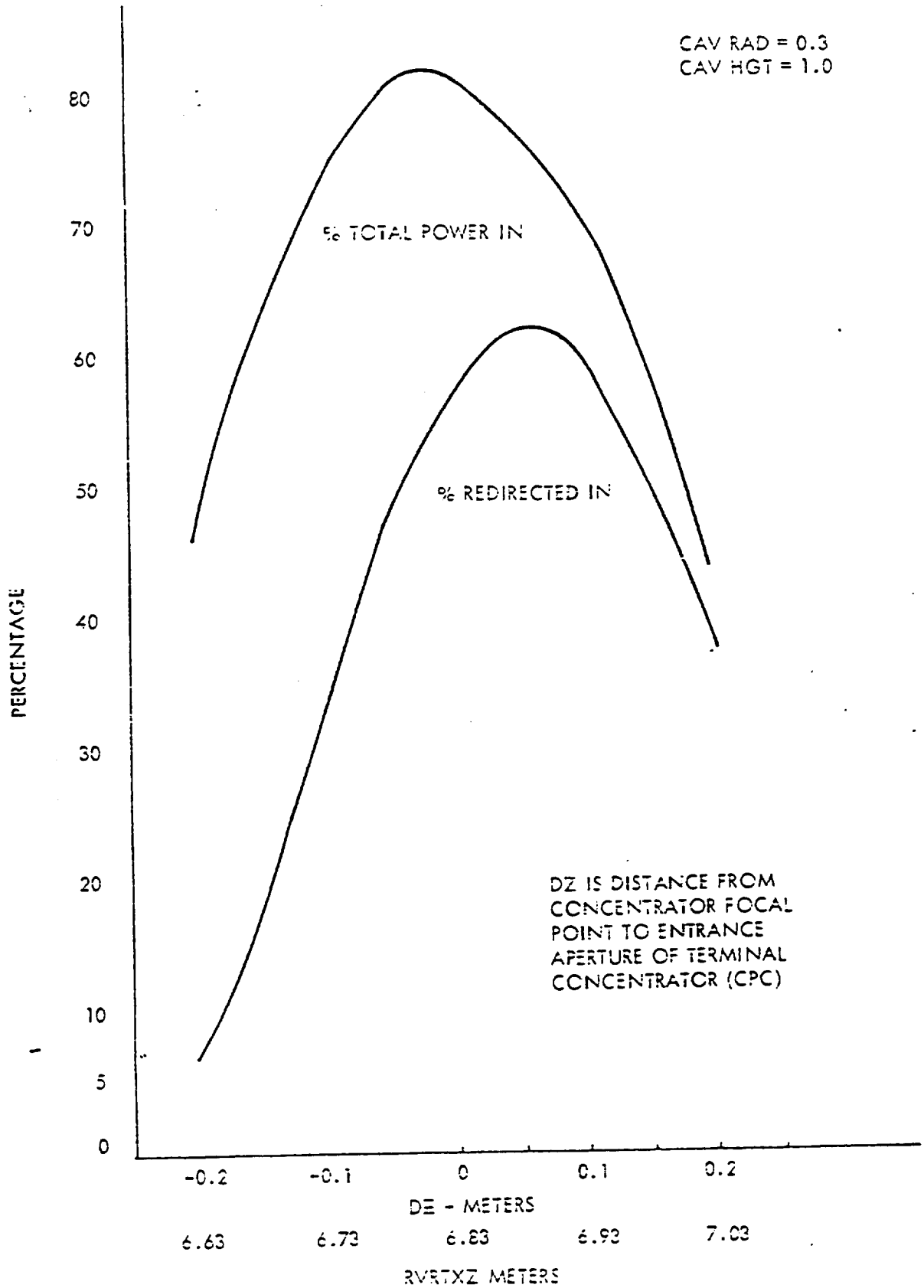


Figure 12A. Energy Distribution

9950-860

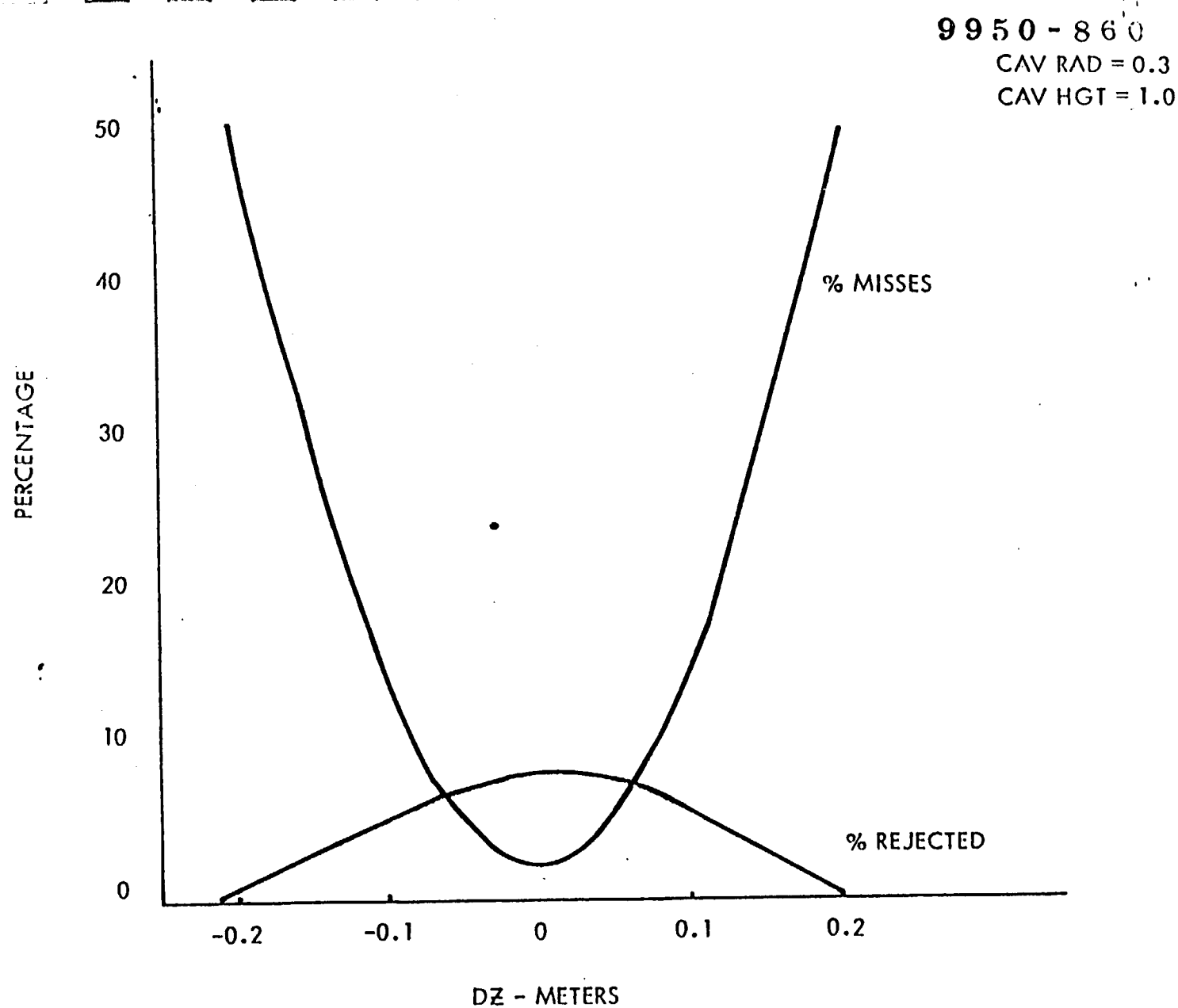


Figure 12B. Energy Distribution

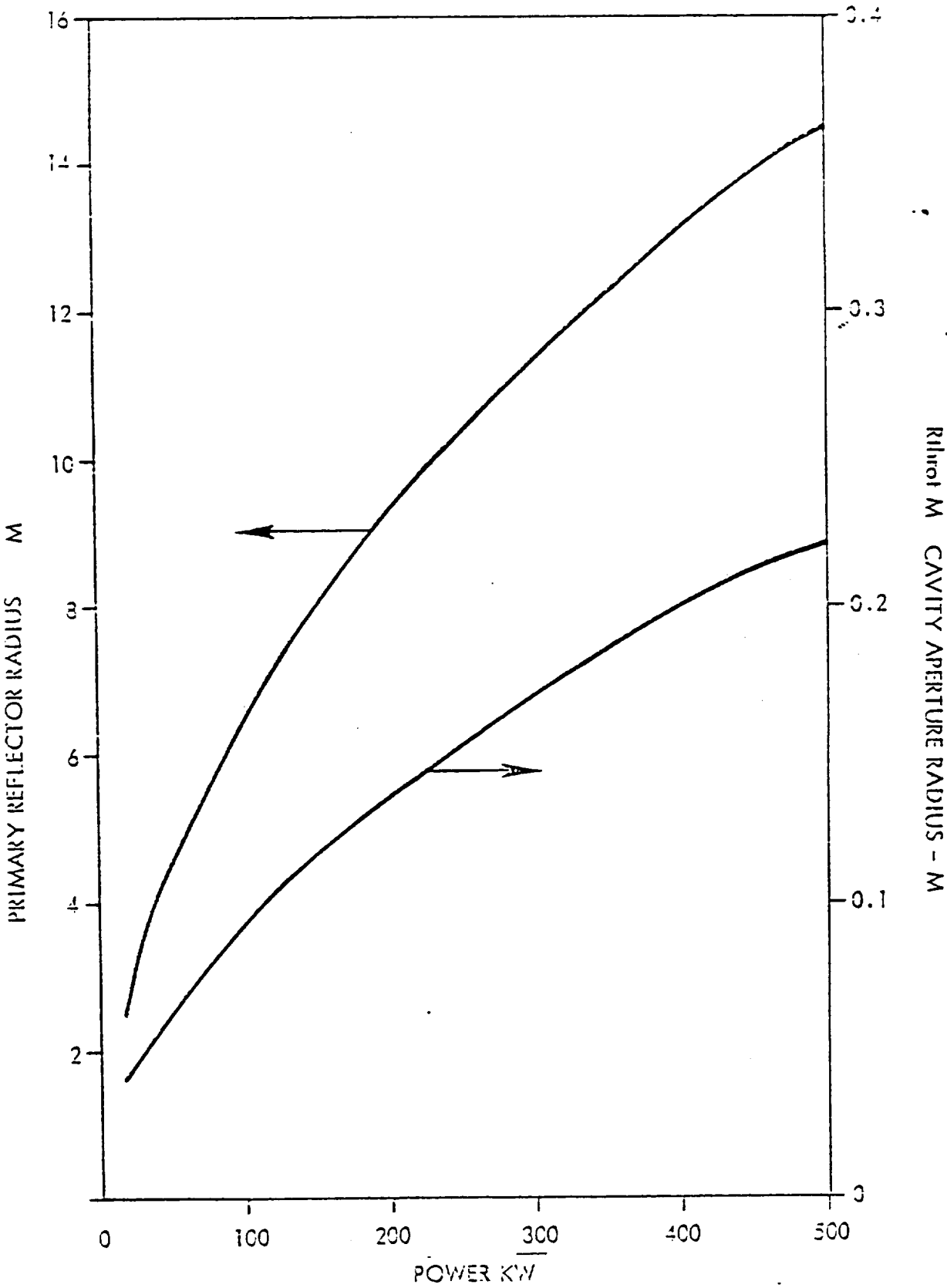
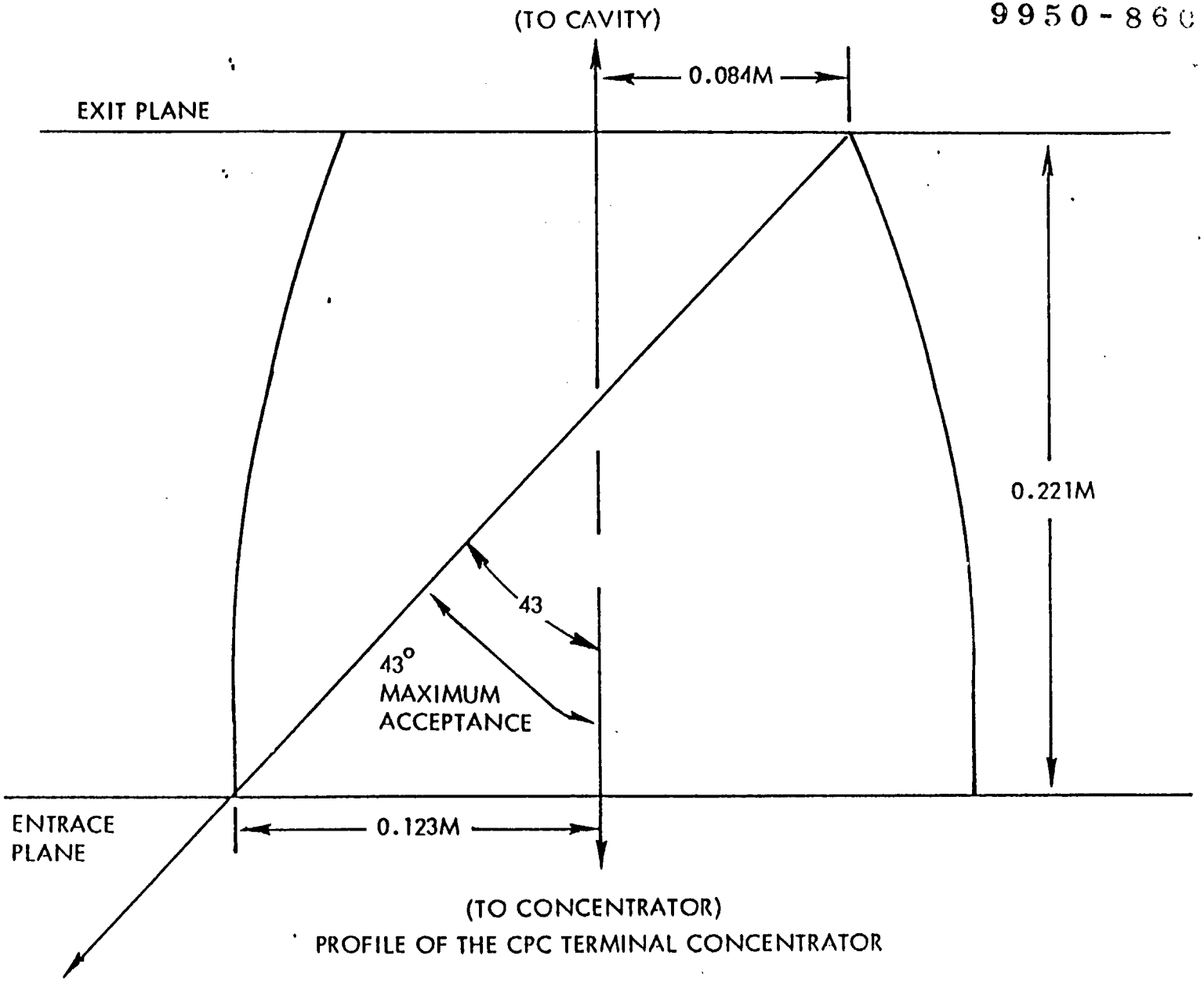


Figure 13.

9950-860



PROFILE OF THE CPC TERMINAL CONCENTRATOR

Figure 14.

9950-860

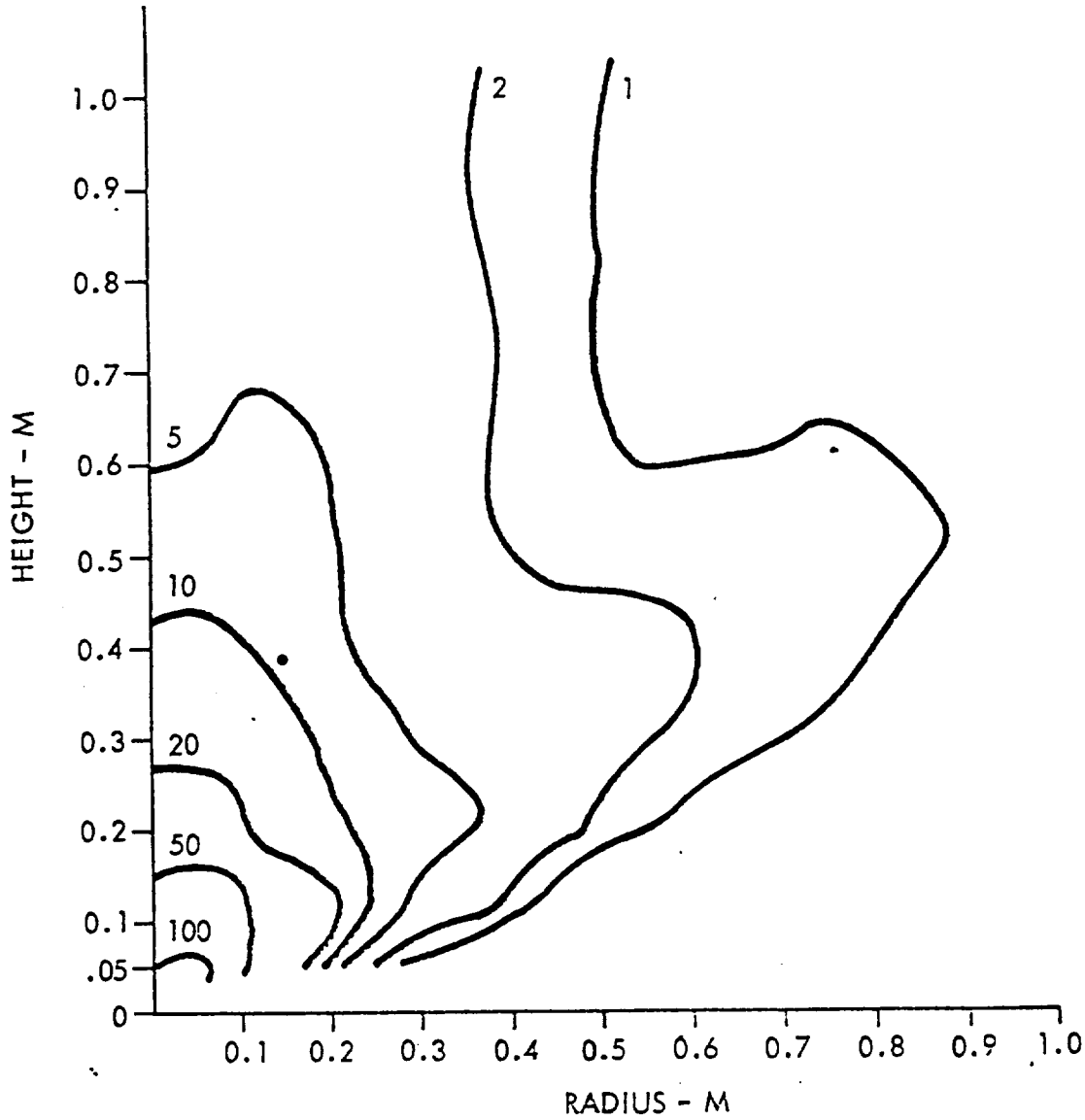


Figure 15. Vertical Flux Component versus Position $W \cdot cm^{-2}$

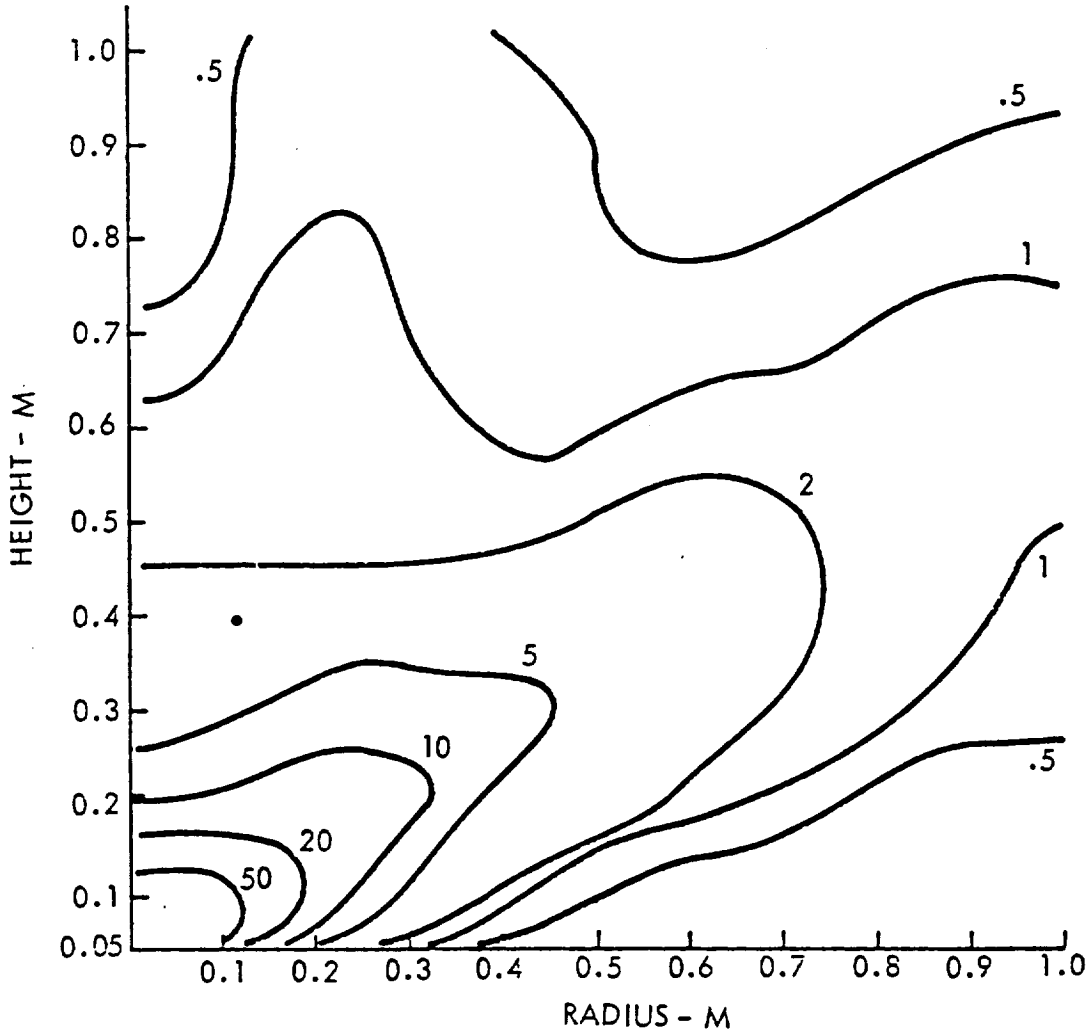


Figure 16. Radial Flux Component versus Position
$W \cdot cm^{-2}$

9950-860

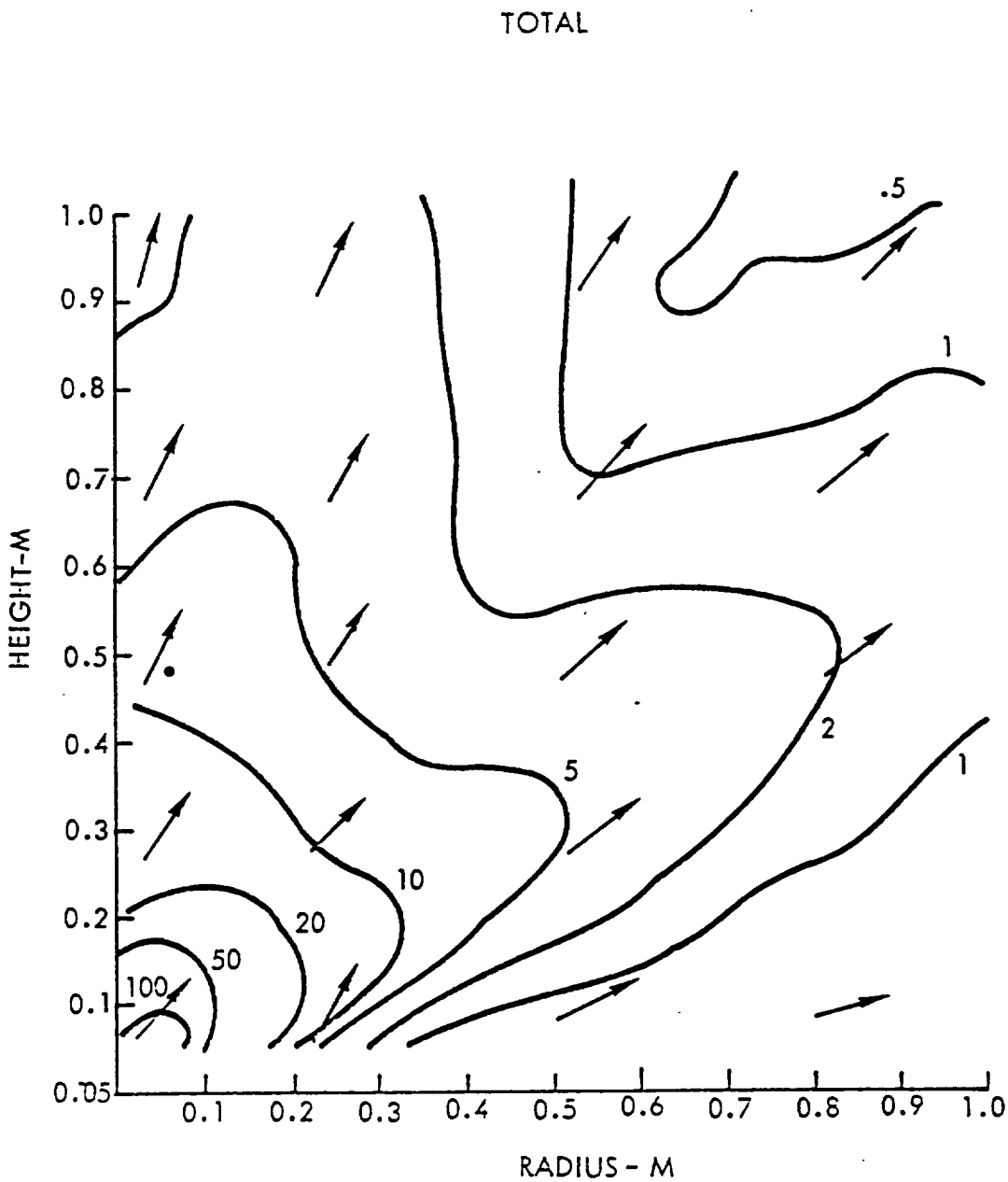


Figure 17. Total Flux versus Position $W \cdot cm^{-2}$

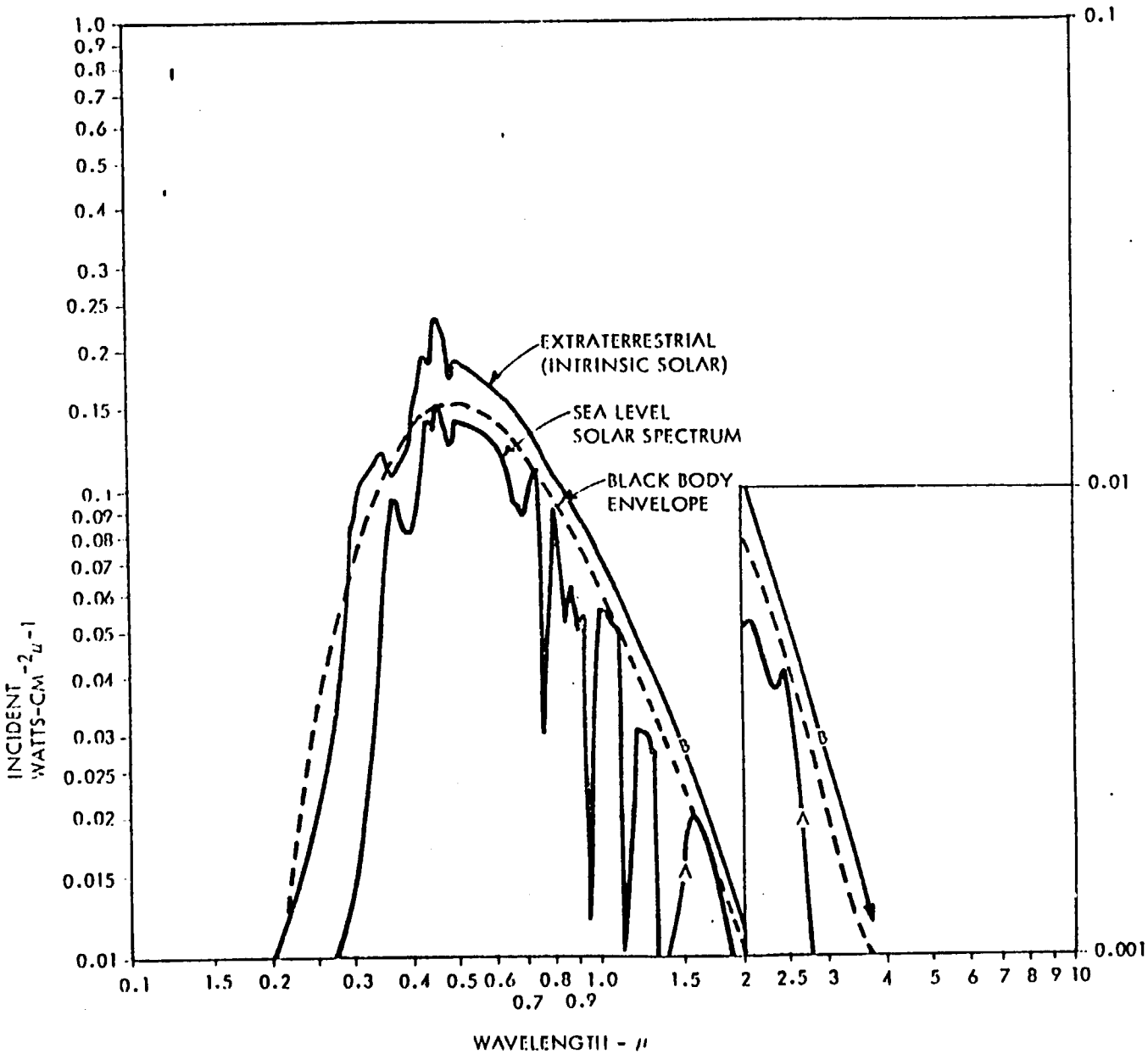


Figure 18. Spectral Energy Distribution

TABLE 7

SPECTRAL INTEGRATION OF BLACK BODY FLUX ABSORPTION
BY A
GE TYPE 125 QUARTZ WINDOW

λ μ	Fomax W cm^{-2}	$f_{\Delta 2}$ %	$F_{\Delta 2}$ W cm^{-2}	$\bar{T}$ %	C ℓn $\bar{T}$	WINDOW THICKNESS (CM) & ΔT 1.0	2.0	3.0	4.0	5.0	6.0
.16-.18	1300	.045	.585	10.	2.30	12	17	18			
.18-.20	1300	1.0	1.3	25.	1.39	27	51	61	65	66	67
.20-.225		.33	4.29	55.	.598	62	172	274	353	410	447
.225-.24		.30	3.90	72.	.328	37	119	219	321	414	497
.24-.26		.52	6.76	78.	.248	51	173	333	509	685	853
.26-.275		.70	9.1	94.	.0619	19	74	160	273	410	568
.275-.300		1.3	16.9	97.	.0306	18	71	156	272	417	589
2.6-2.7		.25	3.2	85.	.162	17	60	121	194	275	358
2.7-2.9		.5	6.5	85.	.162	34	122	246	395	558	728
2.9-3.3		.6	7.8	88.	.128	33	120	250	409	589	782
3.3-3.5		.3	3.9	78.	.248	30	100	192	294	395	492
3.5-3.7		.2	2.6	58.	.545	35	101	166	218	258	285
3.7-3.8		.05	.65	35.	1.05	12	27	36	41	43	44
3.8-4.0		.05	.65	17.	1.77	14	23	25	26	26	26
4.0-4.3		.05	.65	4.	3.22	12	14	14	14	14	14
TOTAL RISE						413	1244	2271	3402	4578	5768

TABLE 8

SPECTRAL INTEGRATION OF SOLAR FLUX ABSORPTION
BY A
GE TYPE 125 QUARTZ WINDOW

μ λ	W-cm^{-2} Fomax	% $f_{\Delta\lambda}$	W cm^{-2} $F_{\Delta\lambda}$	% T	ℓn T C	WINDOW THICKNESS & ΔT 1.0cm	2.0cm	3.0cm	4.0cm	5.0cm	6.0cm
						TEMPERATURE RISE °K					
.16-.18	1300	.010	.130	10	2.30	3	4	4	4	4	4
.18-.20	1300	.020	.260	25	1.39	5	10	12	13	13	13
.20-.225	1300	.066	.858	55	.598	12	34	55	71	82	89
.225-.24	1300	.060	.780	72	.328	7	24	44	64	83	99
.24-.26	1300	.086	1.12	78	.248	8	29	55	84	113	141
.26-.275	1300	.178	1.31	94	.0619	5	19	41	70	104	144
.275-.300	1300	.650	8.45	97	.0306	9	35	78	136	209	294
2.6-2.7	1300	.012	.156	85	.162	1	3	6	9	13	17
2.7-2.9	1300	.025	.325	85	.162	2	6	12	20	28	36
2.9-.3.3	1300	.020	.260	88	.128	1	4	8	14	20	26
3.3-3.5	1300	.01	.130	78	.248	1	3	6	10	13	16
3.5-3.7	1300	.006	.078	58	.545	1	3	5	7	8	9
3.7-3.8	1300	.002	.026	35	1.05	.4	1	1	2	2	2
3.8-4.0	1300	.002	.026	17	1.77	.5	1	1	1	1	1
4.0-4.3	1300	.002	.026	4	3.22	.5	.5	1	1	1	1
TOTAL RISE						56	176	329	506	694	892

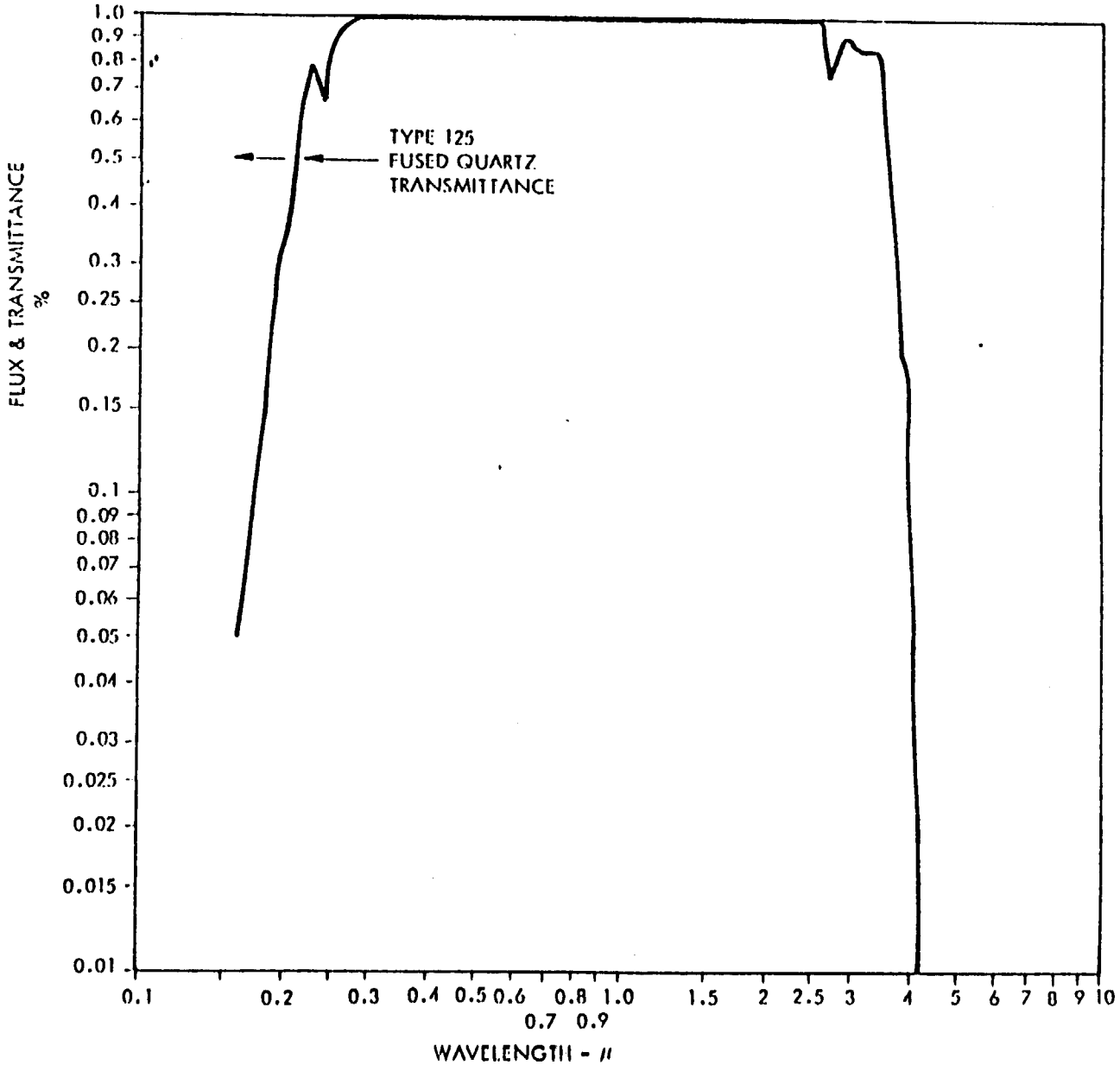

TYPE 125
FUSED QUARTZ
TRANSMITTANCE
FLUX & TRANSMITTANCE
%
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.25
0.2
0.15
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.025
0.02
0.015
0.01
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.5
2
2.5
3
4
5
6
7
8
9
10
WAVELENGTH - μ

Figure 19.

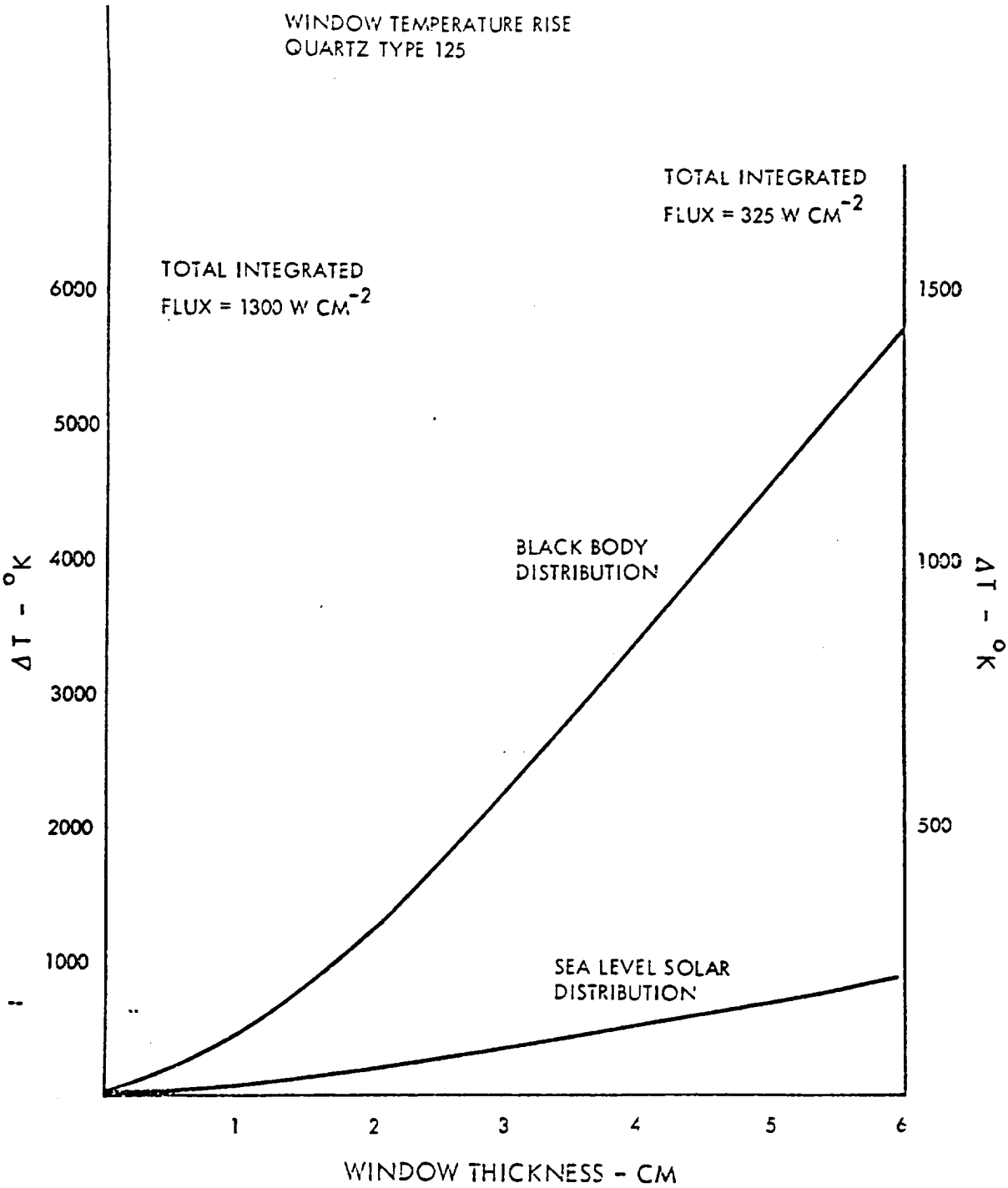


Figure 20. Window Temperature Rise Quartz Type 125 versus Window Thickness

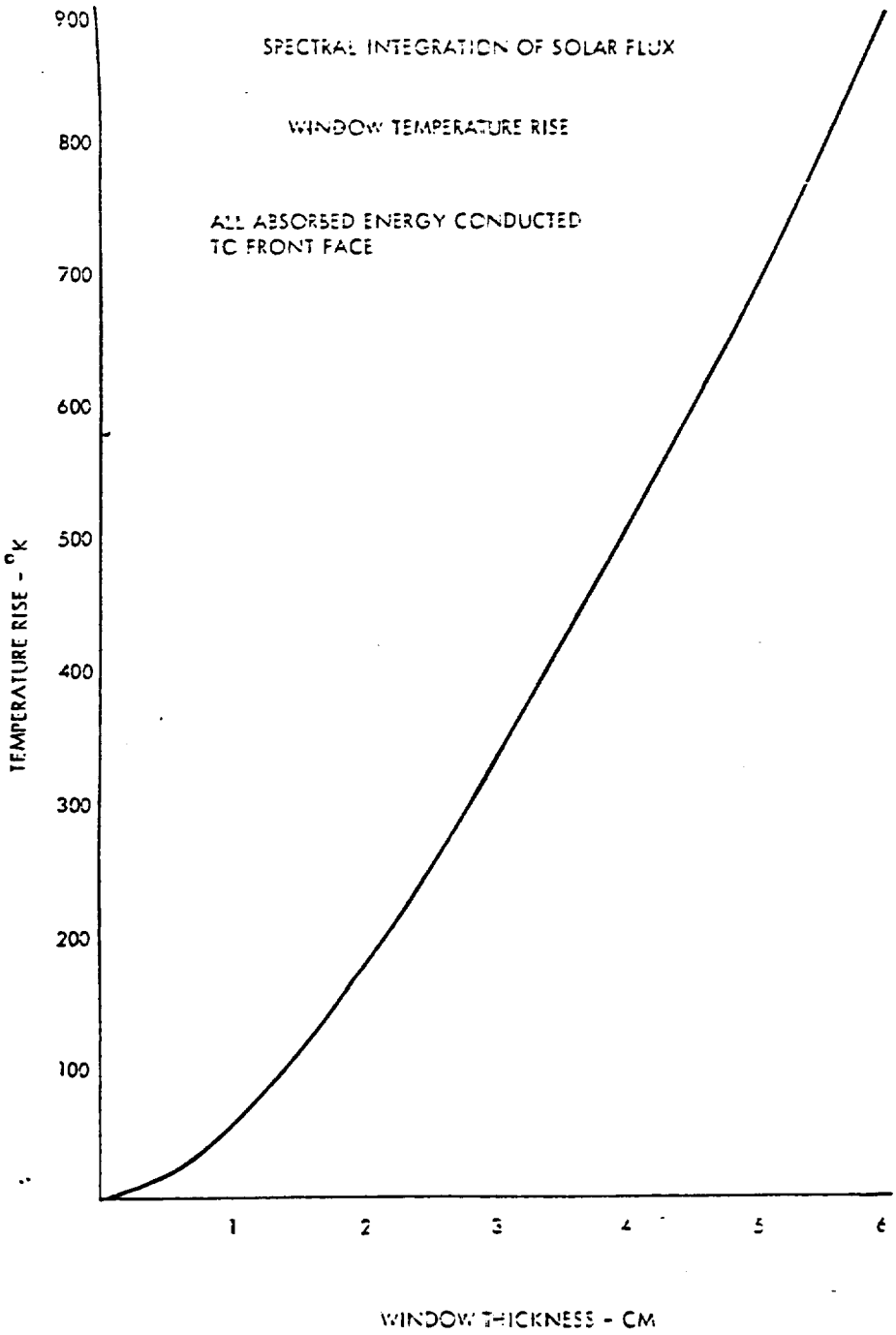


Figure 21. Window Temperature Rise versus Window Thickness

9950-860

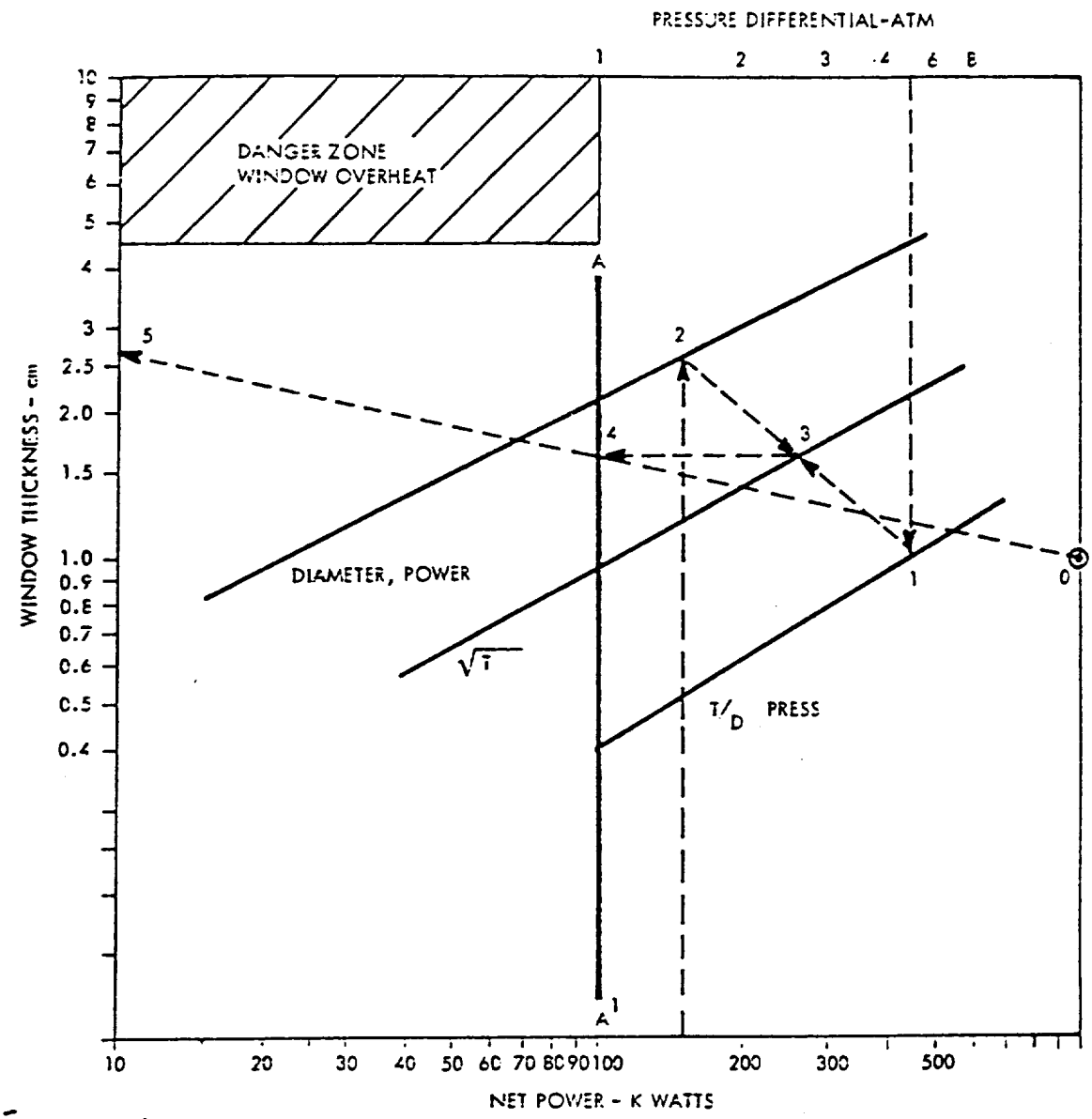


Figure 22. Window Limit Safety Nomogram

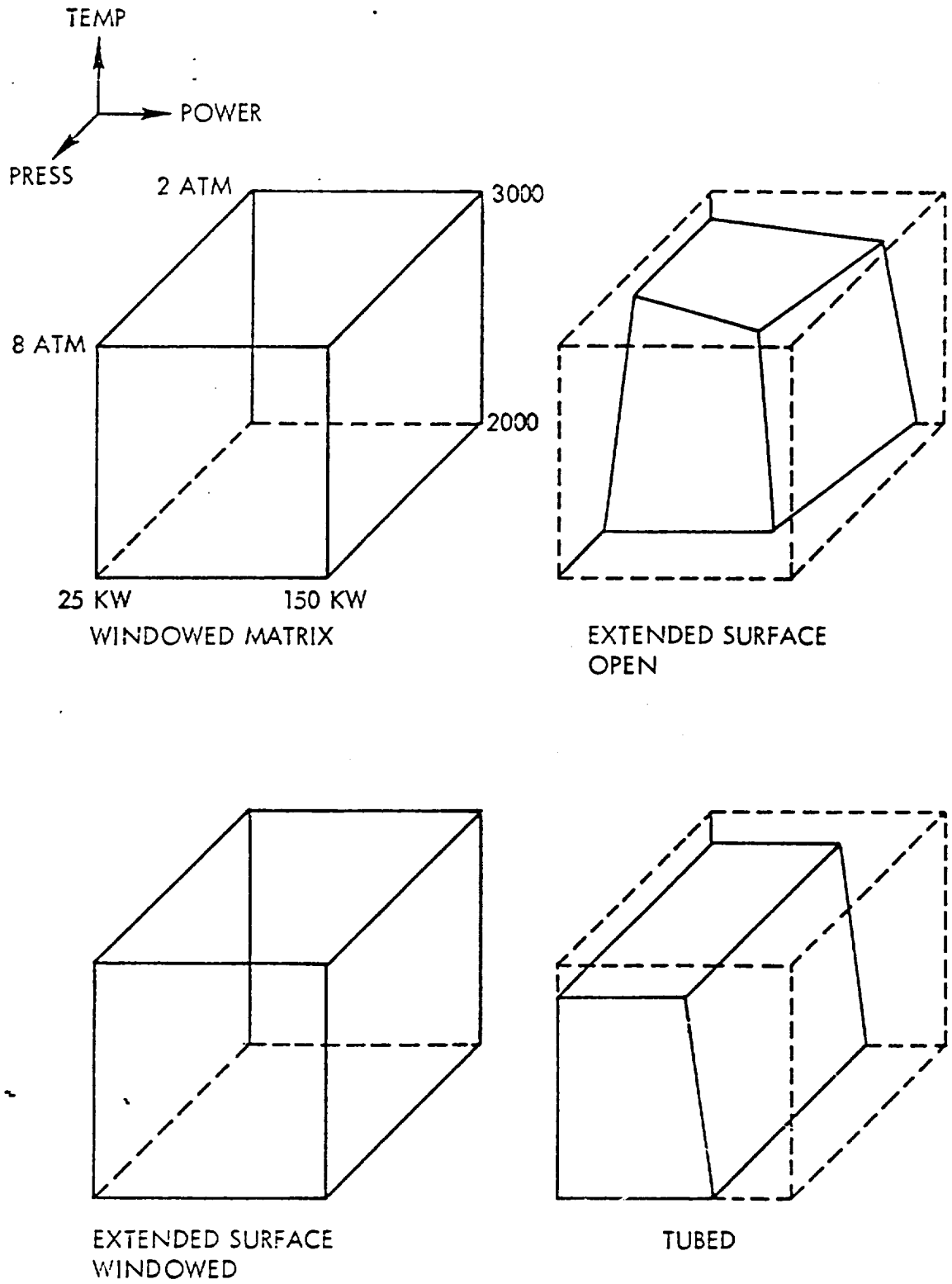


Figure 23. Receiver Regimes of Operation

9950-860

RECOMMENDATIONS

The windowed receivers are recommended for their superior capabilities. The two windowed concepts are very comparable in their overall evaluation but the balance favors the matrix receiver for the reasons given below.

The matrix receiver panels are fully within present day production capabilties.

Thermal buffer material can be optionally installed or omitted.

Thermal buffer material can be a less expensive material (Mullite, Alumina) than the matrix (silicon carbide) because it is not exposed to step transients.

Radiation losses from the thermal buffer are trapped by the matrix and are returned to the airstream; the energy cannot escape through the aperture.

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