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BROOKHAVEN NATIONAL LABORATORY

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Upton, New York 11973

SSC Technical Note No. 60

CDG-N-273

CRYOGENIC BASELINE DESIGN FOR SSC ACCELERATED LIFE TEST

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December 9, 1986

CRYOGENIC BASELINE DESIGN FOR SSC ACCELERATED LIFE TEST

In order to proceed with the design and procurement of the individual components for the SSC Accelerated Life Test cryogenic system it is necessary to establish a baseline design for the system. The load characteristics (pressure, temperature, flow, refrigeration load, liquefaction load, etc.) which the system will see are the most important input parameters in the selection of the baseline design. These parameters are folded into the existing physical plant characteristics to come up with a baseline design or plan to determine the direction which subsequent system engineering must take. In particular, the design requirements for the circulating compressor and ejector which are required for this system must be fixed so that design and procurement of these two relatively long delivery items can be completed.

LOAD CHARACTERISTICS

The left side of Table 1 shows the heat load allowance for each piece of equipment in the cryogenic circuit. The magnets are "standard" SSC magnets but must be operated with warm bore tubes so that magnetic measurements can be made as part of the test. Most of the items on the list, with the exception of the magnets themselves, are only conceptually designed at this point in time. Therefore, it can be expected that the final estimated heat load will differ somewhat from this allowance. The right side of the table shows how this load is distributed in the computer program (MAGCALT3) which is used to simulate the system performance. Figure 1 is the schematic used in MAGCALT3.

Other parameters which effect the design of the system are given below:

Nom. pressure in magnet:	4.5 atm
Max. magnet temp:	4.35 K
Mass flow through magnet:	100 g/s
Pressure drop in magnet:	0.1 atm

REFRIGERATION CYCLE

This testing will be done at the MAGCOOL facility in Building 902. This facility already has a helium refrigerator in place. Its only output is at the 4 Kelvin temperature level and, therefore, it will be necessary to modify the equipment to bring out a helium stream to cool the 20 K heat shield loop. The 20 K load is identified as Q20 in Figure 1. The shield will be operated in series with the flow to the expansion engine as shown in this schematic.

SSC ACCELERATED LIFE TEST

ITEM	HEAT LOAD ALLOWANCE 4K LIQUID g/s	4K REFR. W	20K REFR. W	80K REFR. W	DISTRIBUTION (see computer code MAGCALT3) QMAG 4K W	F22 QLEAD1 4K g/s	4K W	F25 QLEAD2 4K g/s	4K W	Q20 20K W	QSUP 4K W	QRET 4K W
Dipole (5)	0	10	25	150	10					25		
Quad (1)	0	2	5	30	2					5		
Warm Bore Tube, 2 warm for meas.	0	40	0	0	40							
Warm Bore Tube, 4 cold in standby	0	10	0	0	10							
Feedcan (1)	0	5	15	50	5					15		
End Box (1)	0	5	15	50	5					15		
Turnaround (2)	0	10	30	100	10					30		
Power Leads (2 @ 6500 A)	.8	16	0	0				.90	16			
Safety Lead (1 @ 6500 A)	.2	8	0	0				.20	8			
Power Lead Bundle, 12x100A (1)	.1	2	0	0				.10	2			
Power Lead Bundle, 12x50A (1)	.05	1	0	0				.05	1			
Piping & Valves	0	5	50	100	5					50		
TOTAL FOR MAGNET STRING	1.15	114	140	480	87			1.15	27	140		
MAGCOOL piping and valves	0	100	0	0							50	30
Quench Dewar	0	0	50	0						50		
4K Transfer Lines	0	10	0	0							5	5
20K Transfer Lines	0	0	20	0						20		
80K Transfer Lines	0	0	0	25								
TOTAL FOR MAGNETS + ALL OTHER	1.15	224	210	505	87			1.15	27	210	55	35

TABLE 1

BROOKHAVEN NATIONAL LABORATORY

BY D. BROWN DATE 11/7/86 SUBJECT REFRIGERATION SYSTEM SCHEMATIC SHEET No. ____ OF ____

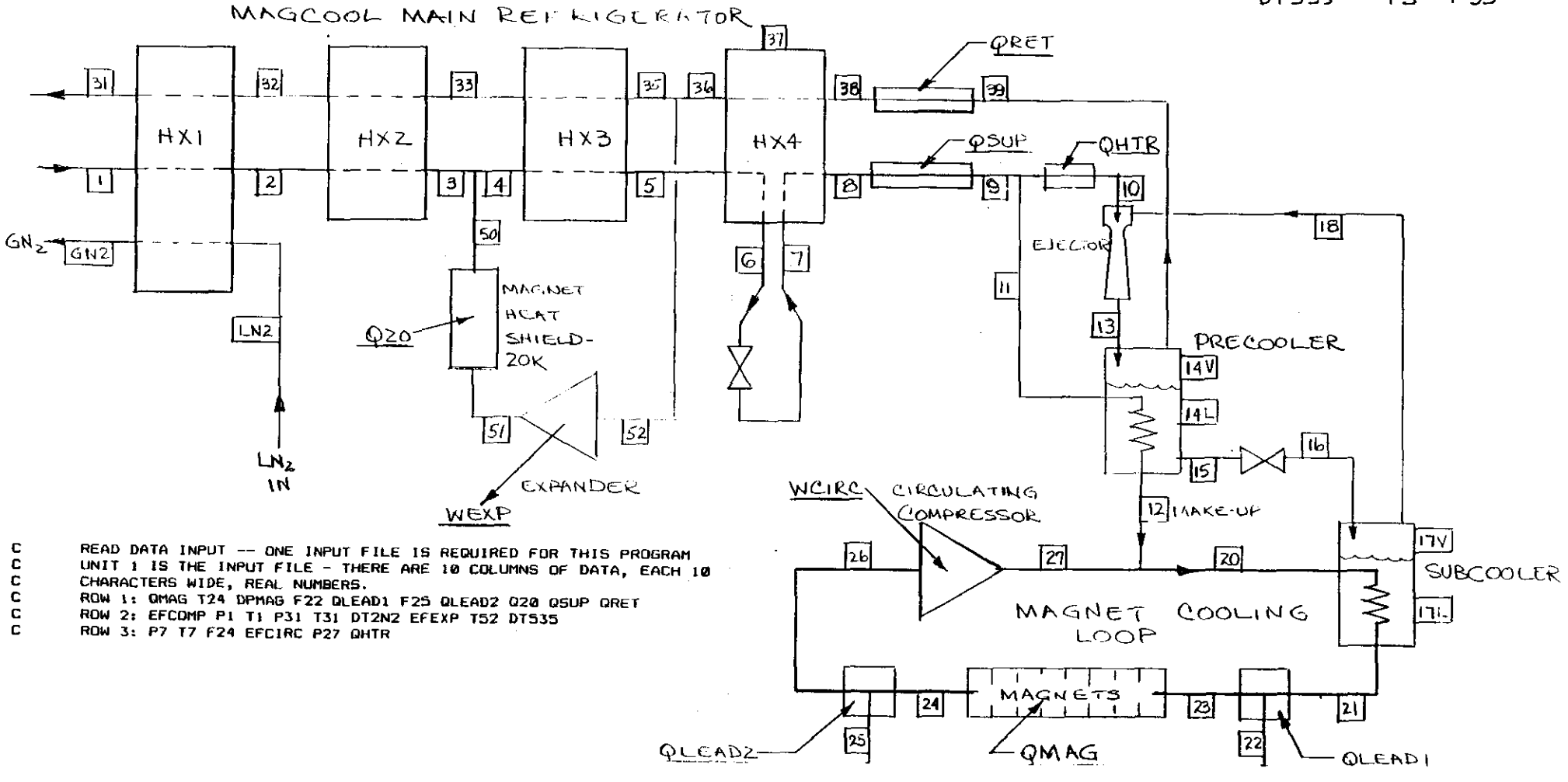
CHKD. BY ____ DATE ____ JOB No. ____

DEPT. OR PROJECT ACCEL. LIFE TEST

```
      PROGRAM MAGCALT3
C     CALCULATES THE PERFORMANCE PARAMETERS OF THE MODEL 4000 HELIUM
C     REFRIGERATOR WHICH HAS BEEN MODIFIED TO PROVIDE COOLING AT 20K
C     IN ADDITION TO REFRIGERATION AND LIQUID AT 4K
C
C     20K COOLING IS PROVIDED BY DIVERTING THE EXPANDER FLOW TO THE
C     20K LOAD AND THEN RETURNING IT TO THE EXPANDER IN THE MANNER OF
C     THE BRAYTON CYCLE  -- THE CYCLE USES LIQUID NITROGEN PRECOOLING
C     AND HAS A SINGLE LEVEL OF EXPANDERS.
```

DEFINITIONS:

DPMAG = P23 - P24
DT2N2 = T2 - TLN2
DT535 = T5 - T35




```
C     READ DATA INPUT -- ONE INPUT FILE IS REQUIRED FOR THIS PROGRAM
C     UNIT 1 IS THE INPUT FILE - THERE ARE 10 COLUMNS OF DATA, EACH 10
C     CHARACTERS WIDE, REAL NUMBERS.
C     ROW 1: QMAG T24 DPMAG F22 QLEAD1 F25 QLEAD2 Q20 QSUP QRET
C     ROW 2: EFCOMP P1 T1 P31 T31 DT2N2 EFEXP T52 DT535
C     ROW 3: P7 T7 F24 EFCIRC P27 QHTR
```

Figure 1

In order to satisfy the flow, pressure and temperature requirements for the magnets, it is necessary to separate the magnet flow rate and pressure from that of the refrigerator so that the refrigerator can be operated in an efficient manner to suit the temperature and load requirements. To facilitate this separation a "Magnet Cooling Loop" (Figure 1) is provided to circulate helium through the magnets. The helium is driven through this loop with the "Circulating Compressor" shown. The helium in the loop is cooled by heat exchange with boiling liquid helium in the "Subcooler". At steady-state conditions, the pressure in the loop will be held constant by controlling the make-up flow to be equal to the helium extracted from the loop to cool the magnet power leads. If the heat load is equal to the allowance made in Table 1, then the temperature rise across the magnet string for 100 g/s flow is about 0.5 K. Allowance must also be made for temperature difference in the subcooler heat exchanger. The refrigeration produced by this refrigerator, if unmodified, would be at a temperature level of about 4.4 K. Therefore, it is necessary to lower the vapor pressure of the helium in the subcooler so that it will be at a sufficiently low temperature to satisfy the 4.35 K max. temperature requirement for the magnets. An ejector (jet pump) has been chosen as the means to provide the necessary pumping capacity at the subcooler. Its position in the cycle is shown in Figure 1.

The MAGCOOL Facility already has an ejector built into its system piping and it also has provisions to mount a circulating compressor, although one has never been used there. If this equipment were to be used, the supply and return headers of MAGCOOL would become part of the load in the Magnet Cooling Loop. This would add about 100 Watts; essentially doubling the load in this loop. Because of this, it is important to move the ejector and subcooler close to the magnets in order to obtain the lowest possible magnet operating temperature. The Interim Subcooler (originally used with another refrigerator, PAT) also has an ejector, provisions for a circulating compressor, is small enough to be portable, is available, and with a few modifications can be used for this test. It will be located in the same trench as the magnets.

The performance of the ejector is a key element and the most uncertain element which must be used in calculations to predict the ability of this refrigerator to meet load conditions at 4.35 K. In 1979, BNL and NBS, Boulder, collaborated to measure the performance of a small ejector sized for use with the Model 2000 Helium Refrigerator here at BNL. These results were coallated by R. Strobridge of NBS. The data is presented in Figure 2. The original raw test data went to NBS and is no longer available. We have built

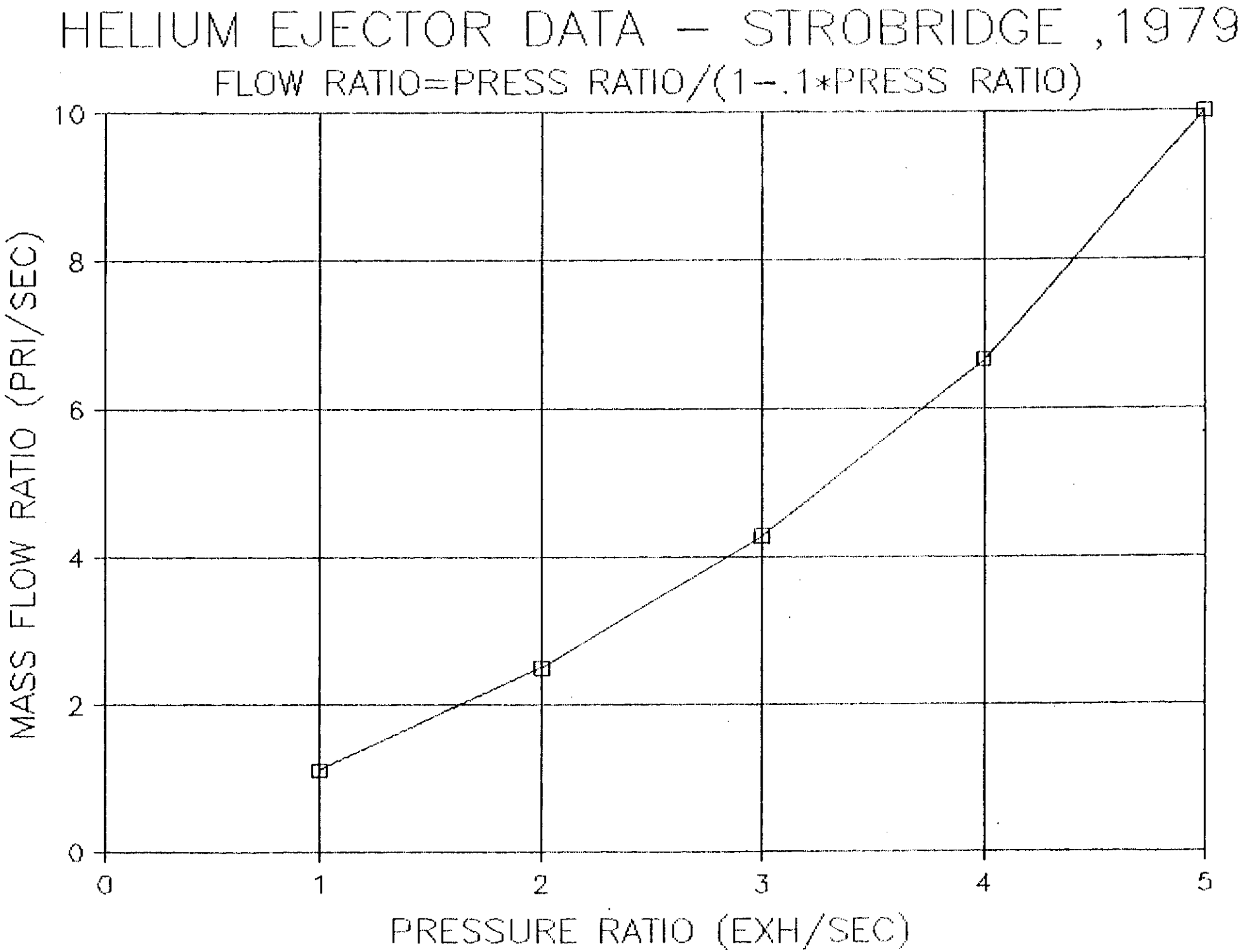

HELIUM EJECTOR DATA – STROBRIDGE ,1979
FLOW RATIO=PRESS RATIO/(1–.1*PRESS RATIO)
MASS FLOW RATIO (PRI/SEC)
PRESSURE RATIO (EXH/SEC)
0
2
4
6
8
10
0
1
2
3
4
5

Figure 2

several ejectors since then and find that they do not come up to the 15% efficiency levels which are predicted by the Strobridge data. We have been able to attain an efficiency of about 10%.

In order to maximize the pumping by the ejector, one must maximize the flow through the primary nozzle (at point 10). This cannot be done indiscriminatly because the balance between the refrigeration produced by the expanders and the flow to the load must be maintained while adjusting the cycle parameters to bring the flow from the room temperature compressors near to its maximum (160 g/s). When the primary nozzle flow is increased, the load must be increased (but not in the Magnet Cooling Loop) or else the liquid level in the precooler will rise because the liquid from the precooler is not called for by the subcooler which has seen no increase in load under these conditions. A heater, shown as QHTR, is used to supply this trim load. This heater can be located anywhere in the piping to or from or internal to the precooler. The optimum position will be selected on the basis of the ejector design studies.

Computer simulation (MAGCALT3) of the cycle performance at loads equal to between one and three times the heat load allowance shown in Table 1 have been run. Best performance at each load level calculated was sought without exceeding the calculated ejector efficiency requirement of 9%. The predicted magnet temperature as a function of the load is shown in Figure 3. It can be seen that if the load were equal to the heat load allowance and the refrigerator performed up to this prediction that a magnet operating temperature of 3.74 K can be reached. The temperature in the subcooler under these conditions would be 3.34 K (0.38 atm). When the load is three times the allowed load, the magnet temperature is predicted to be 4.81 K. This last point is at, or slightly in excess of, the capacity of the refrigerator and the indicated performance probably cannot be attained. The point at 2.5 times allowed load is the last point that can be used with any confidence.

Figure 4 shows the primary nozzle volume flowrate required as a function of load. This flowrate is determined by the flow area built into the nozzle assuming that the inlet conditions do not vary. This means that the nozzle area at 3 times the allowed load needs to be about 2/3 of that required for operation at 1 times the load. This happens because the main compressor flow is fixed and the expander flow must be increased in order to produce the refrigeration needed to satisfy the increased load. The expander flow is increased at the expense of the flow to the primary nozzle. Therefore, the nozzle needs to be smaller for the higher load conditions. The actual load is, of course, not known until

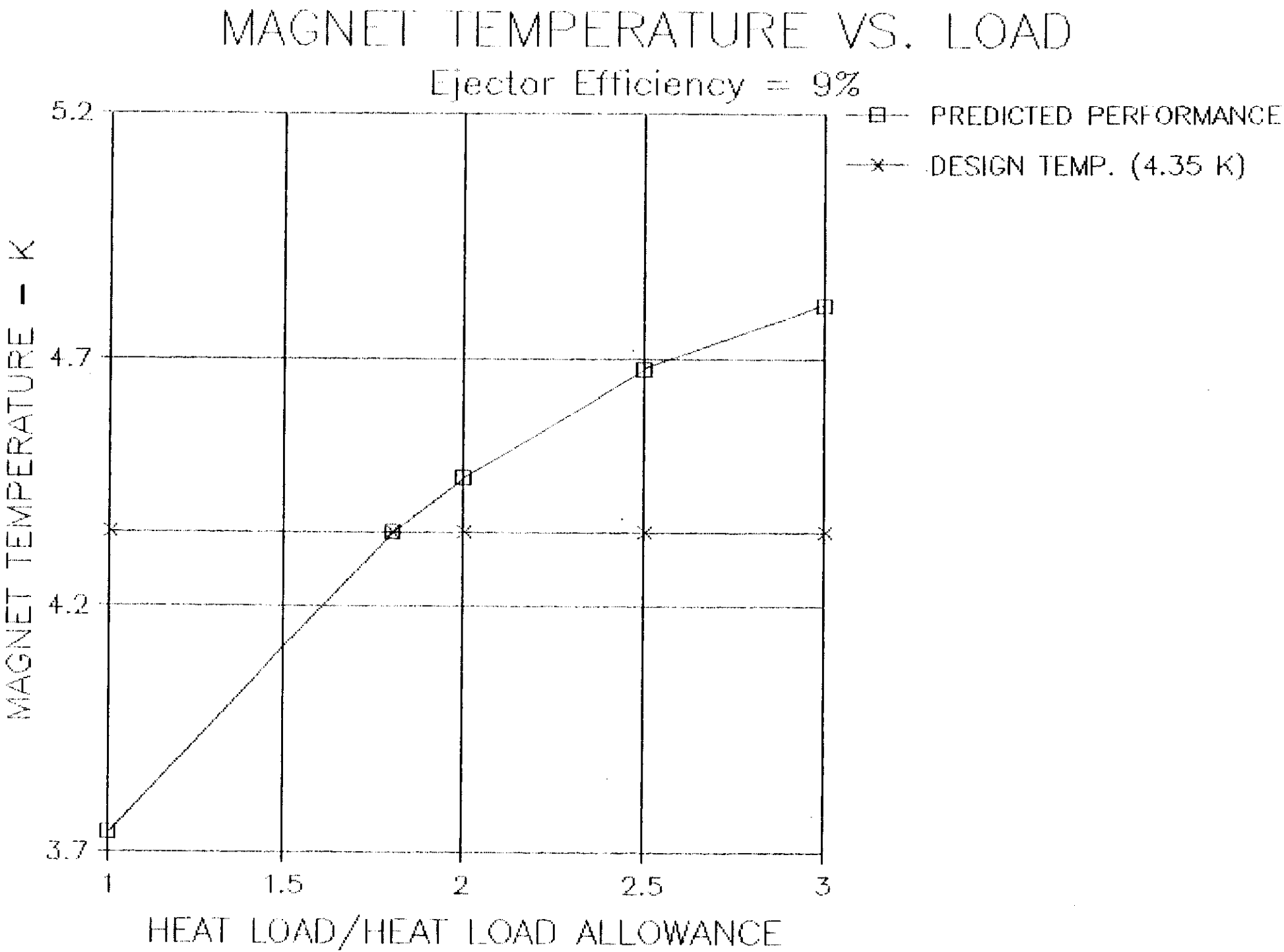

MAGNET TEMPERATURE VS. LOAD
Ejector Efficiency = 9%
PREDICTED PERFORMANCE
DESIGN TEMP. (4.35 K)
MAGNET TEMPERATURE - K
5.2
4.7
4.2
3.7
1
1.5
2
2.5
3
HEAT LOAD/HEAT LOAD ALLOWANCE

Figure 3

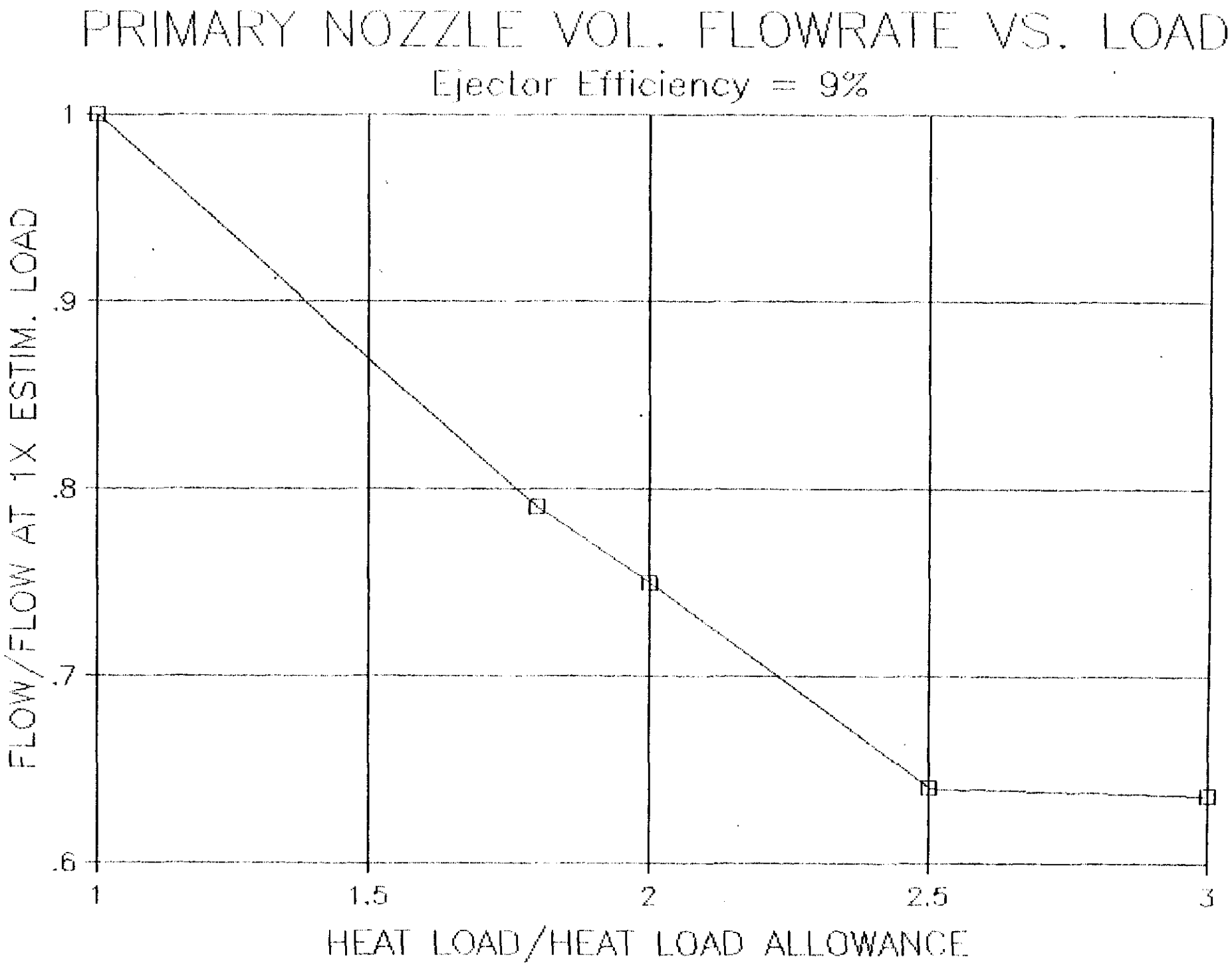

PRIMARY NOZZLE VOL. FLOWRATE VS. LOAD
Ejector Efficiency = 9%
FLOW/FLOW AT 1X ESTIM. LOAD
1
.9
.8
.7
.6
1
1.5
2
2.5
3
HEAT LOAD/HEAT LOAD ALLOWANCE

Figure 4

after the first run (at least), but we must choose a design flow rate now. It seems preferable to stay somewhere near the center of the allowable temperature operating range for the baseline design. Fortunately, the design temperature for the magnets, 4.35K, is near the center of this range, so it is chosen as the design point for the ejector. The load which corresponds to this temperature is 1.8 times the allowed load. This gives up performance capability at both ends of the load range, but should maximize the possiblility of reaching the specified temperature. It will probably be desirable to redesign the ejector to optimize its performance once the load conditions are established. The computer output for the system performance calculations at the suggested baseline design point is given in Figure 5 (2 pages).

EJECTOR SPECIFICATIONS

The ejector performance specifications are found on page 2 of Figure 5.

CIRCULATING COMPRESSOR SPECIFICATIONS

The outlet temperature of a magnet string can be lowered if the flowrate through the magnets is increased (other parameters being unchanged). This makes it useful to have a higher flowrate circulating compressor available in case the actual load is such that the desired temperature of 4.35 K cannot be attained with the a flow rate through the magnets of only 100 g/s. A second operating point for the 2.5X Allowed Load was calculated allowing the magnet flow to rise to 150 g/s. The maximum magnet temperature drops from 4.68 K to 4.55 K. The circulating compressor specification should require a high enough head that this higher flow can be maintained. The performance specification would have two required points, the first would be that given on page 2 of Figure 5 and the second, which is derived from the calculation mentioned above, is given in Figure 6.

COMPUTER CODE

The Appendix to this report contains the main Fortran program used for the calculations reported herein. The last page of the appendix indicates the linked routines used.

PROGRAM MAGCALT3

CALCULATES THE PERFORMANCE OF THE MODEL 4000 HELIUM REFRIGERATOR MODIFIED TO PROVIDE 20K COOLING IN ADDITION TO REFRIGERATION AND LIQUID AT 4K - USES EJECTOR AND CIRCULATING COMPRESSOR

*****INPUT DATA*****

QMAG	T24	DPMAG	F22	QLEAD1	F25	QLEAD2	Q20	QSUP	QRET
157.00	4.35	.10	.00	.00	2.10	49.00	378.00	99.00	99.00

EFCOMP	P1	T1	P31	T31	DT2N2	EFEXP	T52	DT535
.50	18.00	300.00	1.05	290.00	1.00	.75	7.90	1.20

P7	T7	F24	EFCIRC	P27	QHTR
15.00	6.40	100.00	.50	4.50	280.00

HX HEAT LEAK (W): HX1= 50. HX2= 15. HX3= 10. HX4A= 5. HX4B= 5.

NITROGEN ENTHALPY (J/GM): IN= 42.66 OUT= 456.90

*****CALCULATED SYSTEM DATA*****

	CIRC COMPR	MAIN COMPR	EXPANDER	J-T	LIQUID	LN2
FLOW - G/S:	97.900	143.512	85.768	57.744	2.100	22.644
WORK - W:	34.	507383.	3238.			
WORK - HP:	.045	680.138	4.341			

EJECTOR EFFIC. REQ'D= 8.96 %

*****CALCULATED FLUID PROPERTIES FOR SYSTEM*****

PRESSURE (ATM), TEMPERATURE (DEGREE K), ENTHALPY (J/GM) AND FLOW (GM/S)

POINT	PRESS.	TEMP.	ENTHAL.	FLOW	POINT	PRESS.	TEMP.	ENTHAL.	FLOW
1	18.00	300.00	1578.61	143.51	31	1.05	290.00	1521.01	141.41
2	17.60	79.00	428.67	143.51	32	1.10	78.00	419.96	141.41
3	17.30	16.17	86.22	143.51	33	1.15	11.41	72.33	141.41
4	17.30	16.17	86.22	57.74					
5	17.10	9.10	38.76	57.74	35	1.18	7.90	52.87	141.41
6	17.05	6.20	23.89	57.74	36	1.18	7.90	52.87	55.64
7	15.00	6.40	23.89	57.74	37	1.19	5.32	37.36	55.64
8	14.95	5.00	18.49	57.74	38	1.20	4.59	31.67	55.64
9	14.90	5.48	20.21	57.74	39	1.25	4.46	29.89	55.64
10	14.87	6.71	25.24	55.64					
11	14.90	5.48	20.21	2.10					
12	4.50	4.51	11.96	2.10					
13	1.27	4.46	26.12	68.37					
14V	1.25	4.46	29.89		14L	1.25	4.46	11.02	
15	1.25	4.46	11.02	12.72					
16	.67	3.81	11.02	12.72					
17V	.67	3.81	29.99		17L	.67	3.81	7.87	
18	.66	3.81	29.99	12.72					
20	4.50	4.55	12.11	100.00	50	17.30	16.17	86.22	85.77
21	4.42	3.86	9.70	100.00	51	17.00	16.85	90.63	85.77
22	4.42	3.86	9.70	.00	52	1.23	7.90	52.87	85.77
23	4.42	3.86	9.70	100.00					
24	4.32	4.35	11.27	100.00					
25	4.32	4.35	11.27	2.10					
26	4.27	4.49	11.77	97.90					
27	4.50	4.55	12.11	97.90					

Figure 5 (p. 1 of 2)

*****EXPANDER SPECIFICATIONS*****

ADIABATIC EFFICIENCY	.750	ESTIM. FLOW (G/S) PER RPM	.313
FLOW RATE-GM/SEC	85.768	ESTIMATED RPM REQUIRED	274.053
PRESS RATIO	13.821	INLET VALVE CUT-OFF RATIO	.330
WORK-WATTS	3238.317	EXPAN. RATIO AFTER CUT-OFF	2.763

FLUID PROPERTIES	INLET	OUTLET
PRESSURE-ATM	17.000	1.230
TEMPERATURE-K	16.849	7.900
ENTHALPY-J/GM	90.631	52.875
ENTROPY-J/GM-K	10.014	11.874
SPECIFIC HEAT,CP-J/GM-K	6.243	5.674
SPECIFIC HEAT RATIO,CP/CV	2.002	1.824
DENSITY-GM/CC	5.08E-02	8.14E-03
VISCOSITY-GM/CM-S	3.96E-05	1.94E-05

*****CIRCULATING COMPRESSOR SPECIFICATIONS*****

ADIABATIC EFFICIENCY	.500
FLOW RATE-GM/SEC	97.900
PRESS RATIO	1.054
WORK-WATTS	33.885

FLUID PROPERTIES	INLET	OUTLET
PRESSURE-ATM	4.270	4.500
TEMPERATURE-K	4.485	4.550
ENTHALPY-J/GM	11.766	12.112
ENTROPY-J/GM-K	3.342	3.381
SPECIFIC HEAT,CP-J/GM-K	3.990	4.053
SPECIFIC HEAT RATIO,CP/CV	1.697	1.711
DENSITY-GM/CC	1.35E-01	1.35E-01
VISCOSITY-GM/CM-S	3.76E-05	3.76E-05

*****EJECTOR SPECIFICATIONS*****

ADIABATIC EFFICIENCY	8.963		
ENTRAINMENT RATIO: SEC/PRI=	.229	PRI/SEC=	4.373
PRESSURE RATIO: SEC/EXH=	.518	EXH/SEC=	1.930

FLUID PROPERTIES	PRIMARY	SECONDARY	EXHAUST
FLOW RATE-GM/SEC	55.644	12.724	68.368
FLOW RATE-CC/SEC	411.485	1133.650	569.123
PRESSURE-ATM	14.870	.658	1.270
TEMPERATURE-K	6.714	3.813	4.461
ENTHALPY-J/GM	25.238	29.986	26.122
ENTROPY-J/GM-K	4.336	8.869	3.702
SPECIFIC HEAT,CP-J/GM-K	4.594	7.974	6.192
SPECIFIC HEAT RATIO,CP/CV	1.813	2.403	2.508
DENSITY-GM/CC	1.35E-01	1.12E-02	1.20E-01
VISCOSITY-GM/CM-S	4.26E-05	1.08E-05	3.05E-05

Figure 5 (p. 2 of 2)

*****CIRCULATING COMPRESSOR SPECIFICATIONS*****

ADIABATIC EFFICIENCY	.500
FLOW RATE-GM/SEC	147.120
PRESS RATIO	1.066
WORK-WATTS	63.940

FLUID PROPERTIES	INLET	OUTLET
PRESSURE-ATM	4.220	4.500
TEMPERATURE-K	4.661	4.738
ENTHALPY-J/GM	12.489	12.924
ENTROPY-J/GM-K	3.508	3.554
SPECIFIC HEAT,CP-J/GM-K	4.381	4.459
SPECIFIC HEAT RATIO,CP/CV	1.810	1.825
DENSITY-GM/CC	1.32E-01	1.32E-01
VISCOSITY-GM/CM-S	3.64E-05	3.65E-05

Figure 6. SPECIFICATION FOR HIGH FLOW POINT

APPENDIX

```
TYPE MAGCALT3.FOR
       PROGRAM MAGCALT3
C      CALCULATES THE PERFORMANCE PARAMETERS OF THE MODEL 4000 HELIUM
C      REFRIGERATOR WHICH HAS BEEN MODIFIED TO PROVIDE COOLING AT 20K
C      IN ADDITION TO REFRIGERATION AND LIQUID AT 4K
C
C      20K COOLING IS PROVIDED BY DIVERTING THE EXPANDER FLOW TO THE
C      20K LOAD AND THEN RETURNING IT TO THE EXPANDER IN THE MANNER OF
C      THE BRAYTON CYCLE  -- THE CYCLE USES LIQUID NITROGEN PRECOOLING
C      AND HAS A SINGLE LEVEL OF EXPANDERS.
       COMMON DI,ETA
       COMMON/COEFF/TESTAR(81)
       REAL LIQ,LIQBAL
       INTEGER FIRSTPT,SECONDPT
C       READ DATA INPUT -- ONE INPUT FILE IS REQUIRED FOR THIS PROGRAM
C       UNIT 1 IS THE INPUT FILE - THERE ARE 10 COLUMNS OF DATA, EACH 10
C       CHARACTERS WIDE, REAL NUMBERS.
C       ROW 1: QMAG T24 DPMAG F22 QLEAD1 F25 QLEAD2 Q20 QSUP QRET
C       ROW 2: EFCOMP P1 T1 P31 T31 DT2N2 EFEXP T52 DT535
C       ROW 3: P7 T7 F24 EFCIRC P27 QHTR
       OPEN (1,FILE='      ')
        READ (1,10)QMAG,T24,DPMAG,F22,QLEAD1,F25,QLEAD2,Q20,QSUP,QRET
        READ (1,10)EFCOMP,P1,T1,P31,T31,DT2N2,EFEXP,T52,DT535
        READ (1,10)P7,T7,F24,EFCIRC,P27,QHTR
   10   FORMAT(10F10.3)
C       SET NITROGEN INLET AND OUTLET CONDITIONS.
       TLN2=78.
C       INPUT ENTHALPY OF LIQUID NITROGEN ASSUMES IT IS SUPPLIED
C       FROM A DEWAR AT 2 ATM PRESSURE -- TEMP. IS FOR 1.1 ATM
       HLN2=42.66
       PLN2=1.2
       TGN2=295
       HGN2=456.9
       PGN2=1.2
C       SET T32 AND ESTIMATE PRESSURE DROP IN HEAT EXCHANGERS.
       T32=TLN2
       T35=T52
       T5=T35+DT535
       T36=T52
       P2=P1-.4
       P3=P2-.3
       P4=P3
       P50=P3
       P51=P50-.3
       P5=P4-.2
       P6=P5-.05
       P8=P7-.05
       P9=P8-.05
       P10=P9-.03
       P11=P9
       P32=P31+.05
       P33=P32+.05
       P35=P33+.03
       P36=P35
       P37=P35+.01
       P52=P35+.05
       P38=P37+.01
       P14=P38+.05
       P39=P14
       P13=P14+.02
       P12=P27
       P20=P27
       P21=P20-.08
       P22=P21
       P23=P21
```

```
      P24=P23-DPMAG
      P25=P24
      P26=P24-.05
      F12=F22+F25
      F11=F12
      T25=T24
      QLOAD=QMAG+QLEAD1+QLEAD2
      QEQUIV=QLOAD+101.*F12
C         ESTIMATED HEAT EXCHANGER HEAT LOSSES
      QHX1=50.
      QHX2=15.
      QHX3=10.
      QHX4A=5.
      QHX4B=5.
      QHX4=QHX4A+QHX4B
      QHX=QHX1+QHX2+QHX3+QHX4
C      SELECT ESTIM DENSITY (DI) FOR USE IN FINDD
      DI=-1.0
C      WRITE INPUT DATA
       WRITE (*,100)
  100  FORMAT(1H1,30X16HPROGRAM MAGCALT3,/  3X  'CALCULATES THE PERFORMA
     1NCE OF THE MODEL 4000 HELIUM'/         3X  'REFRIGERATOR MODIFIED T
     2O PROVIDE 20K COOLING IN ADDITION TO'/3X'REFRIGERATION AND LIQUID
     3AT 4K - USES EJECTOR AND CIRCULATING COMPRESSOR')
      WRITE (*,101)
  101 FORMAT(//25X20H*****INPUT DATA*****)
      WRITE (*,11)
  11  FORMAT(/4X4HQMAG,5X3HT24,3X5HDPMAG,5X3HF22,2X6HQLEAD1,5X3HF25,
     12X6HQLEAD2,5X3HQ20,4X4HQSUP,4X4HQRET)
      WRITE (*,12)QMAG,T24,DPMAG,F22,QLEAD1,F25,QLEAD2,Q20,QSUP,QRET
   12 FORMAT( 10F8.2)
      WRITE (*,13)
   13 FORMAT( /2X6HEFCOMP,6X2HP1,6X2HT1,5X3HP31,5X3HT31,3X5HDT2N2,
     1 3X5HEFEXP,5X3HT52,3X5HDT535)
      WRITE (*,12)EFCOMP,P1,T1,P31,T31,DT2N2,EFEXP,T52,DT535
      WRITE (*,25)
   25 FORMAT( /6X2HP7,6X2HT7,5X3HF24,2X6HEFCIRC,
     1 5X3HP27,4X4HQHTR)
      WRITE (*,12)P7,T7,F24,EFCIRC,P27,QHTR
      WRITE (*,15)QHX1,QHX2,QHX3,QHX4A,QHX4B
   15 FORMAT (/'  HX HEAT LEAK (W): HX1='F4.0'  HX2='F4.0'  HX3='F4.0
     1'  HX4A='F4.0'  HX4B='F4.0)
      WRITE(*,16)HLN2,HGN2
   16 FORMAT(/'  NITROGEN ENTHALPY (J/GM): IN='F8.2'  OUT='F8.2)
      D24=FINDD(P24,T24,DI)
      H24=ENTHAL(D24,T24)
      H25=H24
C          LOAD MASS FLOW BALANCE CONDITIONS
      F26=F24-F25
      F27=F26
      F20=F27+F12
      F21=F20
      F23=F21-F22
      H21=H24-(QMAG+QLEAD1)/F24
      T21=TPH(P21,H21)
      T17=T21-.05
      P17=VPA(T17)
      P18=P17-.01
      T22=T21
      H22=H21
      H26=H24+QLEAD2/F26
      H23=H21+QLEAD1/F23
      T23=TPH(P23,H23)
C          ESTIMATE T26 FOR USE IN PHTD
      T26=T24
      CALL PHTD(P26,H26,T26,D26)
```

```
C          CALCULATE THE WORK INPUT REQUIRED BY THE CIRCULATING COMPR.
      S26=ENTROP(D26,T26)
      S27I=S26
C          ESTIMATE T27I TO ENTER PSTD
      T27I=T21
      CALL PSTD(P27,S27I,T27I,D27I)
      H27I=ENTHAL(D27I,T27I)
      WCIRC=((H27I-H26)/EFCIRC)*F26
      HPCIRC=WCIRC/746.
      H27=H26+((H27I-H26)/EFCIRC)
      T27=TPH(P27,H27)
C     CALCULATE FLOW RATE F8 - HI PRESS SIDE OF THE J-T HX TRAIN
      T14=VPTEMP(P14)
      D14L=DSATL(T14)
      D14V=DSATV(T14)
      H14L=ENTHAL(D14L,T14)
      H14V=ENTHAL(D14V,T14)
      P15=P14
      T15=T14
      H15=H14L
      P16=P17
      T16=T17
      H16=H15
      T12=T14+.05
      D12=FINDD(P12,T12,DI)
      H12=ENTHAL(D12,T12)
      H20=((F12*H12)+(F27*H27))/F20
      T20=TPH(P20,H20)
      D17L=DSATL(T17)
      H17L=ENTHAL(D17L,T17)
      D17V=DSATV(T17)
      H17V=ENTHAL(D17V,T17)
      LIQ=1.0-(H14L-H17L)/(H17V-H17L)
      F16=(F20*(H20-H21))/((H17V-H17L)*LIQ)
      F15=F16
      F18=F16
      H18=H17V
      T18=T17
      D18=D17V
C          HEAT BALANCE OF EJECTOR SYSTEM AND HX 4
      D52=FINDD(P52,T52,DI)
      H52=ENTHAL(D52,T52)
      H35=H52
      H36=H52
      D5=FINDD(P5,T5,DI)
      H5=ENTHAL(D5,T5)
      F8=(F22*(H36-H22)+F25*(H36-H25)+QLOAD+QSUP+QRET+QHTR+WCIRC+QHX4)/
     1 (H36-H5)
      F39=F8-F12
      F38=F39
      T39=T14
      H39=H14V
      H38=H39+QRET/F39
      T38=TPH(P38,H38)
      H8=H5-((H36-H38)*F38-QHX4)/F8
      T8=TPH(P8,H8)
      F9=F8
      H9=H8+QSUP/F9
      T9=TPH(P9,H9)
      F10=F9-F12
      H10=H9+QHTR/F10
      T10=TPH(P10,H10)
      H11=H9
      T11=T9
      T13=T14
      F13=F10+F18
```

```
      H13=(F10*H10+F18*H18)/F13
      H14=H13
      FRLIQ=FLIQPH(P14,H14)
C         CHECK LIQUID BALANCE IN PRECOOLER
      F7=F8
      F6=F7
      F5=F6
      F4=F5
      F37=F38
      F36=F37
      LIQBAL=(FRLIQ*F13)-((F12*(H11-H12))/(H14V-H14L))-F15
      IF (ABS(LIQBAL).GT.(0.005*F8)) GO TO 45
      GO TO 40
   45 WRITE (*,44) LIQBAL
   44 FORMAT (//' LIQUID BALANCE OF PRECOOLER IS N.G., IMBALANCE='
     1 1F8.2//)
   40 CONTINUE
C         CHECK PRECOOLER HEAT BALANCE
      HTBAL=F12*(H11-H12)+F13*H13-F15*H14L-F38*H14V
C         COMPARE TO 1/2 PERCENT OF TOTAL LOAD
      DELTL=0.005*QEQUIV
      IF (ABS(HTBAL).GT.DELTL) GO TO 46
      GO TO 50
   46 WRITE (*,48)HTBAL
   48 FORMAT(//'  HEAT BALANCE OF PRECOOLER IS N.G., IMBALANCE='
     1 1F8.2)
   50 CONTINUE
C         CALCULATE THE REQUIRED EJECTOR EFFICIENCY
C
C         STANDARD EFFICIENCY=WORK OUT/WORK IN=STEFF
      D10=FINDD(P10,T10,DI)
      S10=ENTROP(D10,T10)
      S13I=S10
      H13IP=HPS(P13,S13I)
C         FOR IDEAL PROCESS, S18=S13I
      S18=ENTROP(D18,T18)
      H13IS=HPS(P13,S18)
      STEFF=(F18*(H13IS-H18))/(F10*(H10-H13IP))*100.
C         CALC THE INLET TEMP AND ENTHAL OF THE EXPANDER
      ETA=EFEXP
      CALL EXPTTH(P52,P51,T52,T51,H51,ETA)
      D51=FINDD(P51,T51,DI)
C     CALCULATE THE TURBINE FLOW RATE FROM HEAT BALANCE OF HX2 AND HX3
      D32=FINDD(P32,T32,DI)
      H32=ENTHAL(D32,T32)
      T2=DT2N2+TLN2
      D2=FINDD(P2,T2,DI)
      H2=ENTHAL(D2,T2)
      F51=((H2-H5)*F8+F10*(H35-H32)+Q20+QHX2+QHX3)/(H51-H52+H32-H2)
      WEXP=(H51-H52)*F51
      HPEXP=WEXP/746.
      F50=F51
      F52=F51
      F3=F50+F4
      F2=F3
      F1=F2
      F35=F36+F52
      F33=F35
      F32=F33
      F31=F32
C       CALCULATE THE TEMP. AT PT. 3, HIGH PRESS. EXIT OF HX2
      H50=H51-(Q20/F51)
      H4=H50
      H3=H50
C       ESTIMATE T50 FOR USE IN PHTD
      T50=T51
```

```
C          FIND T50 AND D50
      CALL PHTD(P50,H50,T50,D50)
      T4=T50
      T3=T50
C          CALCULATE H33 FROM HEAT BALANCE OF HX3
      H33=H35+((H4-H5)*F4+QHX3)/F33
C     ESTIMATE T33 FORPHTD
      T33=T32
      CALL PHTD(P33,H33,T33,D33)
C     CALCULATE NITROGEN FLOW (FN2) FROM HEAT BALANCE OF HEAT EXCHANGER1
C    1---GM/SEC
      D1=FINDD(P1,T1,DI)
      H1=ENTHAL(D1,T1)
      D31=FINDD(P31, T31,DI)
      H31=ENTHAL(D31,T31)
      FN2=((F1)*(H1-H2)+QHX1-(F1-F12)*(H31-H32))/(HGN2-HLN2)
      F1=F1
C     HEAT BALANCE IN HEAT EXCHANGER 4B
      D7=FINDD(P7,T7,DI)
      H7=ENTHAL(D7,T7)
       H37=H38+((H7-H8)*F8+QHX4B)/F37
C      ESTIMATE T37 FOR PHTD
       T37=T7
      CALL PHTD(P37,H37,T37,D37)
       H6=H7
C      ESTIMATE T6 FORPHTD
      T6=T37
      CALL PHTD(P6,H6,T6,D6)
C     CHECK SYSTEM OVERALL HEAT BALANCE
      HTBAL=F1*H1-F31*H31-F22*H22-F25*H25+QLOAD+Q20+QHX+QSUP+QRET+
     1QHTR+F51*(H52-H51)+FN2*(HLN2-HGN2)+WCIRC
      IF(ABS(HTBAL).LE.(10.0)) GO TO 81
      WRITE (*,83)HTBAL
   83 FORMAT(1H1,1X  'OVERALL HEAT BALANCE OF REFRIGERATOR IS N.G.,IMBAL
     1ANCE=' 1F8.2)
   81 CONTINUE
C     CALCULATE COMPRESSOR WORK
C     EFCOMP IS THE ISOTHERMAL EFFICIENCY
      WCOMP=(F1)*8.3*T1*ALOG(P1/P31)/(4.0026*EFCOMP)
      HPCOMP=WCOMP/746
C     CALCULATE COST -STROBRIDGE FORMULA+.25INFLATION
      COST=(6000.*(WCOMP/1000.)**.7)*1.25
C          WRITE OUTPUT DATA
      WRITE (*,14)
   14 FORMAT(/ / 20X32H*****CALCULATED SYSTEM DATA***** /)
      WRITE (*,1003)
 1003 FORMAT( 12X10HCIRC COMPR,1X10HMAIN COMPR,
     12X8HEXPANDER,4X3HJ-T,7X6HLIQUID,5X3HLN2)
      WRITE (*,1004)F26,F1,F51,F8,F12,FN2
 1004 FORMAT (1X11HFLOW - G/S:,6F10.3)
      WRITE(*,1005) WCIRC,WCOMP,WEXP
 1005 FORMAT(1X11H  WORK - W:,3F10.0)
      WRITE (*,1006)HPCIRC,HPCOMP,HPEXP
 1006 FORMAT(1X11H WORK - HP:,3F10.3)
      WRITE (*,1007) STEFF
 1007 FORMAT ( /10X21HEJECTOR EFFIC. REQ'D=,F5.2,' %')
      WRITE (*,1009)
 1009 FORMAT(//15X48H*****CALCULATED FLUID PROPERTIES FOR SYSTEM*****)
      WRITE (*,1010)
 1010 FORMAT(/10X71HPRESSURE (ATM), TEMPERATURE (DEGREE K), ENTHALPY (J/
     1GM) AND FLOW (GM/S))
      WRITE (*,1011)
 1011 FORMAT( /2X5HPOINT,2X6HPRESS.,3X5HTEMP.,1X7HENTHAL.,4X4HFLOW,
     15X5HPOINT,2X6HPRESS.,3X5HTEMP.,1X7HENTHAL.,4X4HFLOW)
 1012 FORMAT (I7,4F8.2,I10,4F8.2)
 1013 FORMAT ( 39X,I17,4F8.2)
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1014 FORMAT (I7,4F8.2)
     FIRSTPT=1
     SECONDPT=31
     WRITE (*,1012)FIRSTPT,P1,T1,H1,F1,SECONDPT,P31,T31,H31,F31
     FIRSTPT=2
     SECONDPT=32
     WRITE (*,1012) FIRSTPT,P2,T2,H2,F2,SECONDPT,P32,T32,H32,F32
     FIRST PT=3
     SECONDPT=33
     WRITE (*,1012) FIRSTPT,P3,T3,H3,F3,SECONDPT,P33,T33,H33,F33
     FIRSTPT=4
     WRITE (*,1014) FIRST PT,P4,T4,H4,F4
     FIRSTPT=5
     SECONDPT=35
     WRITE (*,1012)FIRSTPT,P5,T5,H5,F5,SECONDPT,P35,T35,H35,F35
     FIRSTPT=6
     SECONDPT=36
     WRITE (*,1012) FIRSTPT,P6,T6,H6,F6,SECONDPT,P36,T36,H36,F36
     FIRSTPT=7
     SECONDPT=37
     WRITE (*,1012)FIRSTPT,P7,T7,H7,F7,SECONDPT,P37,T37,H37,F37
     FIRST PT=8
     SECONDPT=38
     WRITE (*,1012) FIRSTPT,P8,T8,H8,F8,SECONDPT,P38,T38,H38,F38
     FIRSTPT=9
     SECONDPT=39
     WRITE(*,1012)FIRSTPT,P9,T9,H9,F9,SECONDPT,P39,T39,H39,F39
     FIRSTPT=10
     WRITE (*,1014)FIRSTPT,P10,T10,H10,F10
     FIRSTPT=11
     WRITE (*,1014) FIRSTPT,P11,T11,H11,F11
     FIRSTPT=12
     WRITE (*,1014) FIRSTPT,P12,T12,H12,F12
     FIRST PT=13
     WRITE (*,1014) FIRSTPT,P13,T13,H13,F13
     WRITE (*,1015) P14,T14,H14V,P14,T14,H14L
1015 FORMAT (4X3H14V,3F8.2,15X3H14L,3F8.2)
     FIRSTPT=15
     WRITE (*,1014) FIRSTPT,P15,T15,H15,F15
     FIRSTPT=16
     WRITE (*,1014) FIRSTPT,P16,T16,H16,F16
     WRITE (*,1016)P17,T17,H17V,P17,T17,H17L
1016 FORMAT(4X3H17V,3F8.2,15X3H17L,3F8.2)
     FIRSTPT=18
     WRITE (*,1014)FIRSTPT,P18,T18,H18,F18
     FIRSTPT=20
     SECONDPT=50
     WRITE(*,1012) FIRSTPT,P20,T20,H20,F20,SECONDPT,P50,T50,H50,F50
     FIRSTPT=21
     SECONDPT=51
     WRITE (*,1012) FIRSTPT,P21,T21,H21,F21,SECONDPT,P51,T51,H51,F51
     FIRSTPT=22
     SECONDPT=52
     WRITE(*,1012) FIRSTPT,P22,T22,H22,F22,SECONDPT,P52,T52,H52,F52
     FIRSTPT=23
     WRITE (*,1014) FIRSTPT,P23,T23,H23,F23
     FIRSTPT=24
     WRITE (*,1014) FIRSTPT,P24,T24,H24,F24
     FIRSTPT=25
     WRITE (*,1014) FIRSTPT,P25,T25,H25,F25
     FIRSTPT=26
     WRITE(*,1014) FIRSTPT,P26,T26,H26,F26
     FIRSTPT=27
     WRITE (*,1014) FIRSTPT,P27,T27,H27,F27
C          CALCULATE DATA FOR EXPANDER SPECS
C      CALCULATE "HEPERRPM"=ESTIM. FLOW RATE (G/S) PER RPM FOR
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C       3.6" BORE×3" STROKE, 2 CYLINDERS--ASSUMES THAT THE CLEARANCE
C       VOLUME="CL", THAT THE INLET CUT-OFF RATIO EQUALS "COR", AND
C       THAT THE PRESSURE DROP ACROSS THE INLET AND OUTLET VALVES IS
C       0.1 ATM.  -- "SWEPT"=SWEPT VOL. OF ONE CYLINDER (CU. CM.)
      CL=.05
      COR=.33
      SWEPT=500.5
      P51CYL=P51-0.1
C       P52CYL IS THE PRESSURE IN THE CYLINDER AT THE START OF THE
C       INTAKE PROCESS
      P52CYL=P52+0.1
C       ESTIMATE T51CYL
      T51CYL=T51
      CALL PHTD(P51CYL,H51,T51CYL,D51CYL)
C       ESTIMATE T52CYL
      T52CYL=T52
      CALL PHTD(P52CYL,H52,T52CYL,D52CYL)
      HEPERRPM=(2.0*SWEPT/60.)*((D51CYL-D52CYL)*CL+(D51CYL*COR))
      RPM=F51/HEPERRPM
      EXPRATIO=(1.+CL)/(COR+CL)
      PR=P51/P52
      S51=ENTROP(D51,T51)
      S52=ENTROP(D52,T52)
      CP51=CP(D51,T51)
      CP52=CP(D52,T52)
      CPCV51=CP51/CV(D51,T51)
      CPCV52=CP52/CV(D52,T52)
      VISC52=VISCDT(D52,T52)
      VISC51=VISCDT(D51,T51)
      WRITE (*,1200)
 1200 FORMAT (//////20X33H*****EXPANDER SPECIFICATIONS*****)
      WRITE (*,1220) EFEXP,HEPERRPM
 1220 FORMAT(/ 5X20HADIABATIC EFFICIENCY,1F10.3,
     15X25HESTIM. FLOW (G/S) PER RPM,F10.3)
      WRITE (*,1230)F51,RPM
 1230 FORMAT( 8X17H FLOW RATE-GM/SEC,1F10.3,
     1 8X22HESTIMATED RPM REQUIRED,F10.3)
      WRITE (*,1240)PR,COR
 1240 FORMAT( 14X11HPRESS RATIO,1F10.3,
     1 5X25HINLET VALVE CUT-OFF RATIO,F10.3)
      WRITE(*,1250) WEXP,EXPRATIO
 1250 FORMAT( 14X11H WORK-WATTS,1F10.3,
     1 4X26HEXPAN. RATIO AFTER CUT-OFF,F10.3)
      WRITE (*,1260)
 1260 FORMAT(/14X16HFLUID PROPERTIES,5X5HINLET,4X6HOUTLET)
      WRITE (*,1270)P51,P52
 1270 FORMAT ( 17X13H PRESSURE-ATM,2F10.3)
      WRITE (*,1280)T51,T52
 1280 FORMAT ( 16X14H TEMPERATURE-K ,2F10.3)
       WRITE (*,1290)H51,H52
 1290 FORMAT ( 16X14H ENTHALPY-J/GM ,2F10.3)
      WRITE (*,1300)S51,S52
 1300 FORMAT ( 15X15H ENTROPY-J/GM-K ,2F10.3)
      WRITE (*,1310)CP51,CP52
 1310 FORMAT ( 6X24H SPECIFIC HEAT,CP-J/GM-K ,2F10.3)
      WRITE (*,1320) CPCV51, CPCV52
 1320 FORMAT ( 5X25HSPECIFIC HEAT RATIO,CP/CV,2F10.3)
      WRITE (*,1330)  D51,D52
 1330 FORMAT ( 16X14H DENSITY-GM/CC ,1P2E10.2)
 3000  WRITE (*,1340)VISC51, VISC52
 1340 FORMAT ( 12X18H VISCOSITY-GM/CM-S ,1P2E10.2)
C          CALCULATE PROPERTIES FOR CIRC COMPR PRINTOUT
      PR=P27/P26
      D26=FINDD(P26,T26,DI)
      D27=FINDD(P27,T27,DI)
      S26=ENTROP(D26,T26)
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      S27=ENTROP(D27,T27)
      CP26=CP(D26,T26)
      CP27=CP(D27,T27)
      CPCV26=CP26/CV(D26,T26)
      CPCV27=CP27/CV(D27,T27)
      VISC27=VISCDT(D27,T27)
      VISC26=VISCDT(D26,T26)
      WRITE (*,2200)
 2200 FORMAT (//15X47H*****CIRCULATING COMPRESSOR SPECIFICATIONS*****)
      WRITE (*,2220) EFCIRC
 2220 FORMAT(/10X20HADIABATIC EFFICIENCY,1F10.3)
      WRITE (*,2230)F26
 2230 FORMAT(13X17H FLOW RATE-GM/SEC,1F10.3)
      WRITE (*,2240)PR
 2240 FORMAT( 19X11HPRESS RATIO,1F10.3)
      WRITE(*,2250) WCIRC
 2250 FORMAT( 19X11H WORK-WATTS,1F10.3)
      WRITE (*,1260)
      WRITE (*,1270)P26,P27
      WRITE (*,1280)T26,T27
      WRITE (*,1290)H26,H27
      WRITE (*,1300)S26,S27
      WRITE (*,1310)CP26,CP27
      WRITE (*,1320) CPCV26, CPCV27
      WRITE (*,1330)  D26,D27
      WRITE (*,1340)VISC26, VISC27
C          CALCULATE PROPERTIES FOR EJECTOR PRINTOUT
      ENTRN1=F18/F10
      ENTRN2=F10/F18
      PRATO1=P18/P13
      PRATO2=P13/P18
      D13=FINDD(P13,T13,DI)
      S13=ENTROP(D13,T13)
      VOL10=F10/D10
      VOL13=F13/D13
      VOL18=F18/D18
      CP10=CP(D10,T10)
      CP13=CP(D13,T13)
      CP18=CP(D18,T18)
      CPCV10=CP10/CV(D10,T10)
      CPCV13=CP13/CV(D13,T13)
      CPCV18=CP18/CV(D18,T18)
      VISC10=VISCDT(D10,T10)
      VISC13=VISCDT(D13,T13)
      VISC18=VISCDT(D18,T18)
      WRITE (*,3200)
 3200 FORMAT (//20X32H*****EJECTOR SPECIFICATIONS*****)
      WRITE (*,3220) STEFF
 3220 FORMAT(/10X20HADIABATIC EFFICIENCY,1F10.3)
      WRITE (*,3230)ENTRN1,ENTRN2
 3230 FORMAT( 3X27HENTRAINMENT RATIO: SEC/PRI=,F10.3,
     1 2X8HPRI/SEC=,F10.3)
      WRITE (*,3240) PRATO1,PRATO2
 3240 FORMAT( 6X24HPRESSURE RATIO: SEC/EXH=,F10.3,
     1 2X8HEXH/SEC=,F10.3)
      WRITE (*,3260)
 3260 FORMAT(/14X16HFLUID PROPERTIES,3X7HPRIMARY,1X9HSECONDARY,
     1 3X7HEXHAUST/)
      WRITE (*,3265)F10,F18,F13
 3265 FORMAT(13X17H FLOW RATE-GM/SEC,3F10.3)
      WRITE (*,3267)VOL10,VOL18,VOL13
 3267 FORMAT(13X17H FLOW RATE-CC/SEC,3F10.3)
      WRITE (*,3270)P10,P18,P13
 3270 FORMAT ( 17X13H PRESSURE-ATM,3F10.3)
      WRITE (*,3280)T10,T18,T13
 3280 FORMAT ( 16X14H TEMPERATURE-K ,3F10.3)
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      WRITE (*,3290)H10,H18,H13
 3290 FORMAT ( 16X14H ENTHALPY-J/GM ,3F10.3)
      WRITE (*,3300)S10,S18,S13
 3300 FORMAT ( 15X15H ENTROPY-J/GM-K ,3F10.3)
      WRITE (*,3310)CP10,CP18,CP13
 3310 FORMAT ( 6X24H SPECIFIC HEAT,CP-J/GM-K ,3F10.3)
      WRITE (*,3320) CPCV10, CPCV18, CPCV13
 3320 FORMAT ( 5X25HSPECIFIC HEAT RATIO,CP/CV,3F10.3)
      WRITE (*,3330)  D10,D18,D13
 3330 FORMAT ( 16X14H DENSITY-GM/CC ,1P3E10.2)
      WRITE (*,3340)VISC10, VISC18, VISC13
 3340 FORMAT ( 12X18H VISCOSITY-GM/CM-S ,1P3E10.2)
      IF((T1-T31).LE.5.0) GO TO 1351
      IF((T2-T32).LE.0.5) GO TO 1351
      IF((T4-T33).LE.0.5) GO TO 1351
      IF((T5-T35).LE.0.5) GO TO 1352
      IF((T7-T37).LE.0.5) GO TO 1353
      IF((T8-T38).LE.0.2) GO TO 1354
      GO TO 1360
      WRITE (*,1350)
 1350 FORMAT(1H1)
C     COOLING CURVE CALCULATIONS
 1351 WRITE (*,1350)
      HX=2.
      CALL COOLCUR(H2,H3,H33,H32,P2,P32,F1,F32,HX,QHX2)
      IF((T5-T35).LE.0.5) GO TO 1362
      IF((T7-T37).LE.0.5) GO TO 1363
      IF((T8-T38).LE.0.2) GO TO 1364
      GO TO 1360
 1352 WRITE (*,1350)
 1362 HX=3.
      CALL COOLCUR(H4,H5,H35,H33,P4,P33,F4,F33,HX,QHX3)
      IF((T7-T37).LE.0.5) GO TO 1363
      IF((T8-T38).LE.0.2) GO TO 1364
      GO TO 1360
 1353 WRITE (*,1350)
 1363 HX=4.1
      CALL COOLCUR(H5,H6,H37,H36,P5,P35,F8,F37,HX,QHX4A)
      IF((T8-T38).LE.0.2) GO TO 1364
      GO TO 1360
 1354 WRITE (*,1350)
 1364 HX=4.2
      CALL COOLCUR(H7,H8,H38,H37,P7,P37,F8,F37,HX,QHX4B)
 1360 WRITE (*,1350)
      END

C:\DOS\FORTRAN>
```

```
LINK

Microsoft (R) 8086 Object Linker  Version 3.04
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Object Modules [.OBJ]: MAGCALT3+@NBSLINK2
Object Modules [.OBJ]: CP+VISCDT+FINDH+HRTR+THCON+PHTD2+TPH+
Object Modules [.OBJ]: HPS+DPDD2+VPTEMP+DPDTVP2+FLIQPH+FLIQPS+
Object Modules [.OBJ]: ENTROP2+DTPRES2+DPDT2+VPH+DSATL2+BLKDAT+CV2+
Object Modules [.OBJ]: VPA2+DSATV2+D2DBDT2+DBDT2+COMPWK+VIRB2+EXPTTH+
Object Modules [.OBJ]: HXEFT+FINDD2+ENTHAL2+PSTD2+PMELT+PLAMDA+COOLCUR
Run File [MAGCALT3.EXE]:
List File [NUL.MAP]:
Libraries [.LIB]:
```