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SHUTTLE ENVIRONMENTAL AND THERMAL CONTROL/LIFE SUPPORT SYSTEM COMPUTER PROGRAM

FINAL REPORT

BY

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PREPARED UNDER CONTRACT NAS 9-12411

By

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For

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ABSTRACT

SHUTTLE ENVIRONMENTAL AND THERMAL

CONTROL/LIFE SUPPORT SYSTEM COMPUTER

PROGRAM

by

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CONTRACT NAS 9-12411

DECEMBER 1975

This user's guide describes the computer programs developed to simulate the RSECS (Representative Shuttle Environmental Control System). These programs have been prepared to provide pretest predictions, post-test analysis and real-time problem analysis for RSECS test planning and evaluation. Hamilton Standard has provided these programs to the NASA on a magnetic tape cassette and on a disk device that is part of Crew Sys-ems Division's WANG-2200 series computer system.

FOREWORD

This report has been prepared by the Hamilton Standard Division of United Technologies Corporation for the National Aeronautics and Space Administration's Lyndon B. Johnson Space Center in accordance with the requirements of Contract NAS 9-12411, Space Shuttle ECS Computer Program. This interim report covers the work accomplished during calendar year 1975. Previous reports SPOZT73, "Users Manual, Space Shuttle Atmospheric Revitalization Subsystem/Active Thermal Control Subsystem Computer Program" covered the work performed under this contract during calendar year 1973; SVHSER 6529, "Shuttle Environmental and Thermal Control/Life Support System Computer Program" covered the work performed under this contract in 1974. Appreciation is expressed to the NASA JSC Technical Monitor, Mr. James Jaaxs, for his support during the conduct of this program.

The Hamilton Standard technical personnel responsible for the work described herein is Mr. William J. Ayotte. The program manager is Mr. Harlan F. Brose.

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INTRODUCTION

To fulfill the requirements of Contract NAS 9-12411, for calendar year 1975, Hamilton Standard has developed the computer programs listed below. These programs were written to support the RSECS (Representative Shuttle Environmental Control System) test program presently being conducted.

- "RSECS" - Calculates a steady state heat balance for a combined RSECS ARS (Air Revitalization Subsystem) gas and water coolant loop system. Required input data consists of RSECS heat loads, flow rates and controller settings, and GSE (Ground Support Equipment) flow rate and inlet temperature.

- "RSECS2" - Draws flow charts of RSECS air loop and water loop. This program is used in conjunction with program "RSECS".

- "350-M Hx"- Analyzes 350-M heat exchanger test data. Calculates heat loads and heat transfer coefficients for the heat exchanger. Required input consists of operating temperatures and flow rates at the heat exchanger.

- "CONDHX" - Calculates 350-M RSECS cabin heat exchanger performance using measured inlet air conditions of temperature and dew point, and inlet coolant conditions of temperature and flow. Used to predict results of heat exchanger tests.

- "ARS DP" - Calculates the corrected pressure drop of the Hamilton Standard supplied RSECS ARS gas loop equipment. The calculations are detailed to the package level. Required input data includes the total air flow rate, and the number of RS-11 fans operating.

- "PLOT" - Generalized plot program used to produce plots of results of RSECS analysis or any other desired data, using a WANG 2200 flat bed plotter.

- "RADIATOR"- Calculates thermal performance for a flowing radiator panel system. Used to predict performance for the Shuttle radiator system.

  Uses environmental inputs (absorbed heats) in combustion with physical input (flow rate, Tin, Area) to generate predictions.

- "WINDA" - Generalized model thermal analyzer program. Used to model any desired thermal system. Inputs are in standard SINDA format - thermal conductances between nodes, thermal masses, boundary conditions, etc.

RSECS STEADY STATE COMPUTER PROGRAM

File Name "RSECS"

Abstract "RSECS" calculates the steady state operating point, for a given set of input data, for the combined RSECS gas and water coolant loops. The program is designed for use with a WANG 2200 - series computer system. A sample case is shown in figure 1.

Program Description

This user's guide is written for the person who has an understanding of the BASIC computer language and is acquainted with the WANG 2200 - series computer system. The program models the functional gas, figure 2, and water loop, figure 3, schematics enclosed.

Rotating equipment characteristics are supplied as input data. However, performance maps for the 350-m and RS-261 heat exchangers are stored in the program as internal data, in addition to Freon-21 and water vapor properties. These data tables are interpolated by using an adaptation of the Hamilton Standard Division's "UNBAR" routine.

As written, the program uses Freon-21 as the RS-261 heat exchanger's cold side fluid. Minor changes to the data tables are required if another fluid is to be considered. The Freon enthalpy table must be revised to reflect the new fluid. A revised RS-261 heat exchanger performance map must be generated and incorporated.

The "Input Data Definition", Table I, provides the user with the information required to supply the program with the appropriate input data. The input data for all the cases is loaded into its storage array prior to the execution of the first case. At the completion of the first case, the results will be printed, the data array cleared and up-dated for the second case, and the second case started. The user has the option of matching the RS-261 heat exchanger's heat load or hot side operating temperatures to Shuttle conditions. When the Shuttle temperatures are duplicated, the NASA-supplied heat sink will compensate for the heat not rejected through the RS-261 heat exchanger.

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RSECS STEADY STATE COMPUTER PROGRAM

RUN #: SAMPLE CASE 1 - MIN LOAD 29000 P/L SYS
DATE : 7/3/74

INPUT DATA -

T RS-20 SETPT	= 70.00	Q CHAMBER-S	= 0.00	Q CHAMBER-L	= 1268.00
Q CHAM AVIONICS	= 0.00	CO2 INLET FLOW	= 0.00	RS-11 FLOW	= 317.00
RS-11 POWER	= 970.00	RS-51 FLOW	= 10.00	RS-51 POWER	= 185.00
RS-251 FLOW	= 779.00	RS-251 POWER	= 73.00	H2O BYPASS FLOW	= 281.00
Q H2O AVIONICS	= 11109.00	T RS-261 F21 IN	= 35.59	W RS-261 F21	= 2587.00

GAS LOOP OUTPUT DATA -

T CHAMBER	= 70.00	TOTAL AIR FLOW	= 1418.04	Q RS-11	= 3311.58
T DEWPOINT	= 50.06	WCP RS-11	= 345.21	Q RS-50 -S	= 0.00
T RS-11 IN	= 70.00	WCP 350-M	= 90.68	Q RS-50 -L	= 0.00
T RS-50 IN	= 70.59	V 350-M	= 73.27	Q RS-51	= 631.58
T 350-M IN	= 70.59	W BYPASS	= 233.72	Q 350-M -S	= 3943.17
T 350-M OUT	= 36.10	W CONDENSATE	= 1.19	Q 350-M -L	= 1268.00
T RS-51 OUT	= 94.10	WA 350-M	= 700.27	Q 350-M -TOT	= 5211.17

COOLANT LOOP OUTPUT DATA -

T RS-261 H2O OUT	= 35.99	T 350-M H2O IN	= 35.99	T 350-M H2O OUT	= 46.46
T RS-251 H2O IN	= 54.68	T AVION H2O IN	= 55.00	T RS-261 H2O IN	= 69.27
T RS-261 F21 OUT	= 61.47	W RS-261/350-M	= 498.00	Q H2O HTSINK	= 0.00
Q RS-251	= 249.22	Q RS-261	= 16569.39		

FIGURE 1 RSECS STEADY STATE COMPUTER PROGRAM SAMPLE CASE

RSECS STEADY STATE COMPUTER PROGRAM

RUN #: SAMPLE CASE 2 - PRELAUNCH 21500 P/L SYS
DATE : 7/3/74

INPUT DATA -

T RS-20 SETPT =	73.00	Q CHAMBER-S =	6352.00	Q CHAMBER-L =	2769.00
Q CHAM AVIONICS =	4100.00	CO2 INLET FLOW =	0.00	RS-11 FLOW =	317.00
RS-11 POWER =	970.00	RS-51 FLOW =	10.00	RS-51 POWER =	135.00
RS-251 FLOW =	697.00	RS-251 POWER =	69.00	H2O BYPASS FLOW =	0.00
Q H20 AVIONICS =	26051.00	T RS-261 F21 IN =	36.20	W RS-261 F21 =	2843.00

GAS LOOP OUTPUT DATA -

T CHAMBER =	73.00	TOTAL AIR FLOW =	1376.47	Q RS-11 =	3311.59
T DEWPOINT =	55.25	UCP RS-11 =	336.10	Q RS-50 -S =	0.00
T RS-11 IN =	35.46	UCP 350-M =	309.97	Q RS-50 -L =	0.00
T RS-50 IN =	95.31	W 350-M =	282.35	Q RS-51 =	631.59
T 350-M IN =	95.31	W BYPASS =	24.64	Q 350-M -S =	14435.17
T 350-M OUT =	48.59	W CONDENSATE =	2.60	Q 350-M -L =	2769.00
T RS-51 OUT =	100.15	UA 350-M =	1309.33	Q 350-M -TOT =	17254.17

COOLANT LOOP OUTPUT DATA -

T RS-261 F20 OUT =	42.50	T 350-M H20 IN =	42.80	T 350-M H20 OUT =	67.55
T RS-251 H20 IN =	67.55	T AVION H20 IN =	67.89	T RS-261 H20 IN =	105.20
T RS-261 F21 OUT =	97.24	W RS-261/350-M =	697.00	Q H20 FTSINK =	-146.90
Q RS-251 =	235.56	Q RS-261 =	43639.79		

FIGURE 1 RSECS STEADY STATE COMPUTER PROGRAM SAMPLE CASE (CONCLUDED)

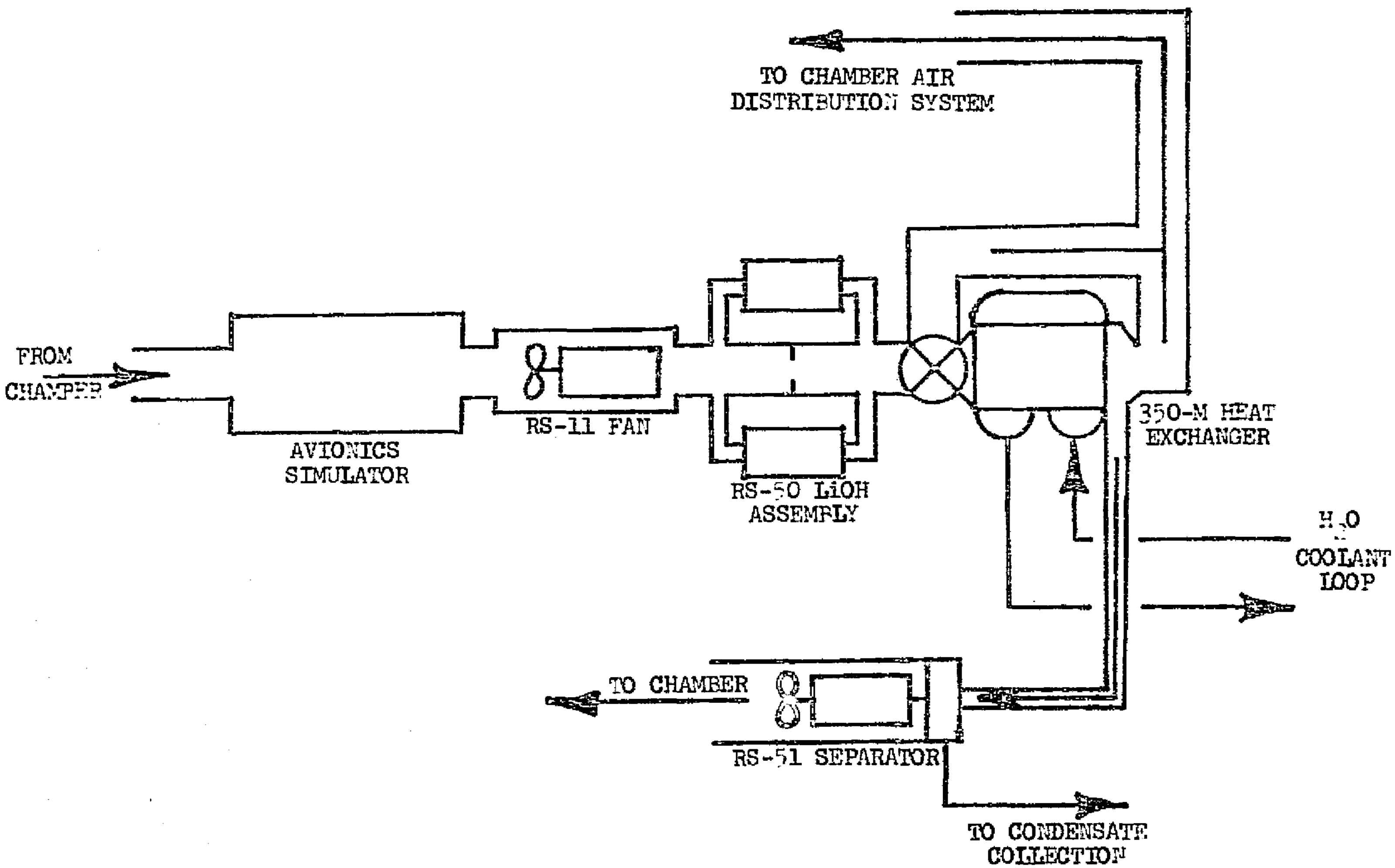

FIGURE [illegible] RSECS ARS GAS LOOP SCHEMATIC

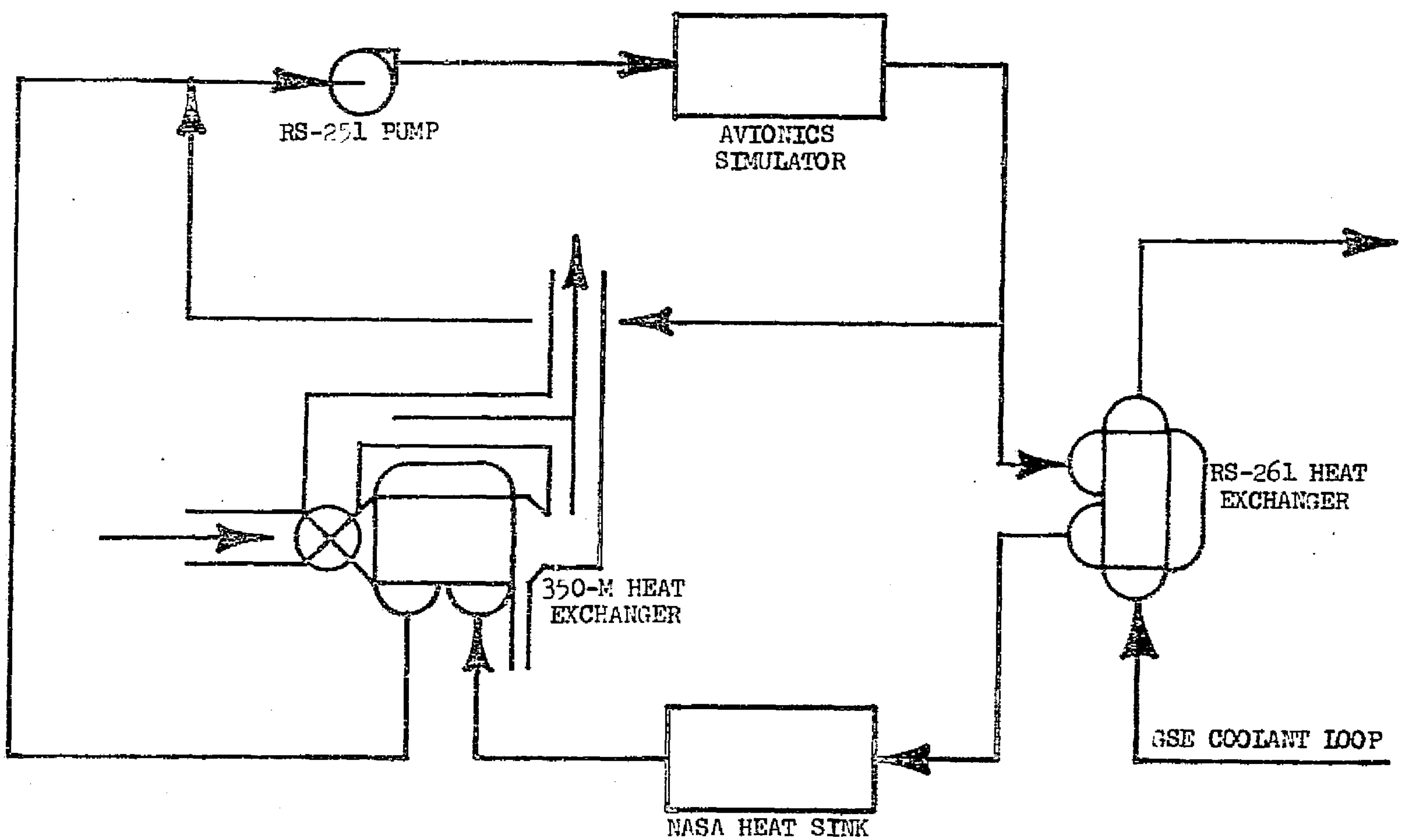

FIGURE 3 RSECS WATER LOOP SCHEMATIC

Table I

INPUT DATA DEFINITION

CRT SYMBOL	PRINTED SYMBOL	DESCRIPTION
# of cases	not printed	number of cases to be run (1 - 10)
date	date	Time identification (16 characters, max)
are flow charts desired	not printed	1 if yes 2 if no
is printout desired	not printed	1 if yes 2 if no
run designation	run #	identifying notation for individual case (64 characters, max)
T RS-20 SETPT	T RS-20 SETPT	RS-20 temperature controller setting for chamber; program will try to balance system at this point (^{o}F)
Q cham-S	Q chamber-S	sum total of all non-RSECS sensible heat added to the chamber (Btu/Hr)
Q cham-L	Q chamber-L	sum total of all non-RSECS latent heat added to the chamber (Btu/Hr)
Q avionics	Q cham avionics	sensible heat supplied by the cabin avionics simulator (Btu/Hr)
CO_2 flow	CO_2 inlet flow	CO_2 injection rate into the chamber (Lb/Hr)
RS-11 flow.	RS-11 flow	total air flow generated by the RS-11 fans (cfm)
RS-11 power	RS-11 power	RS-11 fans input power (watts)
RS-51 flow	RS-51 flow	RS-51 separator air flow rate (cfm)
RS-51 power	RS-51 power	RS-51 separator input power (watts)
RS-251 flow	RS-251 flow	RS-251 pump flow rate (Lb/Hr)

Table I

INPUT DATA DEFINITION (CONCLUDED)

CRT SYMBOL	PRINTED SYMBOL	DESCRIPTION
RS-251 power	RS-251 power	RS-251 pump input power (watts)
bypass flow	H_2O bypass flow	RS-251 pump package bypass flow rate (Lb/Hr)
Q simulator	Q H_2O avionics	sensible heat supplied by the H_2O loop avionics simulator (Btu/Hr)
T 350M H_2O in	not printed	desired 350-M HX H_2O inlet temp. If >0 the heat req'd to compensate for the difference between this temp. and the RS-261 HX outlet will be calculated. If = 0 the H_2O heat sink Q will be set at 0 and the RS-261 HX outlet temp. will be used (°F)
T 261 H_2O in	not printed	desired RS-261 HX H_2O inlet temp. must be > 0 if T 350M H_2O in is > 0 / or must = 0 if T 350M H_2O in = 0 (°F)
T 261 F21 in	T RS-261 F21 IN	RS-261 HX cold side inlet temperature (°F)
261 F21 flow	W RS-261 F21	RS-261 HX cold side flow rate (Lb/Hr)

The "Output Data Definition", Table II, provides the user with a description of the output data's printed symbols. Two sample cases are provided to assist the user in understanding the data tables and the program operation.

For user reference, the following information is enclosed:

1. RS-11 Fan Performance Map, figure 4

2. 350-M Heat Exchanger Performance Curves

   Hot Side Film Coefficient vs. Air Velocity, figure 5

   Cold Side Film Coefficient vs. Water Flow Rate Per Start, figure 6

3. RS-261 Heat Exchanger Performance Maps, Effectiveness vs. Hot and Cold Side Flow Rates.

   Uses Cold Side Fluid of - Freon-21, figure 7

   - Water/Glycol, figure 8

   - Water, figure 9

4. Internal Data Summary, Table III

5. Data Array, Table IV

6. Input Data Array, Table V

7. Logic Key Array, Table VI

8. Scalar Variable Summary List, Table VII

9. Subroutine Descriptions, Table VIII

10. Program Listing, Table IX

Table II

OUTPUT DATA DEFINITION

PRINTED SYMBOL	DESCRIPTION
T chamber	steady state chamber temperature (°F)
total air flow	air weight flow at the RS-11 fans (Lb/Hr)
Q RS-11	sensible heat generated by the RS-11 fans (Btu/Hr)
T dewpoint	chamber dewpoint temperature (°F)
WCP RS-11	air weight flow X specific heat at the RS-11 fans (Btu/Hr - °F)
Q RS-50-S	sensible heat generated by the LiOH/CO_2 reaction (Btu/Hr)
T RS-11 in	RS-11 fans inlet temperature (°F)
WCP 350-M	air weight flow X specific heat through the 350-M HX (Btu/Hr - °F)
Q RS-50-L	latent heat generated by the LiOH/CO_2 reaction (Btu/Hr)
T RS-50 in	RS-50 LiOH assembly inlet temperature (°F)
V 350-M	air flow rate exiting the 350-M HX (cfm)
Q RS-51	sensible heat generated by the RS-51 separator (Btu/Hr)
T 350-M in	350-M HX air inlet temperature (°F)
V bypass	air flow rate through the 350-M HX bypass (cfm)
Q 350-M-S	350-M HX sensible heat load (Btu/Hr)
T 350-M out	350-M HX air outlet temperature (°F)
W condensate	condensate flow rate exiting the RS-51 separator (Lb/Hr)
Q 350-M-L	350-M HX latent heat load (Btu/Hr)

Table II

OUTPUT DATA DEFINITION (CONCLUDED)

PRINTED SYMBOL	DESCRIPTION
T RS-51 out	RS-51 separator air outlet temperature (°F)
UA 350-M	350-M HX UA (Btu/Hr - °F)
Q 350-M -TOT	350-M HX total heat load (Btu/Hr)
T RS-261 H_2O out	RS-261 HX H_2O outlet temperature (°F)
T 350-M H_2O in	350-M HX H_2O inlet temperature (°F)
T 350-M H_2O out	350-M H_2O outlet temperature (°F)
T RS-251 H_2O in	RS-251 pump inlet temperature (°F)
T avion H_2O in	H_2O loop avionics simulator inlet temperature (°F)
T RS-261 H_2O in	RS-261 HX H_2O inlet temperature (°F)
T RS-261 F21 out	RS-261 HX cold side outlet temperature
W RS-261/350-M	RS-261/350-M HX H_2O flow rate (Lb/Hr)
Q H_2O HTSINK	H_2O loop heat sink load (Btu/Hr)
Q RS-251	heat generated by the RS-251 pump
Q RS-261	RS-261 HX heat load (Btu/Hr)

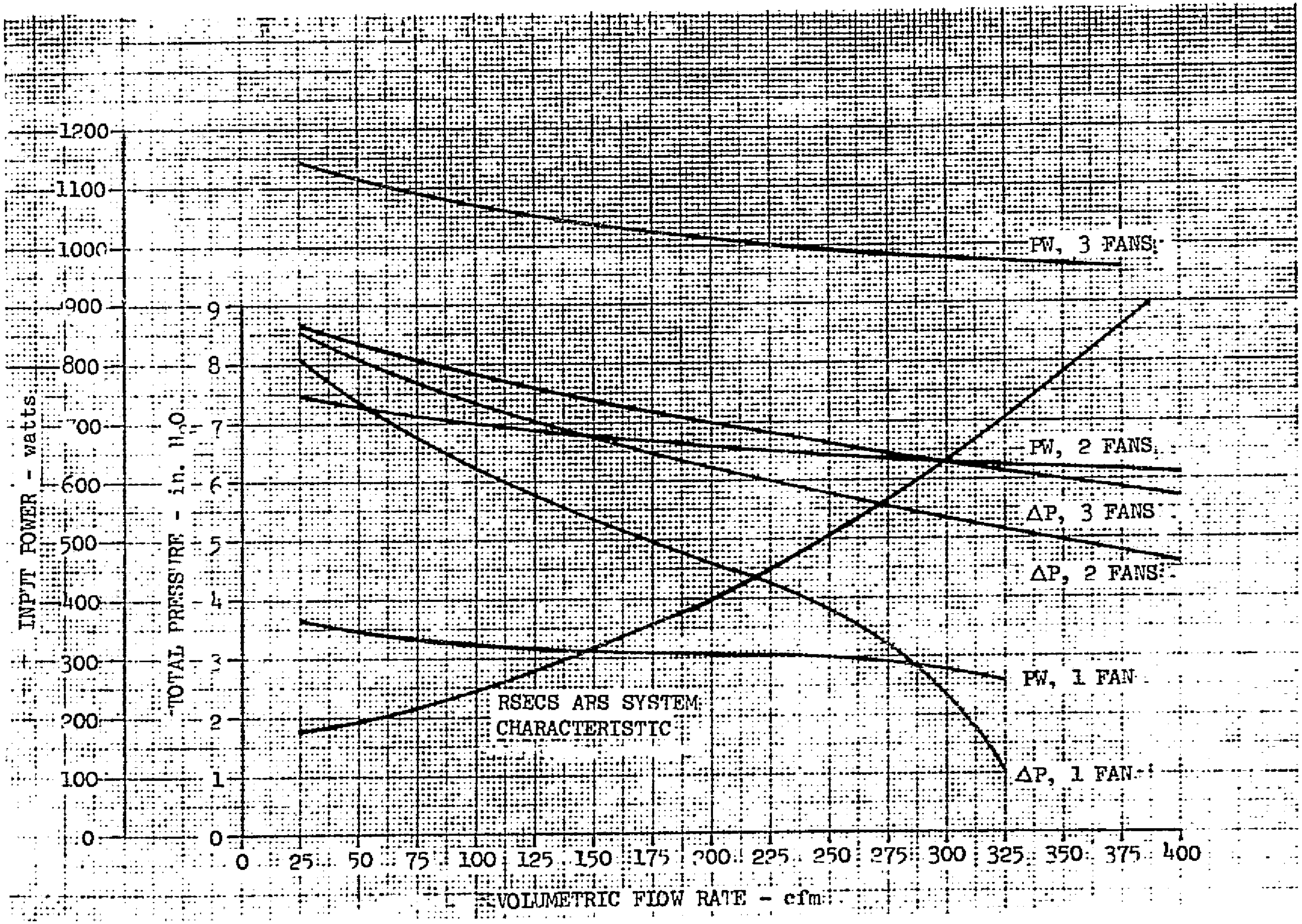

FIGURE 4 RS-11 FAN PERFORMANCE MAP

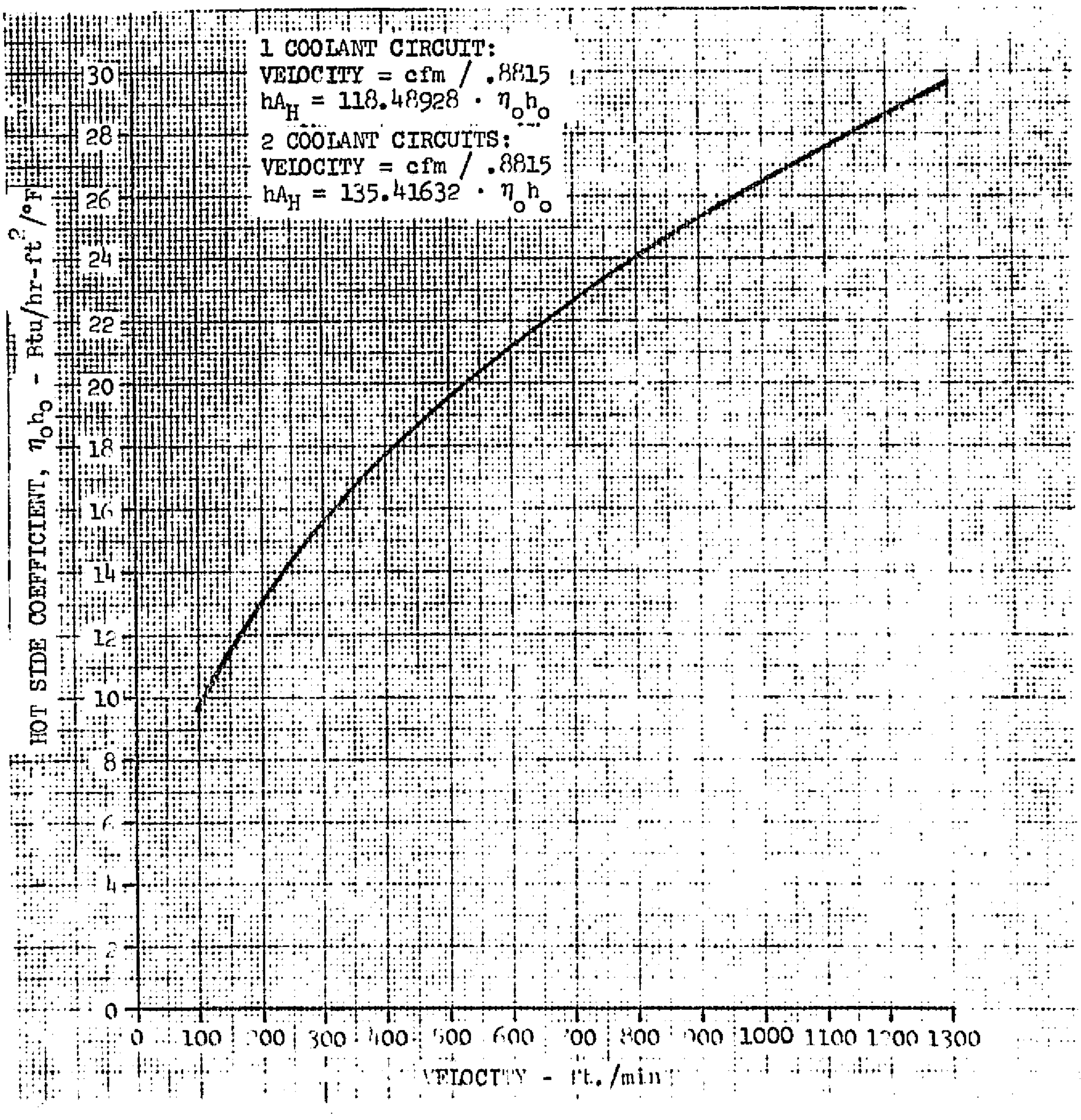

FIGURE 5 RSECS 5-O-M HEAT EXCHANGER PERFORMANCE

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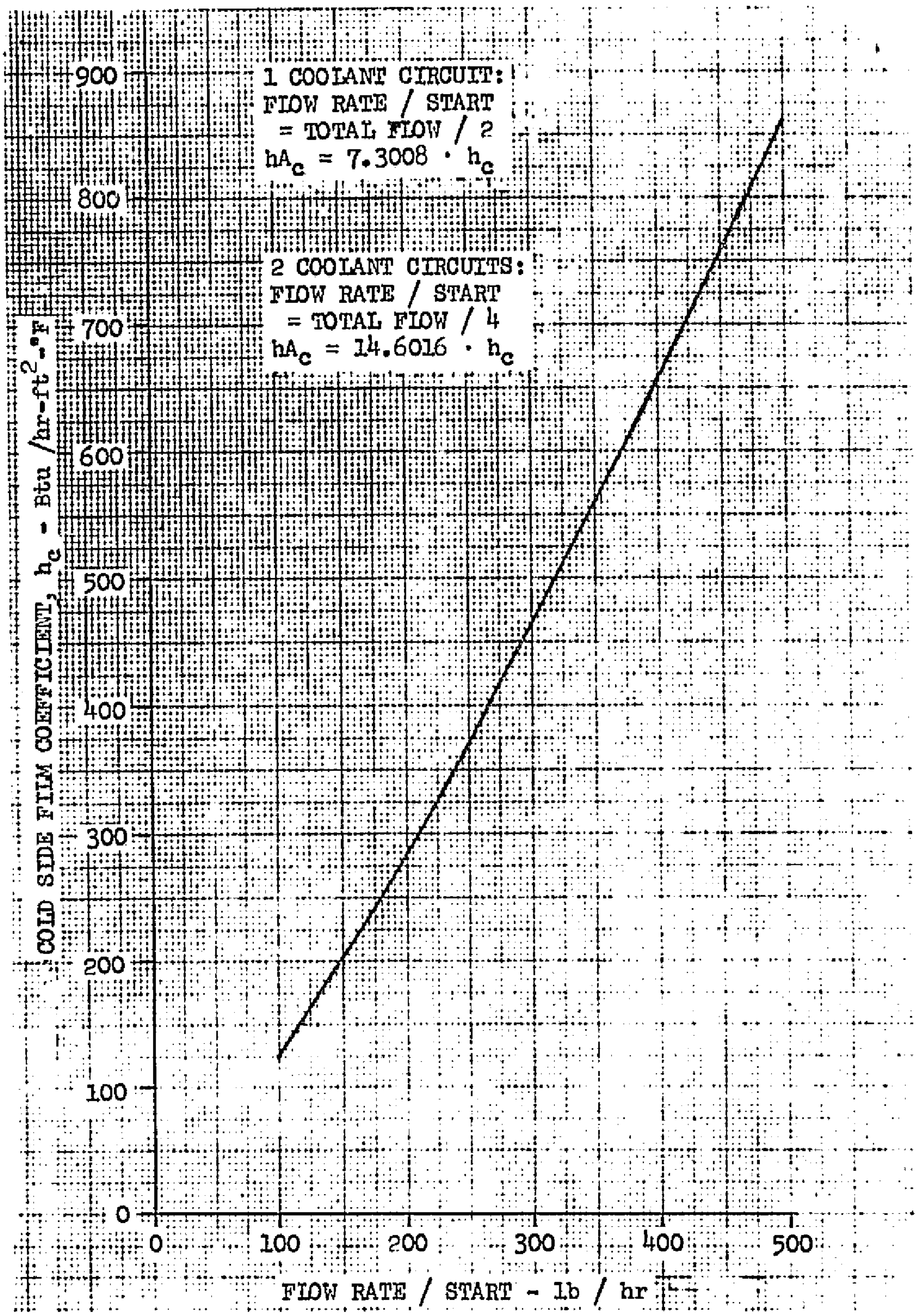

FIGURE 6 RSECS 350-M HEAT EXCHANGER PERFORMANCE

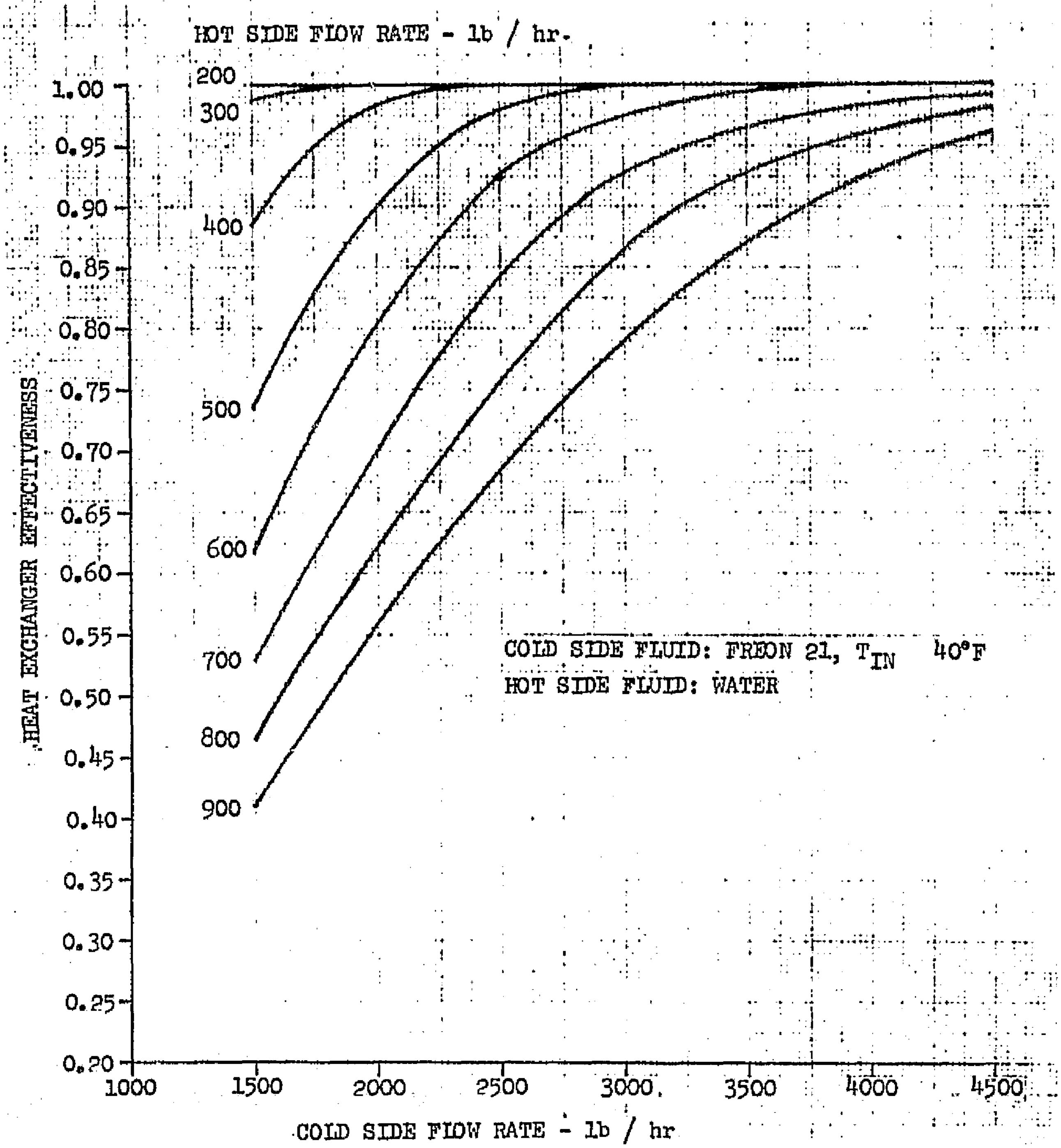

FIGURE 7 RSECS ?-1 HEAT EXCHANGER PERFORMANCE

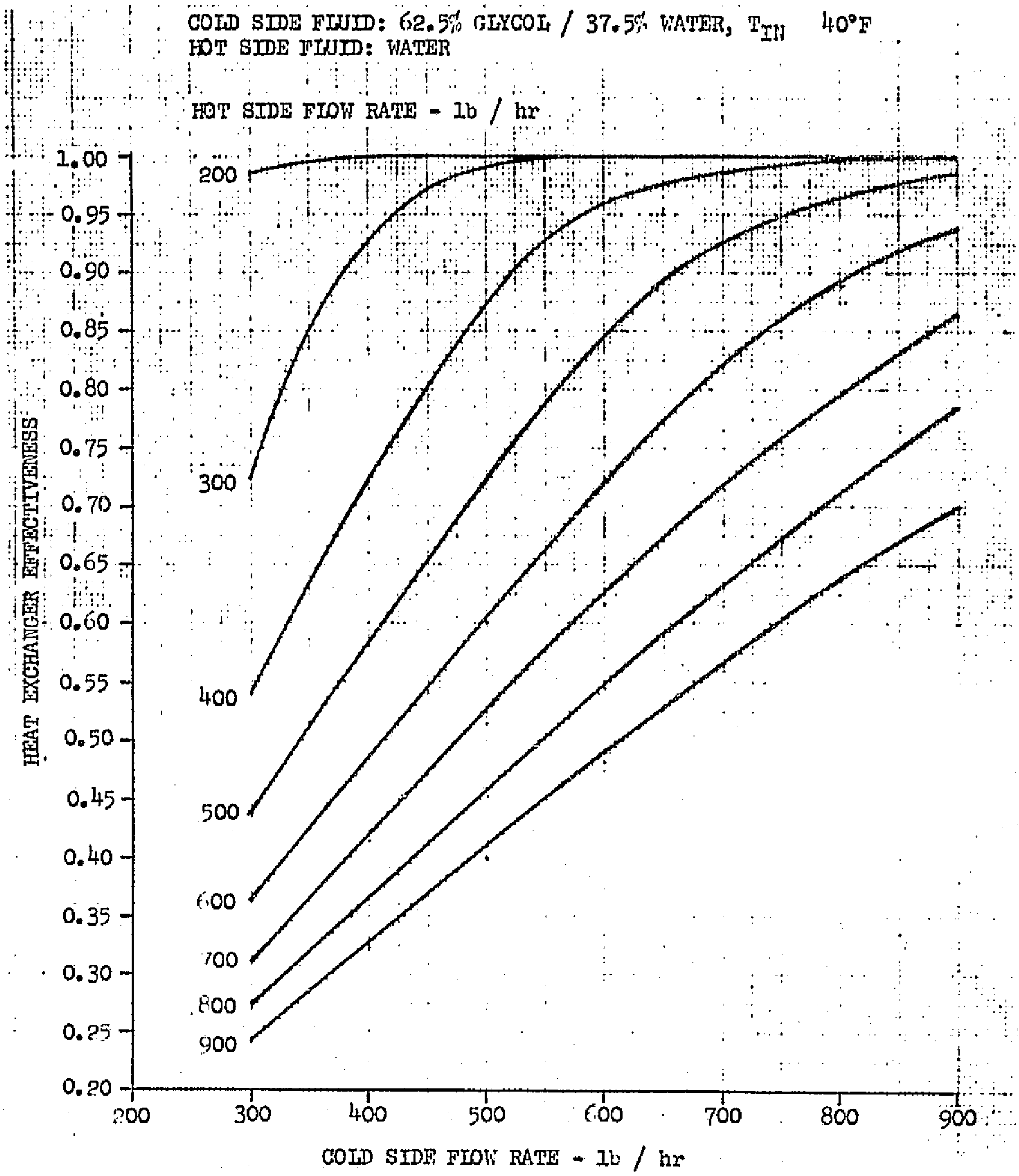

FIGURE 8 RSECS No. 1 HEAT EXCHANGER PERFORMANCE

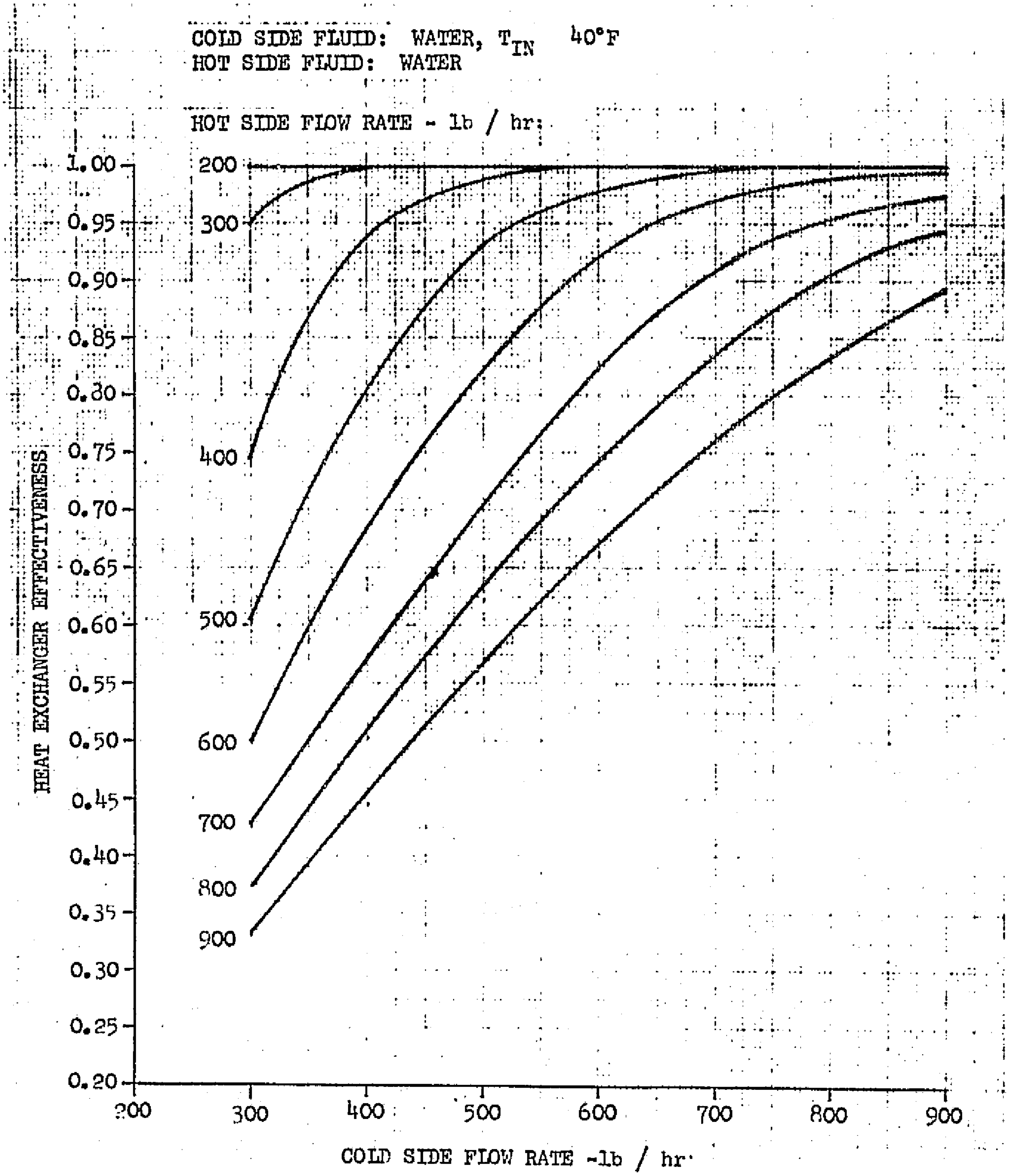

FIGURE 9 RSECS 261 HEAT EXCHANGER PERFORMANCE

Table III

INTERNAL DATA SUMMARY

STORAGE LOCATION	DATA DESCRIPTION
1-25	Freon temperatures, 0-240°F in 10° increments
26-50	Freon enthalpy, Btu/Lb, corresponding to temperatures in locations 1-25
51-70	Water vapor temperatures, 32-70°F in 2° increments
71-90	Water vapor pressure, PSIA, corresponding to temperatures in locations 51-70
91-118	350-M HX air side film coefficient curve, $\eta_o h_o$ vs. velocity 91: # of X values (13) 92: # of Y values (0) 93-103: air velocity, 100-1300 ft/min in 100 ft/min increments 104-118: $\eta_o h_o$, Btu/Hr-Ft^2 - °F, corresponding to air velocities in locations 93-103
119-138	350-M HX H_2O side film coefficient curve, h_c vs. flow/start 119: # of X values (9) 120: # of Y values (0) 121-129: flow/start, 100-500 Lb/Hr in 50 Lb/Hr increments 130-138: h_c, Btu/Hr-Ft^2 °F, corresponding to flow/start in locations 121-129
139-211	RS-261 HX effectiveness map; H_2O/F21, T F21 - in = 40°F 139: # of X values (8) 140: # of Y values (7) 141-148: H_2O flow, 200-900 Lb/Hr in 100 Lb/Hr increments 149-155: F21 flow, 1500-4500 Lb/Hr in 500 Lb/Hr increments 156-211: HX effectiveness in following order: X_1, Y_1, X_1, Y_2, -------X_1Y_7,X_2Y_1----X_2Y_7,-----X_8Y_7

Table IV

DATA ARRAY

– Provides storage for individual case calculations

ARRAY LOCATION	DATA DESCRIPTION
1	RS-20 temperature controller set point
2	Non-RSECS sensible heat added to the chamber
3	Non-RSECS latent heat added to the chamber
4	Cabin avionics simulator heat load
5	CO_2 injection flow rate to chamber
6	RS-11 fans total volumetric flow rate
7	RS-11 fans power requirement
8	RS-51 separator volumetric flow rate
9	RS-51 separator power requirement
10	RS-251 pump total mass flow rate
11	RS-251 pump power requirement
12	H_2O bypass mass flow rate
13	H_2O loop avionics simulator heat load
14	350-M HX H_2O inlet temperature
15	RS-261 HX H_2O inlet temperature
16	RS-261 HX F21 inlet temperature
17	RS-261 HX F21 mass flow rate
18	Chamber temperature
19	RS-11 fan heat load
20	Sensible heat generated by the CO_2/LiOH reaction

Table IV

DATA ARRAY (CONTINUED)

- Provides storage for individual case calculations

ARRAY LOCATION	DATA DESCRIPTION
21	Latent heat generated by the CO_2/LiOH reaction
22	RS-51 separator heat load
23	Sensible heat at the 350-M HX inlet - air side
24	350-M HX total sensible heat
25	350-M HX total latent heat
26	350-M HX total heat load
27	RS-251 pump heat load
28	H_2O loop sink heat load
29	RS-261 HX heat load
30	RS-261/350-M HX's H_2O mass flow rate
31	RS-261 HX H_2O outlet temperature
32	RS-261 HX F21 outlet temperature
33	350-M HX H_2O outlet temperature
34	RS-251 pump H_2O inlet temperature
35	H_2O loop avionics simulator inlet temperature
36	RS-11 fan air mass flow rate X specific heat
37	350-M HX air mass flow rate X specific heat
38	RS-11 fan inlet temperature
39	RS-11 fan air mass flow rate
40	Chamber temperature from previous iteration

Table IV

DATA ARRAY (CONCLUDED)

ARRAY LOCATION	DATA DESCRIPTION
41	350-M HX UA req'd from previous iteration
42	Chamber dewpoint
43	350-M HX minimum air flow rate - decimal fraction of total flow
44	350-M HX air inlet temperature
45	350-M HX air outlet temperature
46	350-M HX UA
47	350-M HX volumetric air flow rate
48	350-M HX bypass volumetric air flow rate
49	RS-50 LiOH assembly inlet temperature
50	RS-51 separator air outlet temperature
51	RS-51 separator condensate mass flow rate
101-200	Reserved for internal data storage for table interpolation

Table V

INPUT DATA ARRAY

– Provides input data storage for a maximum of 10 cases

ARRAY LOCATION	DATA DESCRIPTION
1,1 - 1,17	Case #1 input data: corresponds to X-array locations 1-17
2,1 - 2,17	Case #2 input data
10,1 - 10,17	Case #10 input data

Table VI

LOGIC KEY ARRAY

– Provides storage for program keys

ARRAY LOCATION	DATA DESCRIPTION
1	Case # being run
2	Max # of cases to be run
3	Flow chart key
4	Print-out key

Table VII

SCALAR VARIABLES SUMMARY LIST

B$	M2	U2
E1	Q1	U3
E2	Q2	W1
H	T1	Z
H1	T2	Z1
H2	U	
K	U	
M1	U1	

Table VIII

SUBROUTINE DESCRIPTIONS

SUBROUTINE NUMBER	SUMMARY
01	Interpolates data curves that have been transferred to the X-array in locations 101-200 Array must be set-up in following order: X(101) : # of X-values (N) X(102) : # of Y-values (M) X(103) - X (102 + N): X-values in ascending order X(102 + N + 1) - X(102 + N + M) : Y-values in ascending order, omit if M = 0 X(102 + N + M + 1) - X(200) : Z-values in following order - $Z(N_1, M_1)$, $Z(N_1, M_2)$, ----$Z(N_1, M)$, $Z(N_2, M_1)$,------$Z(N_2, M)$,----- Z(N, M) Array and scalar variables used: A1(6) X1(6) Y1(6) C1 C2 C3 C4 D D1 D2 I I1 J J1 J2 J7 J8 J9 K1 K8 L L7 L8 M N N1 N2 N8

Table VIII

SUBROUTINE DESCRIPTIONS (CONTINUED)

SUBROUTINE NUMBER	SUMMARY
	N9 Z1
02	Calculates air flow rate X Cp by iterating 350-M HX air outlet temperature and chamber dewpoint Scalar variables: B
03	Calculates air dewpoint at 350-M HX inlet Scalar variables: A2 C P2 Z1
04	Calculates 350-M HX hA_{hot} and UA Scalar variables: E H1 H2 V1 Z1
05	Calculates 350-M HX NTU's Scalar variables: E3 K M3
06	Calculates chamber dewpoint Scalar variables: A2 F P2 Z1

Table VIII

SUBROUTINE DESCRIPTIONS (CONCLUDED)

SUBROUTINE NUMBER	SUMMARY
07	Calculates air weight flow and Cp by iterating RS-11 fan inlet temperature Scalar variables: C3 G P1 P2 R1 R2 R3 Z1
08	Calculates density of dry air and water vapor Scalar variables: P4 R3 R4
10	Calculates RS-11 fan, RS-50 LiOH assembly and 350-M HX air inlet temperatures
11	Calculates 350-M HX air outlet temperature

Table IX

PROGRAM LISTING

```
10  REM RSECS ARS/H2O LOOP PERFORMANCE
20  COM X(200),A(10,17),A$(10)64,B$,Y(4)
30  IF Y(1)]1 THEN 250: Y(1)=1
40  REM FREON PROPERTIES - TEMPERATURE (1):
    DATA 0  ,10 ,20 ,30 ,40 ,50 ,60 ,70 ,80 ,90 ,100,110,120,
         130,140,150,160,170,180,190,200,210,220,230,240
50  REM FREON PROPERTIES - ENTHALPY (26):
    DATA 9.44 ,11.81,14.21,16.61,19.04,21.49,23.98,26.49,29.03,
         31.59,34.18,36.79,39.46,42.13,44.86,47.62,50.43,53.2
60  DATA 56   ,59   ,62   ,65   ,68   ,71   ,74
70  REM WATER VAPOR PROPERTIES - TEMPERATURE (51):
    DATA 32,34,36,38,40,42,44,46,48,50,52,54,56,58,60,62,64,66,
         68,70
80  REM WATER VAPOR PROPERTIES - PRESSURE (71):
    DATA .08854,.09603,.10401,.11256,.1217 ,.1315 ,.14199,
         .15323,.16525,.17811,.19182,.20642,.222  ,.2386
90  DATA .2563 ,.2751 ,.2951 ,.3164 ,.339  ,.3631
100 REM 350-M HX AIR SIDE FILM COEFFICIENT (91):
    DATA 13  ,0   ,100 ,200 ,300 ,400 ,500 ,600 ,700 ,800 ,
         900 ,1000,1100,1200,1300
110 DATA 9.6 ,13.2,15.6,17.7,19.5,21.2,22.6,24  ,25.3,26.4,
         27.5,28.5,29.6
120 REM 350-M HX H2O SIDE FILM COEFFICIENT (119):
    DATA 9  ,0  ,100,150,200,250,300,350,400,450,500,134,199,
         282,370,463,560,655,765,960
130 REM 261 HX EFFECTIVENESS MAP - F21/H20, T-F21=40F (139):
    DATA 8     ,7     ,200  ,300  ,400  ,500  ,600  ,700  ,800  ,
         900   ,1500  ,2000 ,2500 .3000 ,3500 ,4000 ,4500 ,1
140 DATA 1     ,1     ,1     ,1     ,1     ,1     ,.9376,.9995,1     ,
         1     ,1     ,1     ,1     ,.984  ,.9836,.998  ,.9997,.9999,
         1     ,1     ,.736  ,.9113,.9793,.9952,.9937,.9996,.9999
150 DATA .618  ,.9023,.9232,.9743,.9913,.9968,.9987,.5308,.7093,
         .8405,.9274,.9689,.9864,.9937,.4649,.6169,.7556,.862 ,
         .9282,.9635,.981  ,.4132,.5496,.6797,.7914,.8739,.9269
160 DATA .9577
170 INPUT "# OF CASES                        (1-10): ",Y(2):
    INPUT "DATE                                    : ",B$:
    INPUT "ARE FLOW CHARTS DESIRED, (YES=1/NO=2): ",Y(3)
180 INPUT "IS PRINTOUT DESIRED,      (YES=1/NO=2): ",Y(4):
    FOR Z=1 TO Y(2): SELECT PRINT 005: PRINT "CASE # = ";Z:
    INPUT "RUN DESIGNATION          : ",A$(Z)
190 INPUT "T RS-20 SETPT (DEG F) = ",A(Z,1):
    INPUT "Q CHAM-S      (BTU/HR) = ",A(Z,2):
    INPUT "Q CHAM-L      (BTU/HR) = ",A(Z,3)
200 INPUT "Q AVIONICS    (BTU/HR) = ",A(Z,4):
    INPUT "CO2 FLOW       (LB/HR) = ",A(Z,5):
    INPUT "RS-11 FLOW       (CFM) = ",A(Z,6)
```

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Table IX

PROGRAM LISTING (CONTINUED)

```
210 INPUT "RS-11 POWER   (WATTS) = ",A(Z,7):
    INPUT "RS-51 FLOW      (CFM) = ",A(Z,8):
    INPUT "RS-51 POWER   (WATTS) = ",A(Z,9)
220 INPUT "RS-251 FLOW   (LB/HR) = ",A(Z,10):
    INPUT "RS-251 POWER  (WATTS) = ",A(Z,11):
    INPUT "BYPASS FLOW   (LB/HR) = ",A(Z,12)
230 INPUT "Q SIMULATOR  (BTU/HR) = ",A(Z,13):
    INPUT "T 350M H20 IN (DEG F) = ",A(Z,14):
    INPUT "T 261 H20 IN  (DEG F) = ",A(Z,15)
240 INPUT "T 261 F21 IN  (DEG F) = ",A(Z,16):
    INPUT "261 F21 FLOW  (LB/HR) = ",A(Z,17):
    NEXT Z
250 IF Y(1)[=Y(2) THEN 260: Y(1)=0: REWIND : GOTO 340
260 FOR Z=1 TO 17: X(Z)=A(Y(1),Z): NEXT Z: X(18)=X(1):
    X(19)=3.414*X(7): X(20)=875*X(5): X(21)=427.5*X(5):
    X(22)=3.414*X(9): X(23)=X(4)+X(19)+X(20)
270 X(24)=X(2)+X(22)+X(23): X(25)=X(3)+X(21):
    X(26)=X(24)+X(25): X(27)=3.414*X(11): X(30)=X(10)-X(12):
    RESTORE 139: FOR Z=101 TO 173: READ X(Z): NEXT Z
280 GOSUB '01(X(30),X(17)): E1=Z1: IF X(15)=0 THEN 290:
    X(31)=X(15)-E1*(X(15)-X(16)): X(29)=X(30)*(X(15)-X(31)):
    X(28)=X(30)*(X(31)-X(14)): GOTO 300
290 X(28)=0: X(29)=X(26)+X(27)+X(13):
    X(31)=X(16)+X(29)/X(30)*(1/E1-1): X(15)=X(31)+X(29)/X(30):
    X(14)=X(31)
300 X(101)=25: X(102)=0: RESTORE 1: FOR Z=103 TO 152: READ X(Z):
    NEXT Z: GOSUB '01(X(16),0): H1=Z1: H2=H1+X(29)/X(17):
    RESTORE 26: FOR Z=103 TO 127: READ X(Z): NEXT Z
310 RESTORE 1: FOR Z=128 TO 152: READ X(Z): NEXT Z:
    GOSUB '01(H2,0): X(32)=Z1: X(33)=X(14)+X(26)/X(30):
    X(34)=(X(33)*X(30)+X(15)*X(12))/X(10)
320 X(35)=X(34)+X(27)/X(10): X(40)=0: X(41)=0: X(42)=50:
    X(43)=.1271676: X(39)=2380.656*X(6)/(X(18)+459.6):
    X(36)=.24*X(39): X(37)=X(36): W1=X(30)/2: RESTORE 119
330 FOR Z=101 TO 120: READ X(Z): NEXT Z: GOSUB '01(W1,0):
     H1=7.3008*Z1: GOSUB '02: GOSUB '10: GOSUB '11:
    IF X(45)]=X(14) THEN 360
340 X(45)=X(45)+1: X(44)=X(45)+X(24)/X(37):
    X(18)=X(44)-X(23)/X(36): GOSUB '02: GOSUB '10: GOSUB '11
350 IF X(45)[X(14) THEN 340
360 GOSUB '03: GOSUB '04: H=H2/H1:
    T1=(X(37)*X(44)+X(30)*(H*X(42)+X(42)-X(33)))/
       (H*X(30)+X(37))
370 Q1=X(37)*(T1-X(45)): Q2=Q1+X(25): IF Q2[X(26) THEN 380:
    H1=0: T2=X(33): T1=X(44): Q1=X(24): Q2=X(26): GOTO 390
380 T2=X(42)-H*(T1-X(42)): IF T2]=T1 THEN 510:
    E1=(X(44)-T1)/(X(44)-T2): M1=X(30)/X(37): GOSUB '05(E1,M1):
    U1=K*X(37)
```

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Table IX

PROGRAM LISTING (CONTINUED)

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```
390 E2=(T1-X(45))/(T1-X(14)): M2=X(30)*Q1/X(37)/Q2:
    GOSUB '05(E2,M2): U2=K*X(37)*Q2/Q1:
    U3=((1/H)/(1+1/H))*Q1/Q2+(1/(1+1/H)): U=U1+U2*U3
400 IF U=X(46) THEN 550: IF U]X(46) THEN 510: IF X(14)]=X(45)
    THEN 550: IF X(18)]X(1) THEN 430: IF X(37)]X(43)*X(36)
    THEN 430: X(45)=X(14): X(37)=X(43)*X(36)
410 X(44)=X(45)+X(24)/X(37): X(18)=X(44)-X(23)/X(36): GOSUB '06:
    GOSUB '07: X(37)=X(43)*X(36): GOSUB '10:
    T1=X(44)-X(24)/X(37)
420 E1=(ABS(T1-X(45)))/X(45): IF E1]=.5E-4 THEN 410: GOTO 550
430 IF X(18)=X(1) THEN 440: X(40)=X(18): X(41)=U:
    X(18)=X(18)-.1: GOSUB '02: GOTO 460
440 E1=(ABS(U-X(46)))/X(46): IF E1[.5E-2 THEN 550:
    X(45)=X(14)+(X(45)-X(14))*U/X(46):
    X(37)=X(24)/(X(44)-X(45)): GOSUB '06: GOSUB '07: GOSUB '10
450 X(37)=X(24)/(X(44)-X(45)): IF X(37)]=X(43)*X(36) THEN 460:
    X(37)=X(43)*X(36)
460 GOSUB '10: GOSUB '11: IF X(45)]=X(14) THEN 360:
    IF X(18)]X(1) THEN 490:
    X(37)=X(24)/(X(23)/X(36)+X(18)-X(14)): X(45)=X(14)
470 GOSUB '06: GOSUB '07: GOSUB '10: X(37)=X(24)/(X(44)-X(45)):
    IF X(37)]=X(43)*X(36) THEN 360: X(37)=X(43)*X(36):
    GOSUB '11: GOSUB '06: GOSUB '07: GOSUB '10
480 X(37)=X(43)*X(36): GOSUB '11: GOTO 360
490 X(45)=X(14): X(18)=X(45)+(X(24)-X(23))/X(36): GOSUB '02:
    GOSUB '10: T1=X(44)-X(24)/X(37)
500 E1=(ABS(T1-X(45)))/X(45): IF E1]=.5E-4 THEN 490: GOTO 550
510 IF X(45)=X(44) THEN 530: E1=(ABS(U-X(46)))/X(46):
    IF E1[.5E-2 THEN 550: X(37)=X(24)/(X(44)-X(45)-.1):
    IF X(37)[=X(36) THEN 520: X(37)=X(36)
520 GOSUB '10: GOSUB '11: GOSUB '06: GOSUB '07: GOSUB '10:
    X(37)=X(24)/(X(44)-X(45)): IF X(37)[=X(36) THEN 360:
    X(37)=X(36): GOSUB '11: GOTO 360
530 IF (X(40)-X(18))[].1 THEN 540:
    X(18)=X(18)+.1*((U-X(46))/(U-X(41))): GOSUB '02: GOSUB '10:
    GOSUB '11: GOTO 550
540 X(18)=X(18)+1: GOSUB '02: GOSUB '10: GOSUB '11: GOTO 360
550 GOSUB '06: GOSUB '07: GOSUB '10: GOSUB '11:
    X(48)=X(6)*(X(36)-X(37))/X(36): X(47)=X(6)-X(48)-X(8):
    X(50)=X(45)+X(23)*X(6)/X(36)/X(8): X(51)=X(25)/1065
560 IF Y(4)=1 THEN 570: GOTO 660
570 SELECT PRINT 211(156): PRINT HEX(0D0E):
    PRINT "RSUCF STEADY STATE COMPUTER PROGRAM":
    PRINT HEX(0A0A0A)
580 PRINT "RUN #:  ";A$(Y(1)):
    PRINT "DATE :  ";B$: PRINT HEX(0A0A):
    PRINT "INPUT DATA -"
590 PRINTUSING 680,X(1),X(2),X(3):
    PRINTUSING 690,X(4),X(5),X(6):
    PRINTUSING 700,X(7),X(8),X(9)
```

Table IX

PROGRAM LISTING (CONTINUED)

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```
600 PRINTUSING 710,X(10),X(11),X(12):
    PRINTUSING 720,X(13),X(16),X(17):
    PRINT HEX(0A0A)
610 PRINT "GAS LOOP OUTPUT DATA -":
    PRINTUSING 730,X(18),X(39),X(19):
    PRINTUSING 740,X(42),X(36),X(20)
620 PRINTUSING 750,X(38),X(37),X(21):
    PRINTUSING 760,X(40),X(47),X(22):
    PRINTUSING 770,X(44),X(48),X(24)
630 PRINTUSING 780,X(45),X(51),X(25):
    PRINTUSING 790,X(50),X(46),X(26):
    PRINT HEX(0A)
640 PRINT "COOLANT LOOP OUTPUT DATA -":
    PRINTUSING 800,X(31),X(14),X(33):
    PRINTUSING 810,X(34),X(35),X(15)
650 PRINTUSING 820,X(32),X(30),X(28):
    PRINTUSING 830,X(27),X(29):
    PRINT HEX(0A0A0A0A0A0A0A0A0A0A0A)
660 IF Y(3)=2 THEN 670: LOAD "RSECS2"
670 Y(1)=Y(1)+1: GOTO 250
680 %T RS-20 SETPT       =-#####.##  O CHAMBER-S        =-#####.##  O
 CHAMBER-L       =-#####.##
690 %O CHAM AVIONICS     =-#####.##  CO2 INLET FLOW     =-#####.##  R
S-11 FLOW        =-#####.##
700 %RS-11 POWER         =-#####.##  RS-51 FLOW         =-#####.##  R
S-51 POWER       =-#####.##
710 %RS-251 FLOW         =-#####.##  RS-251 POWER       =-#####.##  H
20 BYPASS FLOW   =-#####.##
720 %O H2O AVIONICS      =-#####.##  T RS-261 F21 IN    =-#####.##  W
 RS-261 F21      =-#####.##
730 %T CHAMBER           =-#####.##  TOTAL AIR FLOW     =-#####.##  O
 RS-11           =-#####.##
740 %T DEWPOINT          =-#####.##  WCP RS-11          =-#####.##  O
 RS-50 -S        =-#####.##
750 %T RS-11 IN          =-#####.##  WCP 350-M          =-#####.##  O
 RS-50 -L        =-#####.##
760 %T RS-50 IN          =-#####.##  V 350-M            =-#####.##  O
 RS-51           =-#####.##
770 %T 350-M IN          =-#####.##  V BYPASS           =-#####.##  O
 350-M -S        =-#####.##
780 %T 350-M OUT         =-#####.##  W CONDENSATE       =-#####.##  O
 350-M -L        =-#####.##
790 %T RS-51 OUT         =-#####.##  UA 350-M           =-#####.##  O
 350-M -TOT      =-#####.##
800 %T RS-261 H2O OUT =-#####.##  T 350-M H2O IN      =-#####.##  T
 350-M H2O OUT   =-#####.##
810 %T RS-251 H2O IN  =-#####.##  T AVION H2O IN      =-#####.##  T
 RS-261 H2O IN   =-#####.##
```

Table IX

PROGRAM LISTING (CONTINUED)

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```
820 %T RS-261 F21 OUT =-#####.##  U RS-261/350-M    =-#####.##  O
 H20 HTSINK      =-#####.##
830 %O RS-251           =-#####.##  O RS-261            =-#####.##
840 END
850 DEFFN'01(C1,D1)
860 DIM A1(6),X1(6),Y1(6)
870 I1=101: N=3: N2=2
880 IF X(I1)=3 THEN 920: IF X(I1)]3 THEN 930:
    IF X(I1)[0 THEN 950: IF X(I1)=0 THEN 920:
    IF X(I1)=2 THEN 900: IF X(I1)]2 THEN 920
890 N=1: GOTO 910
900 N=2
910 N2=1
920 I1=I1+1
930 N1=N+1
940 L=I1: IF X(L)]0 THEN 960
950 K1=-1: Z1=0: GOTO 1230
960 N9=X(L):
    IF X(L+1)[0 THEN 950: IF X(L+1)]0 THEN 980
970 N8=0: GOTO 990
980 N8=X(L+1)
990 K1=0: K8=0: C2=C1: J1=I1+2: J2=N9+I1+1:
    IF C2[X(J1) THEN 1030: IF C2=X(J1) THEN 1040
1000 FOR J=J1 TO J2: IF C2[=X(J) THEN 1050: NEXT J
1010 K1=2: C2=X(J2)
1020 J9=J2-N: GOTO 1060
1030 K1=1: C2=X(J1)
1040 J9=J1: GOTO 1060
1050 IF J-J1[1 THEN 1030: IF J-J1=1 THEN 1040:
     IF J=J2 THEN 1020: IF J]J2 THEN 1010:
     J9=J-N2
1060 C3=C2: IF N8]0 THEN 1070: FOR L=1 TO N1: X1(L)=X(J9):
     L8=J9+N9: Y1(L)=X(L8): J9=J9+1: NEXT L: I=1: GOTO 1150
1070 J1=J1+N9: J2=J2+N8: D2=D1: IF D2[X(J1) THEN 1100:
     IF D2=X(J1) THEN 1110: FOR J=J1 TO J2:
     IF D2[=X(J) THEN 1120: NEXT J
1080 K8=6: D2=X(J2)
1090 J8=J2-N: GOTO 1130
1100 K8=2: D2=X(J1)
1110 J8=J1: GOTO 1130
1120 IF J-J1[1 THEN 1100: IF J-J1=1 THEN 1110:
     IF J=J2 THEN 1090: IF J]J2 THEN 1080: J8=J-N2
1130 J7=J9: L8=J8+N8*(J7-I1-1): L7=L8: FOR L=1 TO N1:
     X1(L)=X(J7): Y1(L)=X(L7): L7=L7+N8: J7=J7+1: NEXT L:
     I=0: GOTO 1150
1140 Y1(1)=Z1: FOR I=1 TO N: L7=L8+I: Y1(I+1)=0: FOR M=1 TO N1:
     Y1(I+1)=Y1(I+1)+X(L7)*X1(M): L7=L7+N8: NEXT M: NEXT I:
     FOR L=1 TO N1: X1(L)=X(J8): J8=J8+1: NEXT L: C3=D2: I=1
```

Table IX

PROGRAM LISTING (CONTINUED)


```
1150 D=1: X1(N+2)=X1(1): X1(N+3)=X1(2): FOR J=1 TO N1:
     A1(J+1)=X1(J+1)-X1(J): C4=C3-X1(J): IF C4[]0 THEN 1170:
     Z1=Y1(J): X1(1)=0: X1(2)=0: X1(3)=0: X1(4)=0
1160 X1(J)=1: GOTO 1220
1170 D=D*C4: ON N GOTO 1180,1190,1200
1180 X1(J)=C4/A1(J+1): GOTO 1210
1190 X1(J)=-C4: GOTO 1210
1200 X1(J)=(X1(J+2)-X1(J))*C4
1210 NEXT J: A1(1)=A1(N+2): Z1=0: FOR J=1 TO N1:
     X1(J)=D/(A1(J)*A1(J+1)*X1(J)): Z1=Z1+Y1(J)*X1(J):
     NEXT J
1220 IF I[=0 THEN 1140
1230 K1=K1+K8: SELECT PRINT 005:
     PRINT "OFF TABLE INDICATOR =";K1
1240 RETURN
1250 DEFFN'02
1260 FOR B=1 TO 4: GOSUB '07: X(37)=X(36):
     X(45)=X(18)-(X(24)-X(23))/X(36): GOSUB '06: GOSUB '07:
     NEXT B: X(37)=X(36)
1270 RETURN
1280 DEFFN'03
1290 X(101)=20: X(102)=0: RESTORE 51: FOR C=103 TO 142:
     READ X(C): NEXT C: GOSUB '01(X(45),0): P2=Z1:
     A2=.622*P2/(14.696-P2)+X(25)*X(36)/1065/X(39)/X(37)
1300 FOR C=1 TO 3: P2=A2*(14.696-P2)/.622: NEXT C:
     RESTORE 71: FOR C=103 TO 122: READ X(C): NEXT C:
     RESTORE 51: FOR C=123 TO 142: READ X(C): NEXT C
1310 GOSUB '01(P2,0): X(42)=Z1:
     RETURN
1320 DEFFN'04
1330 V1=X(6)*X(37)/.3815/X(36): RESTORE 91: FOR E=101 TO 128:
     READ X(E): NEXT E: GOSUB '01(V1,0): H2=118.48928*Z1:
     X(46)=1/(1/H1+1/H2)
1340 RETURN
1350 DEFFN'05(E3,M3)
1360 IF M3=1 THEN 1370: IF M3]1 THEN 1380:
     K=M3/(1-M3)*LOG((1-E3)/(1-E3/M3)): GOTO 1390
1370 K=E3/(1-E3): GOTO 1390
1380 K=M3/(M3-1)*LOG((1-E3/M3)/(1-E3))
1390 RETURN
1400 DEFFN'06
1410 GOSUB '03: A2=A2-X(21)/1065/X(39): FOR F=1 TO 3:
     P2=A2*(14.696-P2)/.622: NEXT F: GOSUB '01(P2,0): X(42)=Z1:
     RETURN
1420 DEFFN'07
1430 X(101)=20: X(102)=0: RESTORE 51: FOR G=103 TO 142:
     READ X(G): NEXT G: GOSUB '01(X(42),0): P1=Z1:
     GOSUB '08(P1,85.76): R1=R3: P2=14.696-P1
```

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Table IX

PROGRAM LISTING (CONCLUDED)

```
1440 GOSUB '08(P2,53.35): R2=R3:
     R3=(85.76*R1+53.35*R2)/(R1+R2): C3=.24+.2799*P1/P2:
     FOR G=1 TO 6
1450 X(39)=126973.44*X(6)/R3/(X(18)+X(4)/X(36)+459.6):
     X(36)=C3*X(39): NEXT G:
     RETURN
1460 DEFFN'08(P4,R4):
     R3=144*P4/R4/(X(18)+459.6):
     RETURN
1470 DEFFN'10:
     X(38)=X(18)+X(4)/X(36):
     X(49)=X(18)+(X(4)+X(19))/X(36)
1480 X(44)=X(18)+X(23)/X(36):
     RETURN
1490 DEFFN'11:
     X(45)=X(44)-X(24)/X(37):
     RETURN
```

RSECS FLOW CHART ROUTINE

File Name "RSECS2"

Abstract "RSECS2" automatically produces flow chart output (on previously prepared schematic drawings) of the case currently being analized by the program "RSECS". The flow charts are produced using the WANG 2200 plot bed plotter.

Program Description

A data block containing values generated by "RSECS" is transferred through use of a common block to program "RSECS2". This program then sorts the data and prints out the values in the appropriate location on the schematic. Two separate schematics are used, one for the air loop and one for the water loop. Samples of program output are given in figures 10 and 11 followed by a program listing Table X included for reference.

The only user action required for this program is the loading of the appropriate schematic on the plotter as required.

CASE: MIN ON ORBIT B/P = 500 DATE: 10/17/74

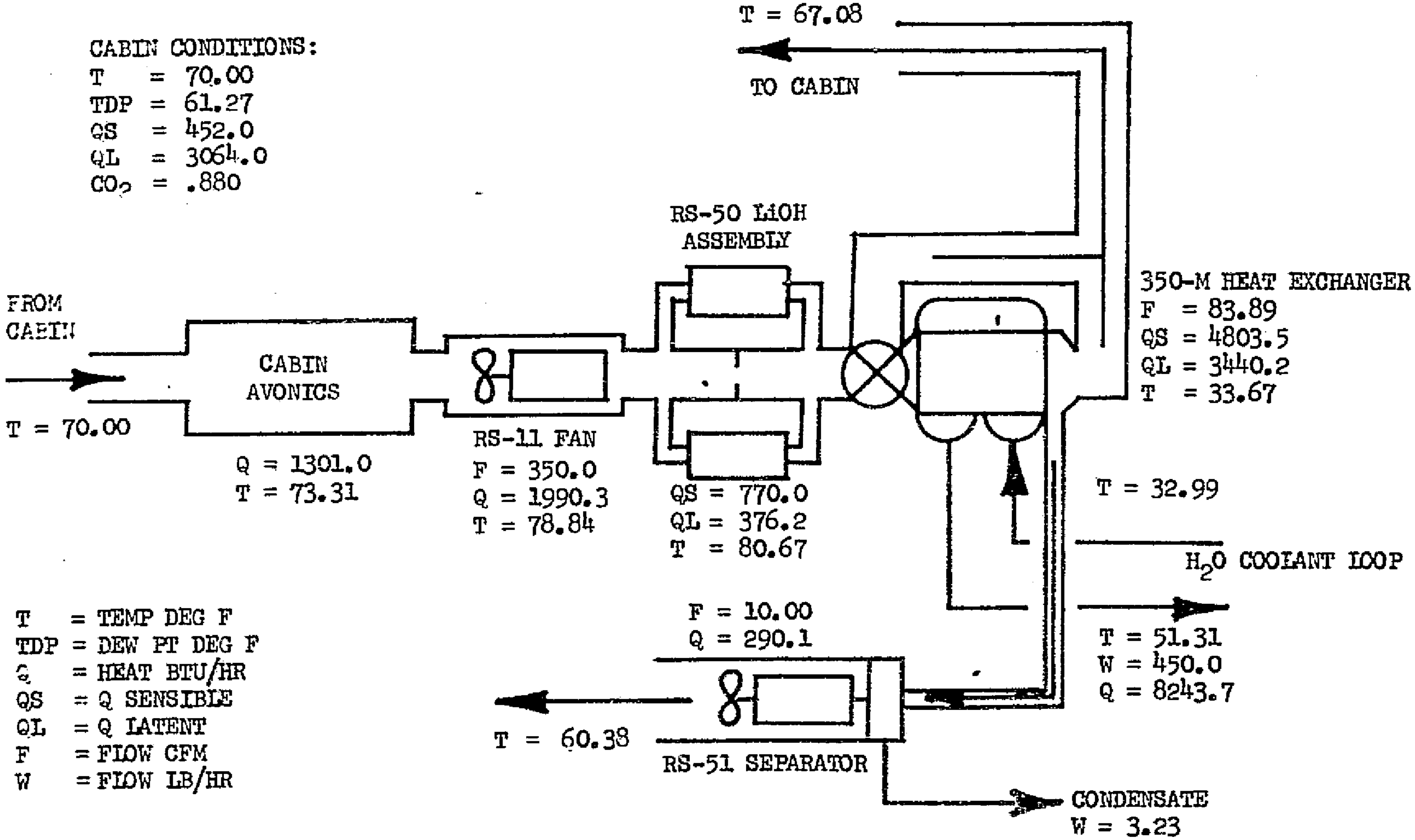
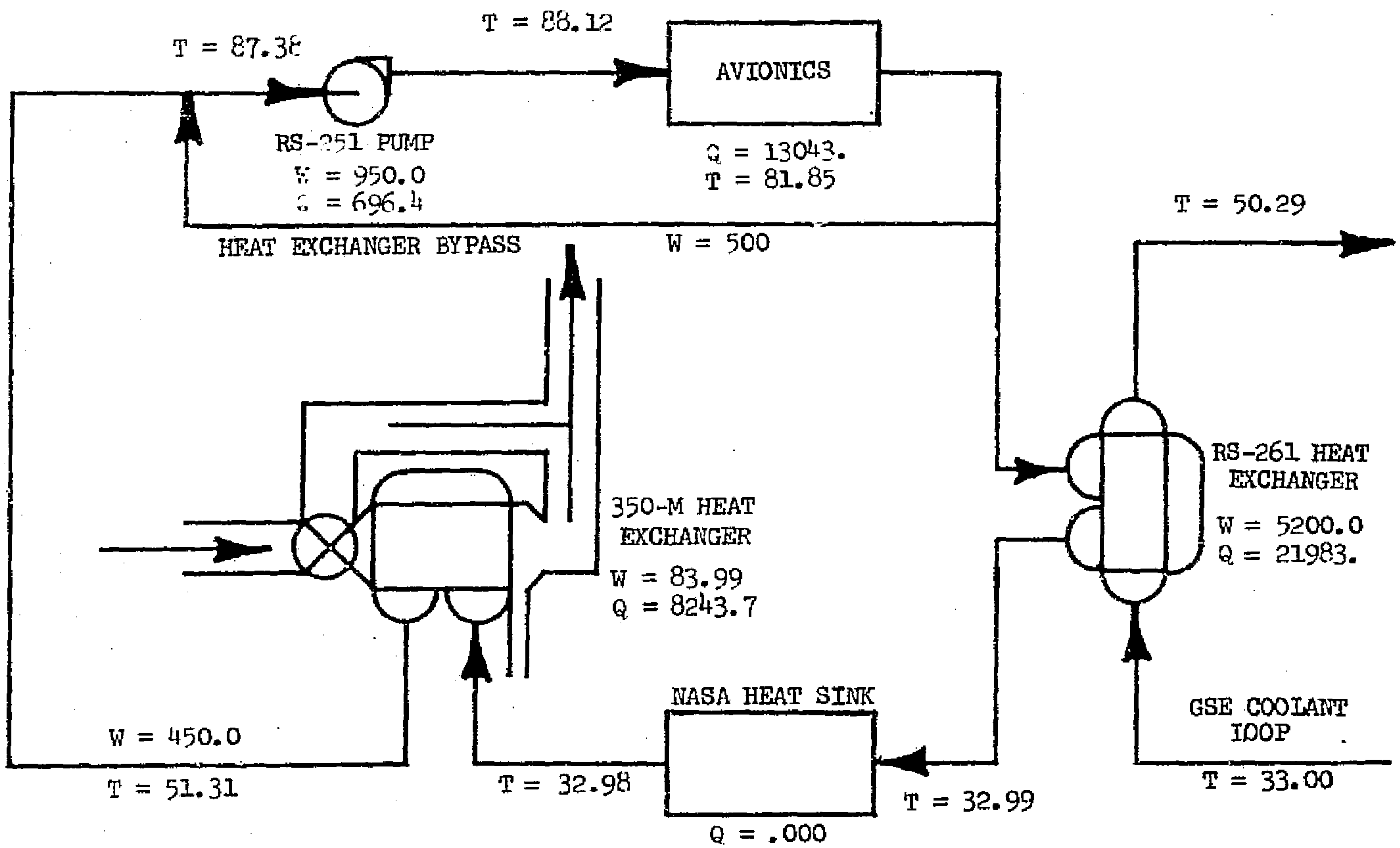


FIGURE 10 RSECS ARS GAS LOOP SCHEMATIC

CASE: MIN ON ORBIT B/P 500 DATE: 10/17/74



Q = HEAT BTU/HR
T = TEMP DEG F
W = FLOW LB/HR

FIGURE 11 RSECS WATER LOOP SCHEMATIC

Table X

PROGRAM LISTING

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```
10 REM RSECS2 PROGRAM LABELS DIAGRAM
20 COM X(200),A(10,17),A$(10)64,B$,Y(4)
30 DIM X$(100)8,B(100)
40 SELECT PRINT 005:PRINT HEX(03):
   PRINT "RSECS FLOW CHART ROUTINE":PRINT
50 FOR I=1 TO 51
60 IF ABS(X(I))]=100000 THEN 80:
   IF ABS(X(I))]=10000 THEN 90:
   IF ABS(X(I))]=1000  THEN 100
70 IF ABS(X(I))]=100    THEN 110:
   IF ABS(X(I))]=10    THEN 120:
   IF ABS(X(I))]=1     THEN 130:GOTO 140
80 CONVERT X(I) TO X$(I),(-######):B(I)=0:GOTO 150
90 CONVERT X(I) TO X$(I),(-#####.):B(I)=0:GOTO 150
100 CONVERT X(I) TO X$(I),(-####.#):B(I)=0:GOTO 150
110 CONVERT X(I) TO X$(I),(-###.#)  :B(I)=1:GOTO 150
120 CONVERT X(I) TO X$(I),(-##.##)  :B(I)=1:GOTO 150
130 CONVERT X(I) TO X$(I),(-#.##)   :B(I)=2:GOTO 150
140 CONVERT X(I) TO X$(I),(-.###)   :B(I)=2:GOTO 150
150 NEXT I
160 SELECT PLOT 414
170 STOP "LOAD GAS LOOP SCHEMATIC ON PLOTTER THEN KEY CONTINUE"
180 PLOT [1,,C],[13,0,S],[,,R]
190 PLOT [19.50*13,29.50*20,U],[,,X$(18)],[B(18)*13,0,U]
200 PLOT [-7*13,-20,U],[,,X$(42)],[B(42)*13,0,U]
210 PLOT [-7*13,-20,U],[,,X$(2)],[B(2)*13,0,U]
220 PLOT [-7*13,-20,U],[,,X$(3)],[B(3)*13,0,U]
230 PLOT [-7*13,-20,U],[,,X$(5)],[B(5)*13,0,U]
240 PLOT [-17*13,-7.25*20,U],[,,X$(18)],[B(18)*13,0,U]
250 PLOT [3*13,-20,U],[,,X$(4)],[B(4)*13,0,U]
260 PLOT [-7*13,-20,U],[,,X$(38)],[B(38)*13,0,U]
270 PLOT [5*13,0,U],[,,X$(6)],[B(6)*13,0,U]
280 PLOT [-7*13,-20,U],[,,X$(19)],[B(19)*13,0,U]
290 PLOT [-7*13,-20,U],[,,X$(49)],[B(49)*13,0,U]
300 PLOT [7*13,2*20,U],[,,X$(20)],[B(20)*13,0,U]
310 PLOT [-7*13,-20,U],[,,X$(21)],[B(21)*13,0,U]
320 PLOT [-7*13,-20,U],[,,X$(44)],[B(44)*13,0,U]
330 T=(X(44)*X(48)+X(45)*X(47))/X(6)
340 IF ABS(T)]=100 THEN 350:IF ABS(T)]=10 THEN 360:IF ABS(T)]=
    1 THEN 370:IF ABS(T)]=0 THEN 380
350 CONVERT T TO T$,(-###.##):T2=0:GOTO 390
360 CONVERT T TO T$,(-##.##):T2=1:GOTO 390
370 CONVERT T TO T$,(-#.##):T2=2: GOTO 390
380 CONVERT T TO T$,(-.###):T2=2: GOTO 390
390 PLOT [-2*13,18.25*20,U],[,,T$],[T2*13,0,U]
400 PLOT [11*13,-10.25*20,U],[,,X$(47)],[B(47)*13,0,U]
410 PLOT [-7*13,-20,U],[,,X$(24)],[B(24)*13,0,U]
420 PLOT [-7*13,-20,U],[,,X$(25)],[B(25)*13,0,U]
430 PLOT [-7*13,-20,U],[,,X$(45)],[B(45)*13,0,U]
440 PLOT [-10*13,-3*20,U],[,,X$(14)],[B(14)*13,0,U]
450 PLOT [-7*13,-4*20,U],[,,X$(33)],[B(33)*13,0,U]
460 PLOT [-7*13,-20,U],[,,X$(30)],[B(30)*13,0,U]
470 PLOT [-7*13,-20,U],[,,X$(26)],[B(26)*13,0,U]
480 PLOT [-29*13,-2*20,U],[,,X$(3)],[B(3)*13,0,U]
```

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Table X

PROGRAM LISTING (CONCLUDED)

```
490 PLOT [-7*13,-20,U],[,,X$(22)],[B(22)*13,0,U]
500 PLOT [-21*13,-3.5*20,U],[,,X$(50)],[B(50)*13,0,U]
510 PLOT [25*13,-3.0*20,U],[,,X$(51)],[B(51)*13,0,U]
520 PLOT [,,R],[23*13,34*20,U]
530 K=Y(1):PLOT [,,"CASE:  "],[,,A$(K)]:
    PLOT [3*13,0,U],[,,"DATE:  "],[,,B$],[,,R]
540 SELECT PRINT 005:PRINT :PRINT :STOP " REMOVE GAS LOOP SCHEMA
TIC AND LOAD WATER LOOP SCHEMATIC ON     PLOTTER THEN KEY CONTI
NUE"
550 PLOT [21*13,33*20,U],[,,X$(34)],[B(34)*13,0,U]
560 PLOT [4*13,-.50*20,U],[,,X$(35)],[B(35)*13,0,U]
570 PLOT [-14*13,-6.25*20,U],[,,X$(10)],[B(10)*13,0,U]
580 PLOT [-7*13,-20,U],[,,X$(27)],[B(27)*13,0,U]
590 PLOT [-14*13,-20.50*20,U],[,,X$(30)],[B(30)*13,0,U]
600 PLOT [-7*13,-3*20,U],[,,X$(33)],[B(33)*13,0,U]
610 PLOT [20*13,26.25 *20,U],[,,X$(13)],[B(13)*13,0,U]
620 PLOT [-9*13,-2*20,U],[,,"T="],[,,X$(15)],[B(15)*13,0,U]
630 PLOT [-9*13,-4*20,U],[,,X$(12)],[B(12)*13,0,U]
640 PLOT [-6*13,-8*20,U],[,,X$(47)],[B(47)*13,0,U]
650 PLOT [-7*13,-20,U],[,,X$(26)],[B(26)*13,0,U]
660 PLOT [-16*13,-11.25*20,U],[,,X$(14)],[B(14)*13,0,U]
670 PLOT [3*13,-20,U],[,,X$(28)],[B(28)*13,0,U]
680 PLOT [4*13,20,U],[,,X$(31)],[B(31)*13,0,U]
690 PLOT [5*13,26.5*20,U],[,,X$(32)],[B(32)*13,0,U]
700 PLOT [-5*13,-8*20,U],[,,X$(17)],[B(17)*13,0,U]
710 PLOT [-7*13,-20,U],[,,X$(29)],[B(29)*13,0,U]
720 PLOT [-9*13,-11.5*20,U],[,,X$(16)],[B(16)*13,0,U]
730 PLOT [,,R],[30*13,33.75*20,U], [,,"CASE:  "],[,,A$(K)],
     [3*13,0,U],[,,"DATE:  "],[,,B$],[,,R]
740 SELECT PRINT 005:PRINT  HEX(03)
750 Y(1)=Y(1)+1
760 LOAD DC R "RSECS"
770 END
```

350-M HEAT EXCHANGER TEST RESULTS DATA ANALYSIS

File Name "350-M HX"

Abstract "350-M HX" analyzes test data and provides revised performance curves for the 350-M heat exchanger. The program is designed to be used with a WANG 2200 - series computer system.

Program Description

For a maximum of 50 data points, the program will iterate the hot or cold side hA to obtain a UA balance. Curves of hot side film coefficient verses air velocity and cold side film coefficient versus water flow per start are stored in the program as internal data. These curves and water vapor property tables are interpolated by using an adaptation of the Hamilton Standard Division's "UNBAR" routine. See Appendix B for detailed description of analysis and computer program listing.

350-M HEAT EXCHANGER PERFORMANCE PREDICTION PROGRAM

File Name "CONDHX"

Abstract "CONDHX" uses inlet temperature and flow data to predict performance of the RSECS 350-M condensing heat exchanger. This program runs on the WANG 2200 minicomputer system.

Program Description

This program uses predicted curves of air and water side hA's versus flow combined with a "pinch point" analysis to predict performance of a condensing heat exchanger.

The user supplies input temperatures and flow rates as requested and the program generates values for outlet temperatures and total heat exchanger load.

Presented here is the result of using these programs to analyze the results of testing conducted on the RSECS 350-M condensing heat exchanger. Also presented are the analysis methods for the data analysis program and the HX thermal performance program along with listings of the two programs. See Appendix C for detailed description of analysis technique and program listing.

APPLICATION OF WANG HX DATA ANALYSIS

AND

PERFORMANCE PREDICTION PROGRAMS

1.0 Summary

The RSECS cabin condensing heat exchanger was tested Nov. 26 - Dec. 5, 1974 to determine thermal and pressure drop performance and also the operating characteristics of the integral condensate removal device (SLURPER) for both design and off design operating conditions. (Reduced test data presented in Appendix A).

Thermal performance was evaluated by measuring air and coolant inlet outlet temperatures over a range of (1) air flow, (2) coolant flows and (3) inlet air dewpoints.

Pressure drop performance was determined by measuring inlet and outlet pressures for the air stream and coolant lines. This performance was measured over the same range of conditions as the thermal performance.

The slurper was evaluated by collecting and measuring the condensate removed by the heat exchanger and also observing visually the air ducts downstream of the unit to detect any water carryover.

Test results showed that the unit performed as expected and met all heat and condensate removal requirements for the RSECS system.

This testing was done for two major reasons.

(1) To verify that the heat exchanger thermal and condensate removal performance is within orbiter operating limits.

(2) Verify the analytical procedure used to predict the condensing heat exchanger performance.

Satisfying item #1 indicated that the RSECS condensing heat exchanger could be used in the RSECS system to simulate the orbiter condensing heat exchanger (in terms of heat and condensate removal ability). The RSECS unit for the same inlet conditions will not perform exactly the same as the orbiter unit because of basic differences. The RSECS unit is a tube fin design and the orbiter is a special plate fin design. In spite of this difference, results of this test show that the RSECS unit can be configured to perform exactly as the orbiter unit. The problem is to predict

what configurations are required to produce various desired operating levels. To do this the analytical procedure mentioned in item #2 above must be used. This procedure gives heat and condensate removal performance as a function of inlet conditions for the air side (temperature, dewpoint, flow rate) and coolant side (temperature, flow). Data from this test was used to verify and modify the prediction procedure. This modified procedure can now be used with confidence to set the inlet conditions to those values required to produce any desired orbiter heat removal or condensate removal rates.

2.0 Thermal Performance Analysis

2.1 Data Modification

Test data was hand recorded for each test point after the heat exchanger had apparently reached steady state conditions.

Initial review indicated some problems with this data. First of all, the air side outlet dewpoint consistently read above the outlet air dry bulb temperature. In a real system this effect cannot occur because the water vapor would immediately condense to form liquid water on the duct walls. Also when the amount of heat removed from the air side was compared with heat added to the coolant side (heat balance) these values agreed within less than 85% in most cases. A good heat balance (95%) indicates good test data taken at a steady state condition.

Both of the problems mentioned above were resolved when the results stored by the automatic data recording system during the test were reviewed. This data was presented in the form of computer generated plots of each test parameter vs test time. Detail review of these plots indicated errors in the hand recorded data due to instability in readings and errors in picking steady state conditions.

Corrected values were tabulated and used in subsequent analysis of the RSECS condensing heat exchanger thermal performance.

2.2 Data Reduction

The modified and corrected test data (Appendix A) was input into a data reduction computer program stored on the WANG minicomputer system. The program used this test data to derive curves of film coefficient vs flow rate for both the air and coolant sides using an iterative procedure described in Appendix B.

Results of this analysis are presented in Appendix B.3 and the resulting film coefficients for the air and coolant sides of the HX are plotted in figures 12 and 13. From these results (App. B.3) it is seen that the overall heat balance for each test point was 96%, indicating that the test data analyzed was very good. It is also seen from figures 12 and 13 that the film coefficients behave exactly as predicted in the original Hamilton Standard RSECS condensing heat exchanger documentation.

Results of this procedure satisfied the principle objective of this test; that is, to provide realistic information on film coefficient behavior that can be used to generate heat exchanger performance for any desired conditions.

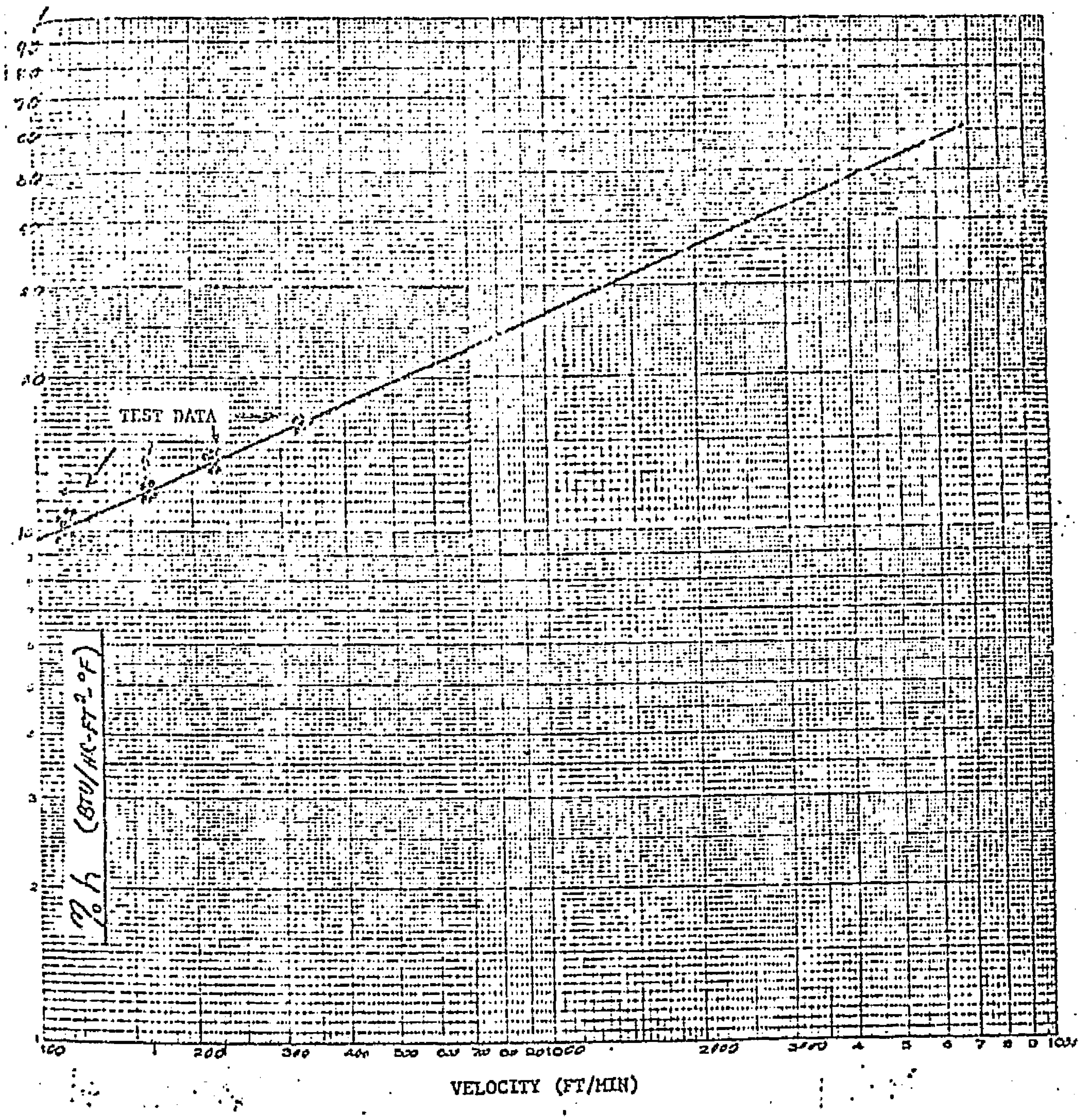


FIGURE 12 350-M CONDENSING HEAT EXCHANGER AIR SIDE FILM COEFFICIENT VS AIR FLOW

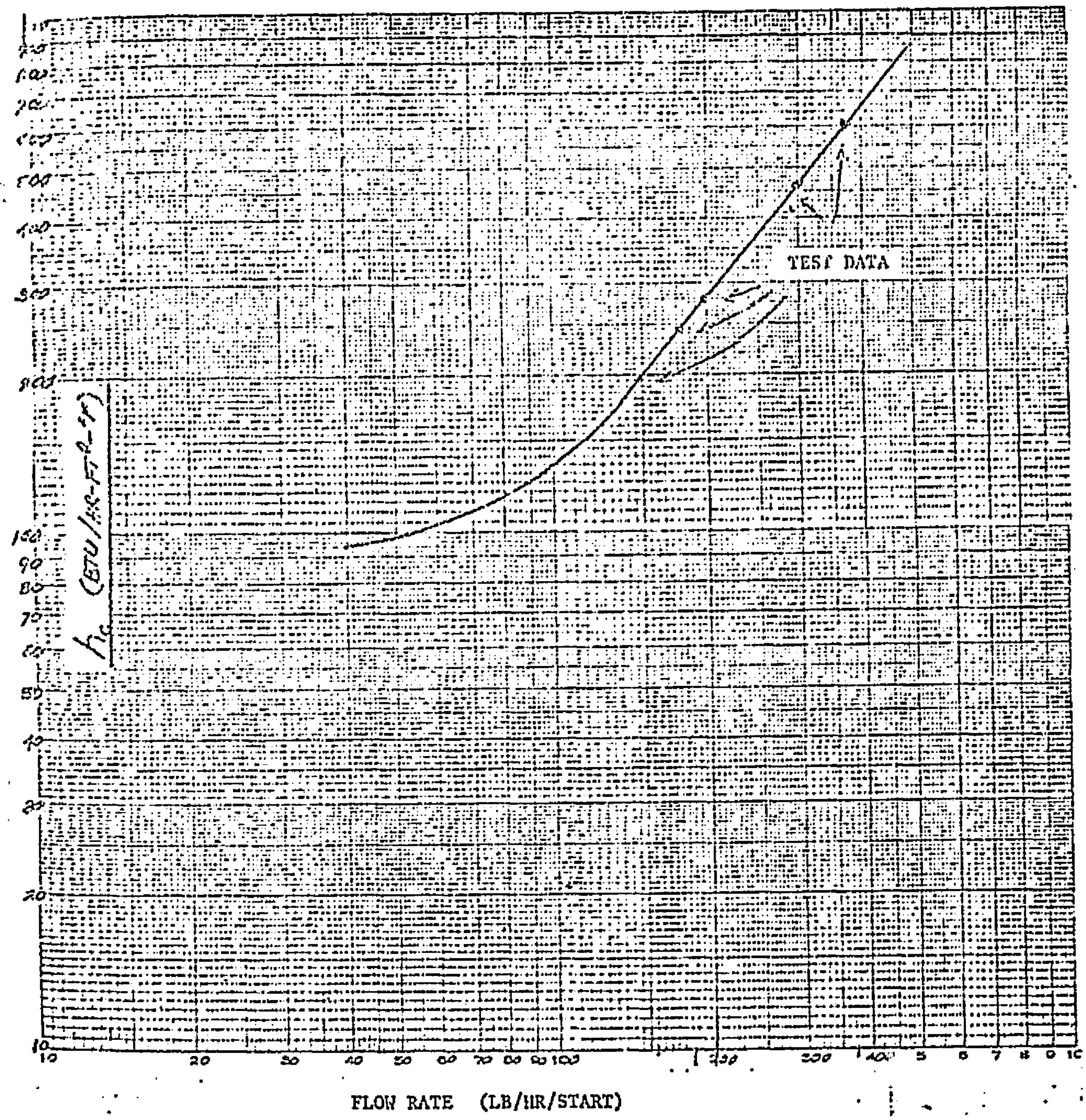


FIGURE 13 350-M HEAT EXCHANGER PREDICTED COOLANT SIDE FILM COEFFICIENT VS FLOW

2.3 Performance Prediction

The film coefficient information generated by the data reduction program is used as input into another WANG minicomputer program to produce RSECS condensing heat exchanger performance predictions.

This program used a procedure described in Appendix C to generate predictions of air and coolant outlet temperatures and heat loads (sensible & latent) and outlet dewpoints for the heat exchanger based on the film coefficient data and input data for air and coolant sides of temperature, dewpoint and flow rates.

One problem area noticed during this test was an uneven split in heat rejection between coolant loops when both loops were working. This condition indicated that for the same inlet temperature into each coolant loop the outlet temperatures were not equal, indicating some sort of uneven flow distribution inside the heat exchanger itself. Test results showed that the split between loops varied with inlet dewpoint, coolant inlet temperature, coolant flow rate and air flow rate. Analysis of these results produced a technique for predicting this heat load split which was incorporated into the performance program (see Appendix C2 for details) to produce a program capable of matching all test results.

This final modified procedure allows the RSECS condensing HX to be configured to simulate any desired orbiter operating conditions. This procedure will allow the RSECS unit to be substituted for the orbiter unit in any RSECS system level testing and still maintain any desired level of thermal performance.

3.0 Conclusions and Recommendations

It can be concluded from this test and subsequent analysis that the RSECS condensing heat exchanger can meet orbiter performance requirements and it can be used as a substitute for the orbiter condensing unit in the RSECS system level tests.

The testing provided correlation with a thermal analytical performance prediction procedure for the unit and subsequent analysis of orbiter operating points indicate the ability of the unit to match orbiter requirements for heat and condensate removal and delivery temperature. Using the correlated procedure it is possible to configure the RSECS unit to match any desired orbiter point. For example: to meet some defined heat removal, delivery temperature and latent load; the prediction procedure will provide necessary settings for air and coolant inlet temperatures or air and coolant flow rates depending on which parameters are fixed.

It is recommended based on the results of this test that the RSECS condensing heat exchanger be used as a substitute for the orbiter condensing unit in RSECS system level tests until an actual orbiter unit becomes available.

RSECS ARS GAS LOOP ΔP ROUTINE

File Name "ARS DP"

Abstract "ARS DP" calculates the corrected (59°F, 29.92 in Hg) pressure drop through the Hamilton Standard supplied RSECS hardware. The program is designed to be used with a WANG 2200 - series computer system.

Program Description

By inputting total RSECS air flow and the number of RS-11 fans operating, the program will calculate the corrected pressure drop through the RS-193 Filter Package, the RS-191 ARS Fan Package, the RS-190 CO_2/Temperature/Humidity Control Package, the 350-M heat exchanger, and the ARS outlet duct. The results are displayed on the CRT.

A program listing, Table XI is enclosed for reference.

Table XI

PROGRAM LISTING

```
10  REM -    RSECS GAS LOOP PRESSURE DROP
20  INPUT "# RS-11 FANS OPERATING = ",F1
30  INPUT "TOTAL AIR FLOW    (CFM) = ",Q1
40  REM -    RS-193
50  P1=(.0765/.0709)*(.0235*Q1!2/173!2+.3*Q1/167)
60  REM -    RS-191
70  P2=(.0765/.0709)*(.00364*Q1!2/173!2+.61+.11*(Q1/F1)!2/500!2
      +.02055*Q1!2/173!2)
80  REM -    RS-190
90  P3=(.0765/.0709)*(.0685*Q1!2/173!2+.9166+.0125*Q1!2/173!2)
100 REM -    OUTLET DUCT
110 P4=(.0765/.0709)*(.00473*Q1!2/173!2+1.0*Q1!2/200!2)
120 REM -    350-M HX
130 C1=+.91296112 36E-4  : C2=+.80635958064E-4:
    C3=+.119613327498E-5: C4=-.1175465209E-7:
    C5=+.70762566031E-10: C6=-.230225532038E-12
140 C7=+.41057121725E-15: C8=-.327021073653E-18
150 P5=(.0765/.0709)*9.9*(C1+C2*(Q1/.815)+C3*(Q1/.815)!2+
      C4*(Q1/.815)!3+C5*(Q1/.815)!4+C6*(Q1/.815)!5+
      C7*(Q1/.815)!6+C8*(Q1/.815)!7)
160 P6=4*(144*Q1*SQR(.0765)/28.26/1096)!2+P5
170 P7=P1+P2+P3+P4+P6
180 PRINT
190 PRINT
200 PRINT "RS-193 DP       (IN H2O) = ";P1
210 PRINT "RS-191 DP       (IN H2O) = ";P2
220 PRINT "RS-190 DP       (IN H2O) = ";P3
230 PRINT "350-M HX DP     (IN H2O) = ";P6
240 PRINT "OUTLET DUCT DP (IN H2O) = ";P4
250 PRINT "-------------------------------------"
260 PRINT "TOTAL DP        (IN H2O) = ";P7
270 END
```

GENERALIZED PLOT PROGRAM

File Name "Plot"

Abstract "Plot" uses the WANG 2200 flat bed plotter to automate production of plotting of any desired set of data. This program can plot point by point or plot a desired function in equation form, and in addition, completely label the resulting plot in any desired format.

Program Description

"Plot" uses the WANG 2200 flat bed plotter and the WANG 2200 minicomputer system commands to produce plots of data or equations. As supplied, the WANG had no software to run the plotter; program "Plot" provides this function.

Required inputs are requested on the CRT and responses are keyed in followed by keying "execute".

Available options of this program are:

1. Point by point plotting.
2. Equation plotting.
3. Matrix point plotting.
4. Regression analysis plotting.

For user reference the following items are included:

Table XII	Description of input requirements for program and plotter set up procedure
Figures 14 - 16	Samples of results of program use in different modes
Table XIII	Program listing.

Table XII

PLOTTER SETUP AND PROGRAM INPUTS

Plotter Setup and Program Inputs

This example is for operation where the user has generated a set of data points in some other program (RSECS), stored them in an array and a plot of the points is desired.

Initially the user must do two things; 1) set up the plotter and 2) decide what type of plot is wanted.

1. Plotter Set up

   - set plotter power switch in "on" position
   - set pen switch in "down" position
   - set chart switch in "release" position
   - insert paper - line it up with bottom ridge and ridge on left of plotting surface
   - set chart switch in "hold" position
   - using control knobs set pen at 0,0 zero reference position and press check button. Press scale adjust check button and set pen at 10,10 using control knobs, then press scale adjust check button again.

2. Type of Pl.t

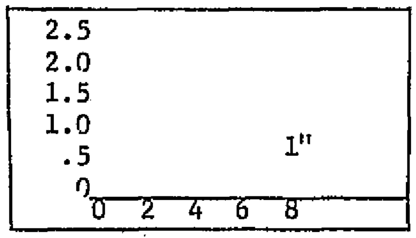
   - Determine desired location of axis intersection point on page
   - Pick X axis's increment for major divisions (units/in)
   - Pick Y axis increment for major divisions
   - Pick X and Y axis ranges
   - Pick X and Y axis labels

Table XII

PLOTTER SETUP AND PROGRAM INPUTS (CONTINUED)

Example:

Position 2,2
X axis unit/in 2
Y axis unit/in .5
X axis range 0,8
Y axis range 0,2.5



3. Now proceed to answer questions that appear on the CRT.

Table XII

PLOTTER SETUP AND PROGRAM INPUTS (CONTINUED)

QUESTION ON CRT	TYPED IN RESPONSE	DESCRIPTION
X axis increment units/in?	2	Delta between major divisions on X axis
Y axis increment units/in?	.5	Delta between major divisions on Y axis
Location of axis intersection (position on page in inches - X, Y)?	2,2	Location of 0,0 point on plot is 2" over and 2" up from pen reference point
Limits of X axis (min value, max value)	0,8	
Limits of Y axis (min value, max value)	0,2.5	
X, Y values at intersection	0,0	
X axis label	Delta dew point (F)	
Y axis label	H_2O flow Lb/Hr	
Location of X axis labels (1=above, 2=below)	2	
Location of Y axis labels (1=left, 2=right)	1	
Plot points or curve (1=point, 2=curve)	1	Purpose is to plot points generated by previous program
Desired plot symbol		Entering nothing causes centered dot to be used as plot symbol

Table XII

PLOTTER SETUP AND PROGRAM INPUTS (CONCLUDED)

QUESTION ON CRT	TYPED IN RESPONSE	DESCRIPTION
Are data points to be loaded from array	1	Array was loaded for previous program
First and last points to be plotted	1,15	15 points were generated and are to be plotted
Key continue to plot points	Continue	Starts plotting of points
Do you wish to connect points with line segments	1	Connects data points to form desired curve
	Reset	End of plot routine
Do you wish to add labels to plot (0=no, 1=yes)	1	Activates portion of program that makes plotter act like a typewriter
Desired character size	1	Selects size of characters for labels (smallest=1, largest=10)
Do you wish to continue plotting	0	Ends program

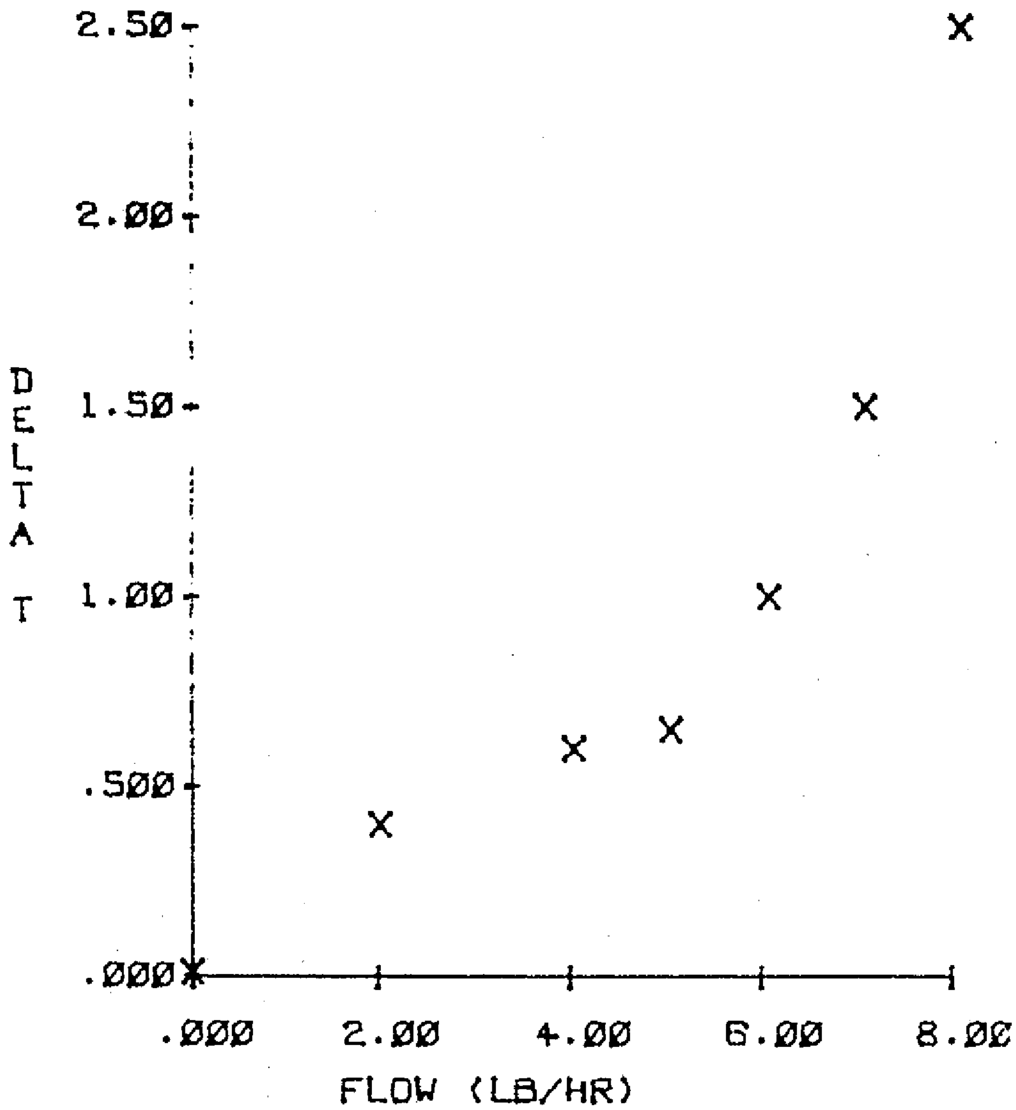


FIGURE 14 SAMPLE PLOT 1

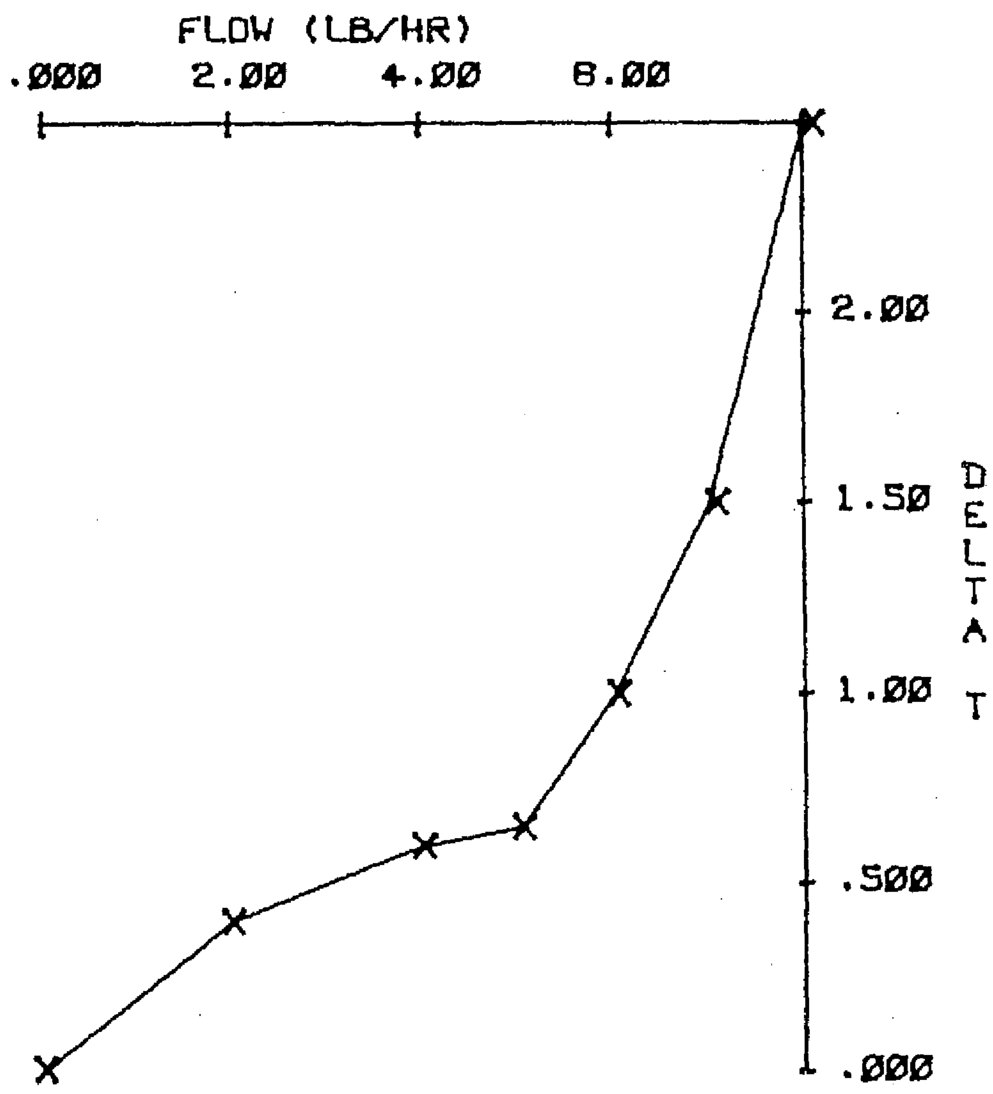


FIGURE 15 SAMPLE PLOT 2

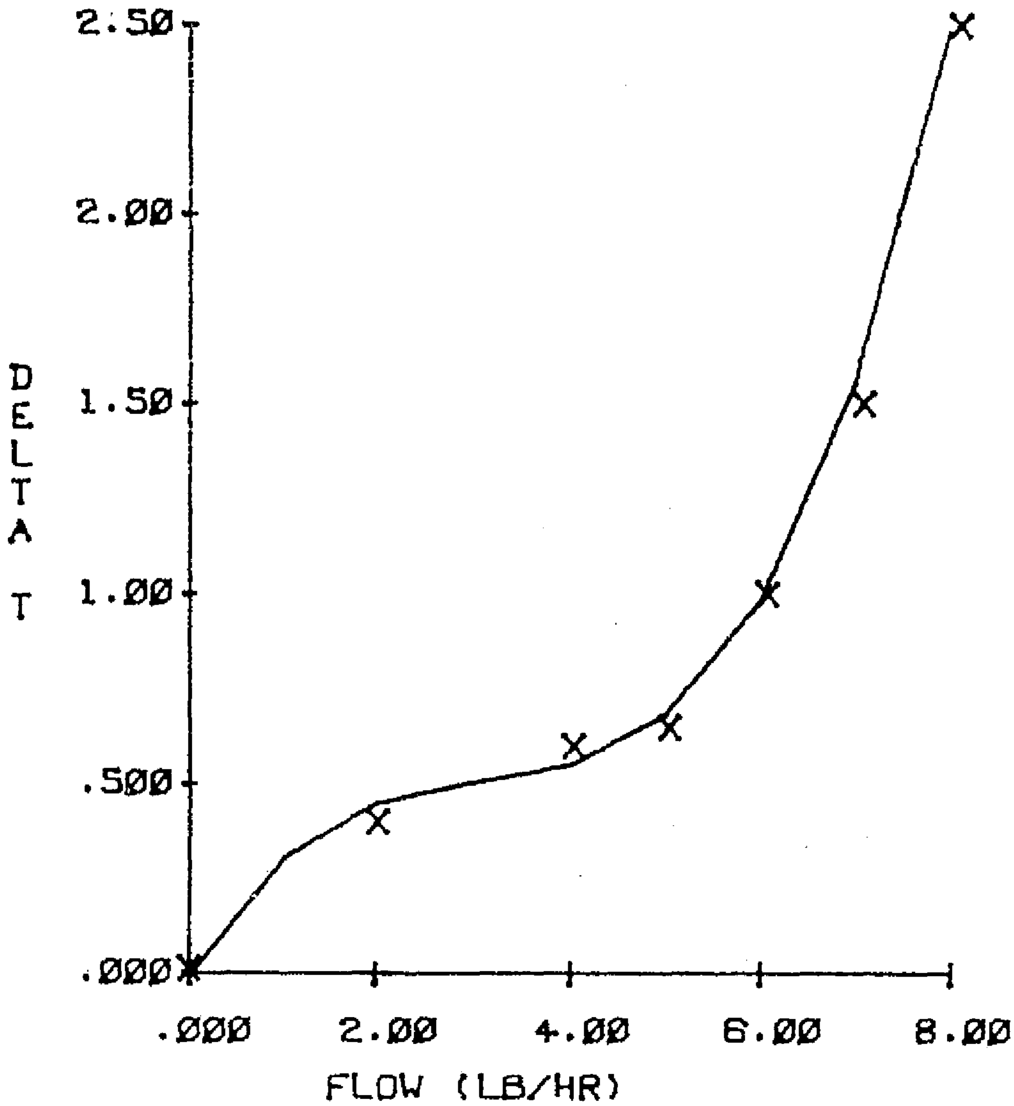


FIGURE 16 SAMPLE PLOT 2

Table XIII

PROGRAM LISTING

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```
10 REM SUBROUTINE "PLOT"
20 COM X9(100),Y9(100),C(10),X$25,Y$25,P$1
30 DEFFN'00"PLOT["
40 DEFFN'01"CONVERT"
50 SELECT PRINT 005:PRINT HEX(03)
60 PRINT :PRINT "          WANG 2200 GENERAL PLOT ROUTINE ":PRINT
 "        DEVELOPED BY 'WILD' BILL AYOTTE (9/74)":PRINT :PRINT
70 INPUT "X AXIS INCREMENT (UNITS/IN)",X0
80 INPUT "Y AXIS INCREMENT (UNITS/IN)",Y0
90 PRINT "LOCATION OF AXIS INTERSECTION":INPUT "(POSITION ON PAG
E IN INCHES- X, Y )",X1,Y1
100 INPUT "LIMITS OF X AXIS (MIN VALUE, MAX VALUE)",S1,S2
110 INPUT "LIMITS OF Y AXIS (MIN VALUE, MAX VALUE)",T1,T2
120 INPUT "X,Y VALUES OF AXIS INTERSECTION",C1,C2
130 INPUT "X AXIS LABEL",X$
140 INPUT "Y AXIS LABEL",Y$
150 F1=100./X0:F2=100./Y0
160 GOSUB 500
170 PLOT [1,,C],[,,S]
180 INPUT "PLOT POINTS OR CURVE (1=POINT,2=CURVE)",U1
190 IF U1=1 THEN 310
200 PLOT [,,R],[100*X1,100*Y1,U]
210 X4,Y4,E,E3,E4,E6,E8,E7=0:X$=" "
220 INPUT "DESIRED PLOT RANGE (MIN AND MAX VALUES)",W1,W2:INPUT
"DESIRED PLOT INCREMENT",D
230 STOP "INPUT EQUATION TO BE PLOTTED ON LINE 250 THEN KEY RUN
240"
240 FOR X=W1 TO W2 STEP D
250 Y=C(1)+C(2)*X+C(3)*X!2+C(4)*X!3+C(5)*X!4+C(6)*X!5+C(7)*X!6
260 X5=X-C1:Y5=Y-C2
270 IF X[]W1 THEN 280:U1=1:GOSUB '02(X5,Y5,X4,Y4):U1=2:GOTO 290
280 GOSUB '02(X5,Y5,X4,Y4)
290 NEXT X
300 PLOT [,,U]:PLOT [,,R]: GOTO 1350
310 X$=" ":PRINT :PRINT :INPUT "DESIRED PLOT SYMBOL",X$:K=1:X4,Y
4=0:INPUT "ARE DATA POINTS TO BE LOADED FROM ARRAY (NO=0,YES=1)"
   ,D:IF D=1 THEN 340
320 PRINT :PRINT "INPUT DATA POINTS (STOP PLOTTING BY SETTING X,
Y=N,N)":PRINT
330 INPUT "X,Y = ",X9$,Y9$:IF X9$="N"THEN 410:CONVERT X9$ TO X9(
K):CONVERT Y9$ TO Y9(K) :GOTO 360
340 PRINT :INPUT "FIRST AND LAST DATA POINTS TO BE PLOTTED",K,K5

350 STOP "KEY CONTINUE TO START PLOTTING POINTS IN ARRAY"
360 X=X9(K)-C1:Y=Y9(K)-C2:X4,Y4=0
370 IF K]1 THEN 380:PLOT [,,R],[100*X1,100*Y1,U],[F1*X,F2*Y,U],
 [,,D],[,,X$]:GOTO 390
380 GOSUB '02(X,Y,X4,Y4)
390 PLOT [-X*F1,-Y*F2,U]
400 K=K+1:IF D=0 THEN 330:IF K]=K5+1 THEN 410:GOTO 360
410 INPUT "DO YOU WISH TO CONNECT PLOTTED POINTS WITH LINE SEGME
NTS                (YES=1,NO=0)",Q
420 IF Q=0 THEN 1350:INPUT "FIRST AND LAST POINTS TO BE CONNECTE
D",L8,L9
430 X4,Y4,E,E3,E4,E6,E8,E7=0:U1=2:PLOT [,,R],[100*X1,100*Y1,U]
440 FOR I=L8 TO L9
450 X=X9(I)-C1:Y=Y9(I)-C2
460 IF I[]L8 THEN 470:U1=1:GOSUB '02(X,Y,X4,Y4):U1=2:GOTO 480
470 GOSUB '02(X,Y,X4,Y4)
480 NEXT I
490 PLOT [,,U]:PLOT [,,R]:GOTO 1350
500 SELECT PLOT 414
510 REM THIS SUBROUTINE DRAWS AND LABELS AXIS
520 PLOT [1,,C],[12,,S]
530 INPUT "LOCATION OF X AXIS LABELS (1=ABOVE,2=BELOW)",L1
540 INPUT "LOCATION OF Y AXIS LABELS (1=LEFT,2=RIGHT)",L2
```

Table XIII

PROGRAM LISTING (CONTINUED)

```
550 A1=F1*ABS(S1-C1):A2=F1*ABS(S2-C1):B1=F2*ABS(T1-C2):B2=F2*ABS
(T2-C2)
560 PLOT [,,R],[100*X1,100*Y1,U],[-A1,0,U],[A1+A2,0,D],[-A2,-B1,
U],[0,B1+B2,D]
570 M5=(ABS(S1-C1)+ABS(S2-C1))/X0:N5=(ABS(T1-C2)+ABS(T2-C2))/Y0
580 K=0
590 S3=S1-X0
600 PLOT [-3,-(B1+B2),U]
610 FOR I3=1 TO N5+1
620 PLOT [6,0,D],[,,U]
630 IF I3=N5+1 THEN 640:PLOT [-6,F2*Y0,U]
640 NEXT I3
650 PLOT [-(A1+3),-(B2+6),U]
660 FOR I4=1 TO M5+1
670 PLOT [0,12,D],[,,U]
680 IF I4=M5+1 THEN 690:PLOT [F1*X0,-12,U]
690 NEXT I4
700 IF L1=2 THEN 710:PLOT [-(A1+A2+24),20,U]:GOTO 720
710 PLOT [-(A1+A2+24),-36,U]
720 FOR I=1 TO M5+1
730 IF I]M5+1 THEN 840
740 S3=S3+X0
750 IF ABS(S3)]=1000.THEN 770:IF ABS(S3)]=100.THEN 730:IF ABS( S
3)]=10.THEN 790:IF ABS(S3)]=1.THEN 800
760 CONVERT S3 TO S3$,(-.###):GOTO 810
770 CONVERT S3 TO S3$,(-####):GOTO 810
780 CONVERT S3 TO S3$,(-###•):GOTO 810
790 CONVERT S3 TO S3$,(-##•#):GOTO 810
800 CONVERT S3 TO S3$,(-#•##):GOTO 810
810 IF K[]0 THEN 820: PLOT [,,S3$]:GOTO 840
820 IF S3[]C1 THEN 830:PLOT [F1*X0,0,U]:GOTO 840
830 PLOT [(F1*X0)-60,0,U],[,,S3$]
840 K=K+1:NEXT I
850 IF L2=1 THEN 860:PLOT [-(A2+20),0,U]:GOTO 870
860 PLOT [-(A2+100),0,U]
870 IF L1=1 THEN 880:PLOT [ 0,-(B1-31),U]:GOTO 890
880 PLOT [0,-(B1+24),U]
890 K=0
900 T3=T1-Y0
910 FOR I2=1 TO N5+1
920 IF I2]N5+1 THEN 1030
930 T3=T3+Y0
940 IF ABS(T3)]=1000.THEN 960:IF ABS(T3)]=100.THEN 970:IF ABS(T3
)]=10.THEN 980:IF ABS(T3)]=1.THEN 990
950 CONVERT T3 TO T3$,(-.###):GOTO 1000
960 CONVERT T3 TO T3$,(-####):GOTO 1000
970 CONVERT T3 TO T3$,(-###•):GOTO 1000
980 CONVERT T3 TO T3$,(-##•#):GOTO 1000
990 CONVERT T3 TO T3$,(-#•##):GOTO 1000
1000 IF K[]0 THEN 1010:PLOT [,,T3$]:GOTO 1030
1010 IF T3[]C2 THEN 1020:PLOT [0,F2*Y0,U]:GOTO 1030
1020 PLOT [-60,F2*Y0,U],[,,T3$]
1030 K=K+1:NEXT I2
1040 PLOT [,,R]
1050 IF X$=" " THEN 1110: PLOT [100*X1,100*Y1,U],[-A1,0,U]
1060 IF L1=2 THEN 1070:PLOT [0,50,U]:GOTO 1080
1070 PLOT [0,-60,U]
```

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Table XIII

PROGRAM LISTING (CONCLUDED)

```
1080 IF A2[]0 THEN 1090:PLOT [A1/5,0,U]:GOTO 1100
1090 PLOT [A1+A2/5,0,U]
1100 PLOT [,,X$]
1110 IF Y$=" " THEN 1180
1120 PLOT [,,R],[100*X1,100*Y1,U],[0,-B1,U]
1130 IF L2=1 THEN 1140:PLOT [90,0,U]:GOTO 1150
1140 PLOT [-90,0,U]
1150 IF B2[]0 THEN 1160:PLOT [0,2*B1/3,U]:GOTO 1170
1160 PLOT [0,B1+B2*2/3,U]
1170 PLOT [0,-20,S],[,,Y$],[12,,S],[,,R]
1180 RETURN
1190 DEFFN'02(U,V,X4,Y4)
1200 X3=U:Y3=V
1210 D1=X3-X4:D2=Y3-Y4:X4=X4+D1:Y4=Y4+D2
1220 IF U1=2 THEN 1230:  PLOT [F1*D1,F2*D2,U],[,,D],[,,X$],[,,U]
:E3=INT(F2*D2):E7=INT(F1*D1):GOTO 1340
1230 E1=F2*Y3-INT(F2*Y3)
1240 E=E+E1+E4
1250 P8=F2*D2+E:P9=INT(P8)
1260 E5=F1*X3-INT(F1*X3)
1270 E6=E6+E5+E8
1280 S8=F1*D1+E6:S9=INT(S8)
1290 PLOT [S9,P9,D]
1300 E3=E3+P9
1310 E4=F2*Y3-E3
1320 E7=S9+E7
1330 E8=F1*X3-E7
1340 RETURN
1350 INPUT "DO YOU WISH TO ADD LABELS OR COMMENTS TO PLOT (0=NO,
1=YES)",G
1360 IF G=0 THEN 1480
1370 INPUT "DESIRED CHARACTER SIZE (NUMBER FROM 1 TO 5)",K
1380 PLOT [K,,C],[,,S]
1390 KEYIN P$,1410,1420
1400 GOTO 1390
1410 IF P$=HEX(0D)THEN 1430:IF P$=HEX(02)THEN 1440:IF P$=HEX(08)
 THEN 1450:PLOT [,,P$],[13*K,,U]:GOTO 1390
1420 IF P$=HEX(00) THEN 1460:IF P$=HEX(01)THEN 1470:
     IF P$=HEX(02) THEN 1370:GOTO 1480
1430 PLOT [0,-20*K,U],[-999,0,U]:GOTO 1390
1440 PLOT [13*K,0,U]:GOTO 1390
1450 PLOT [-13*K,0,U]:GOTO 1390
1460 PLOT [0,20*K,U]:GOTO 1390
1470 PLOT [0,-20*K,U]:GOTO 1390
1480 INPUT "DO YOU WISH TO CONTINUE PLOTTING (0=NO,1=YES)",G:
      IF G=1 THEN 180
1490 END
```

RADIATOR PERFORMANCE PREDICTION PROGRAM

File Name "Radiator"

Abstract "Radiator" calculates thermal performance for a flowing radiator system (Q rejected, T out) given environmental and physical system inputs.

Results from this program have been used to generate a data book of Shuttle radiator performance for various environments that are a function of orbit parameters (altitude, beta angle, vehicle roll angle, etc.). Samples of results presented in this data book are included here. (See figure 17).

Environmental inputs (Q_{ABS} , [illegible]$_{TS}$) were obtained using a computer program TRASYS which uses a detailed geometric model of the Shuttle vehicle along with values for the surface absorbtivity and emissivity.

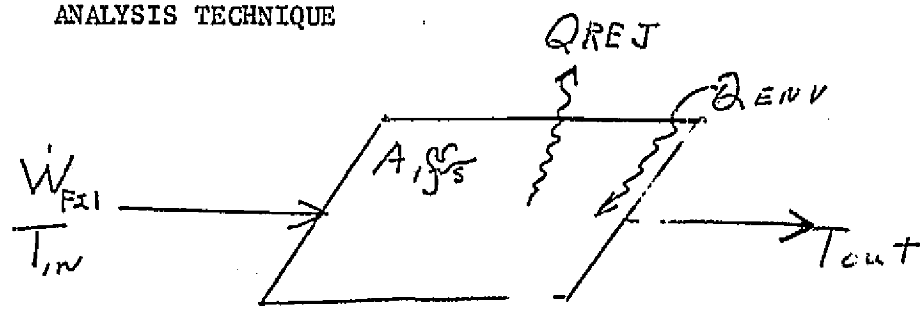
A program listing, Table XIV, is enclosed for reference.

PROGRAM DESCRIPTION

INPUT DATA DEFINITION

CRT SYMBOL	DESCRIPTION
Evaporator H_2O Flow	Maximum radiator system heat rejection is affected by evaporator water flow and it must be input
# of Panels	Usually equal to 6 or 8 (baseline and space lab missions)
Inlet temperature	System inlet temp. ^oF
Data below is repeated for each panel in system	
Panel Type	Single (1) or double sided (2)
Flux	Panel absorbed heat (Btu/Hr-Sq-Ft)
Shape factor to space	View factor to space (dimensionless)
Flow source	# of panel supplying flow
Last panels in system	#'s of last two panels in system (flow from these panels is mixed and becomes inlet to evaporator)

ANALYSIS TECHNIQUE



ASSUMPTIONS: RADIATION FIN η = .9

FLUID TO TUBE ΔT = 3.0°F

ANALYSIS: GUESS VALUE FOR Tout

$$T_{SINK} = \left(Q_{ENV}/\sigma / \varepsilon_s\right)^{1/4}$$

$$(\sigma = .1714 \times 10^{-8})$$

$$Y = (\sigma)(\eta)(T_{SINK})^3 (A)(\varepsilon_s) / \dot{W}_{F21}$$

$$I = (T_{IN} - \Delta T + 460) / T_{SINK}$$

$$O = (T_{OUT} - \Delta T + 460) / T_{SINK}$$

$$U1 = (.25)\left[LOG_e\left(\frac{I+1}{I-1}\right) + .5\,(ARCTAN(I))\right]$$

$$U2 = (.25)\left[LOG_e\left(\frac{O+1}{O-1}\right) + .5\,(ARCTAN(O))\right]$$

Find F21 enthalpy in (H1) and
enthalpy out (H2)

$$\text{AVG Cp} = \frac{H2-H1}{O-I}$$

$$U3 = U1 + Y/Cp$$

If U2 equals U3 within desired tolerance, then model is converged and Tout is the correct value, otherwise re-estimate Tout and return to Tsink calculation. Continue looping until balance is within desired tolerance.

This procedure is then followed for each panel in the system.

Table XIV

RADIATOR PROGRAM LISTING

```
        10 DIM E7(10),E9(10),E8(10),A9(10),F1(10),S1(10),T1(10),C1(10)
   ,F(10)
20  REM PROGRAM "RADIATOR"
30  C2=.0166E-4
40  L1=3.2
50  C1=-.1624E-4
60  C0=.242
70  C=.25
80  S=0.1713E-8
90  M=.00001 :N =.0000001
100  SELECT PRINT 005
110  INPUT "EVAPORATOR H2O FLOW  (LB/HR) ",F1
120  INPUT "NUMBER OF PANELS",P1
130  PRINT : INPUT "RADIATOR INLET TEMP (DEG F)",I:I6=I
140  FOR I=1 TO P1
150  PRINT
160  PRINT "DATA FOR PANEL #", I
170  PRINT
180  INPUT "PANEL TYPE (1=SINGLE SIDE,2=DOUBLE SIDE)",T9
190  INPUT "FLUX (BTU/HR-SQ FT)",E7(I)
200  IF I]1 THEN 201:INPUT "FLOW (LB/HR)", F1(I)
201  F1(I)=F1(1)
210  INPUT "FLOW SOURCES (XY,X=SOURCE#1,Y=SOURCE#2)", S1(I)
215  F(I)=0:INPUT "SHAPE FACTOR TO SPACE (DEFAULT=1.0) ",F(I):
     IF F(I)[]0 THEN 220:F(I)=1.0
220  IF T9=2 THEN 230:E8(I)=.032:E9(I)=.8:A9(I)=166.00:GOTO 240
230  E8(I)=.044:E9(I)=.841:A9(I)=332.00
240  NEXT I
250  INPUT "LAST PANELS IN SYSTEM",L1,L2
260  Q6=0:SELECT PRINT 005: PRINT HEX(03):PRINT "  TIN = ";I6;"
 FLOW = ";F1(1)*2
270  FOR I9=1 TO P1
280  E=E7(I9):E1=E8(I9):E2=E9(I9):R1=A9(I9):R2=F1(I9):F0=F(I9)
290  S2=INT(S1(I9)/10):S3=S1(I9)-S2*10
300  X,Y,X1,Y1,X2,X3=0
310  IF S1=0 THEN 320: GOTO 330
320  IF S2[]0 THEN 330:I=I6:GOTO 380
330  IF S1=0 THEN 340:X=F1(S1)*T1(S1)*C1(S1):X1=F1(S1)*C1(S1)
340  IF S2=0 THEN 350:Y=F1(S2)* T1(S2)*C1(S2):Y1=F1(S2)*C1(S2)
350  IF I9[]B1 THEN 360:X2=W*T*.25:X3=W*.25:GOTO 370
360  IF I9[](B1-1+B2) THEN 370:X2=W*T*.25:X3=W*.25
370  I=(X+Y+X2)/(X1+Y1+X3)
380  K=20
390  T5=(E/S/F0)!.25:0=.2*(T5-460)+.8*I:SELECT PRINT 005:
     PRINT "RESULTS FOR PANEL NUMBER ";I9;"   ";
400  IF E[]0 THEN 410:E=.001
```

Table XIV

RADIATOR PROGRAM LISTING (CONCLUDED)

```
410 T5=(E/S/FO)!.25
420 E1=.90:D=3.0
430 Y=S*E1*T5!3*R1*FO/R2
440 I1=(I-D+459.69)/T5
450 O1=(O-D+459.69)/T5
460 U1 =.25*LOG(ABS((I1+1)/(I1-1)))+.5*ARCTAN(I1)
470 U2 =.25*LOG(ABS((O1+1)/(O1-1)))+.5*ARCTAN(O1)
480 IF ABS(O-I)].00001 THEN 490:O=I+.001
490 H=C0*I+C1*I!2/2+C2*I!3/3:H1=C0*O+C1*O!2/2+C2*O!3/3
500 C=ABS((H1-H)/(O-I))
510 U3=U1+Y/C
520 IF ABS(U2-U3)[=M THEN 660
530 Y=Z
540 Z=O
550 IF U3]U2+N THEN 610
560 O=O+K
570 IF Y[]O THEN 410
580 K=K/2
590 O=O-K
600 GOTO 410
610 O=O-K
620 IF Y[]O THEN 410
630 K=K/2
640 O=O+K
650 GOTO 410
660 Q1=(I-O)*C*R2
670 PRINT "TOUT = ";O
680 % ##   ####.##  ####.##  ##.##    ###.##   ####.##   .###
 .###   #####.##     -###.###  -.#####   -###.###
690 Q6=Q6+Q1
700 T1(I9)=O:C1(I9)=C:NEXT I9
710 O4=(F1(L1)*T1(L1)+F1(L2)*T1(L2))/(F1(L1)+F1(L2))
720 O5=O4-F1*1060/((F1(L1)+F1(L2))*.245)
730 Q7=Q6+F1*1060
740 PRINT : PRINTUSING 780,O4
750 PRINTUSING 790,Q6
760 PRINT :PRINTUSING 800,O5
770 PRINTUSING 810,Q7
780 % RADIATOR OUTLET MIX TEMP = ###.##
790 % RADIATOR TOTAL HEAT REJECTION = -######.##
800 % EVAPORATOR OUTLET TEMP = ###.##
810 % RADIATOR/EVAPORATOR SYSTEM TOTAL HEAT REJECTION = -######.
##
820 SELECT PRINT 005
830 STOP :GOTO 260
840 END
```

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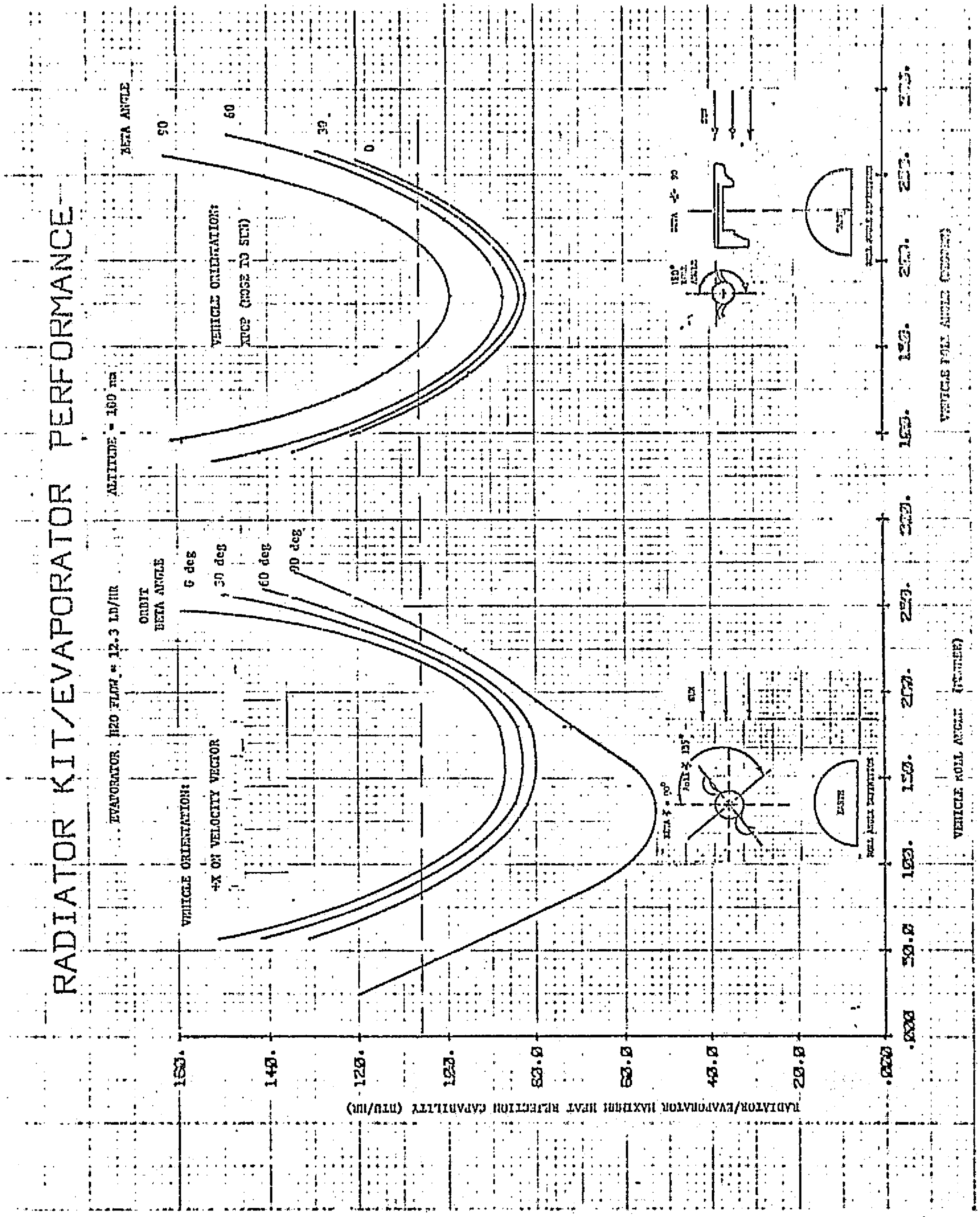

FIGURE 17 SAMPLE INPUT TO RADIATOR HAND BOOK

GENERALIZED THERMAL ANALYZER PROGRAM

File Name "WINDA"

Abstract "Winda" calculates steady state or transient temperature profiles of constant property structural and/or fluid thermal math models. The program is designed for use with a WANG 2200 - series mini computer. A sample case is shown in figure 18.

Program Description

This program is modeled after the System Improved Numerical Differencing Analyzer "SINDA" (Reference 1). Like any thermal analyzer program, the program requires the user to convert his thermal system into a lumped parameter RC network. Reference 2 provides a discussion on thermal mathematical modeling.

"WINDA" can be functionally divided into two programs. A thermal network imput/output and conversion program, and a solution routine program. Therefore, the following discussion has been divided into two parts: I. Thermal Network INPUT and OUTPUT, and II. Thermal Network Solution Routine.

I. Thermal Network Input/Output Program

This portion of the program allows the user to input his thermal math model (TMM) either from a tape or from the console, edit changes and/or corrections to the network heat transfer paths (conductors) and heat sources (Q's) and save the corrected version on tape.

A. Tape Input

The program will search through a tape containing several models (Files) to pick out the user required model. WANG 2200 system tape handling rules apply. The models are written as NAMED data files.

B. <u>Console Input/Edit</u>

1) Node Data

If the user's TMM was loaded from a tape no changes are allowed to the node data. If not, the user is required to supply the number of diffusion, arithmetic and boundary nodes in his problem. Then the program will number his nodes sequentially, starting with the diffusion nodes first, then the arithmetic and finally the boundary nodes. It will then request the required node definition data as follows:

Diffusion Nodes	Initial Temp (°F), Thermal Capacitance (Btu/°F)
Arithmetic Nodes	Initial Temp (°F)
Boundary Nodes	Constant Temp

2) Conductor Data

Upon completion of node data inputs, the program request edits (addition) or original inputs to the conductor arrays.

Two node numbers specifying the hookup and a conductor value ($\frac{Btu}{Time-°F}$ or area) are supplied by the user for each conductor input. If the conductor is to simulate a mass transfer (fluid flow) conductor, and as such will allow energy transfer only downstream, the user is required to input a negative node number on the upstream node only. The conductor value represents the $\dot{M} C_p$ of the fluids. If the conductor is to simulate a radiation hook up, the conductor value is input as a negative $\mathcal{F}\sigma$ A(area). If the conductor is linear, it is input as positive (KA/L , hA or $\dot{M}C_p$ depending on type)

3) Source Array (Q's)

The source array allows the user to input the network's heat sources (limited to diffusion and arithmetic nodes). The input process is additive; the equation being of the form:

$$Q_{new} \text{ (node I)} = Q_{old} \text{ (node I)} + \text{Input}$$

Allowing for input of several sources at a single node.

4) Demand Mode Corrections

At this time, the program allows the user to modify his input, limited to the following:

a. Changing temperatures or thermal capacitance

b. Changing sources

c. Changing conductor values and hookups (not conductor types)

The node number is the index in the temperature (T) and source (Q) array. The edit number printed by the program is the index in the conductor block arrays (G1, G2, G and R1, R2, R). Note that only mass transfer conductors are one way and all others need to be edited on two lines.

5) Model Save Option

If the user desires to save the TMM to tape drive 10B, he has the option of writing over the old model or specifying a new location (the next open file) on the tape.

Table XV summarizes the input sequence of the thermal network.

II. Thermal Network Solution Routines

The program has two solution routines available to the user: a transient forward difference routine and an iterative steady state routine.

Table XVI contains the control variables required to execute the solution routines. The program selects only those variables necessary for the execution of the selected solution routine. At the completion of the solution routine the program can be restarted at the final temperatures (or a new set of initial conditions can be input at the CRT console).

A. Forward Difference Routine

The forward difference solution technique extrapolates the new temperature $T(t + \Delta t)$ from the old temperature $T(t)$. The solution is explicit, the only limitation being the length of the time step. At each time step the solution routine first calculates the new temperatures for the diffusion nodes. The arithmetic nodes are then given a steady state solution based on the "new" diffusion temperatures. (See steady state solution discussion).

The time step for stability purposes is calculated as follows: The program calculates the CSG for each diffusion node where

$$CSG\ (\text{node } I) = \frac{C(I)}{\sum_{J=1}^{N} G_{IJ}^{*}}$$

N = total number of nodes

G_{IJ}^{*} = heat transfer paths to node I linear or linearized radiation conductors

Then the time step is calculated as .95 times the minimum CSG in the network divided by CSGFAC (a user option to modify the time step).

The solution algorithm for diffusion nodes is as follows:

$$T_I(t+\Delta t) = T(t) + \frac{\Delta t}{C_I}\left[Q_I + \sum_{J=1}^{N} G_{IJ}\left(T_J(t) - T_I(t)\right) + (SIGMA)\sum_{J=1}^{N} R_{IJ}\left(T_J(t)^2 + T_I(t)^2\right)\left(T_J(t) + T_I(t)\right)\left(T_J(t) - T_I(t)\right)\right]$$

where
T = temperature
t = time
Δt = time step
C_I = Thermal mass of node I
G_{IJ} = linear (conduction, convection or mass transfer) conduction from node I to J

SIGMA = Stephen Baltzman Constant

Q_I = internal heat generation (source) at the I'th node
R_{IJ} = radiation conductor between node I and J ($\mathcal{F}$A). Note the linearization criteria used.

The forward difference solution routine will output (i.e., print temperatures) at the user specified output interval and upon completion of the problem.

B. Steady State Routine

The steady state solution routine is an iterative solution technique which treats all nodes (i.e., diffusion and arithmetic) identically. The network is assumed at steady state when the temperature change between iteration is less than the user required minimum for both the diffusion and arithmetic nodes, or the user supplied maximum number of iteration is exceeded. The solution algorithm is as follows:

$$X_I(L+1) = \frac{Q_I + \left[\sum_{J=1}^{N} G_{IJ} T_J(L)\right] + \left[(SIGMA)\sum_{J=1}^{N} R_{IJ}\left(T_J^2(L)+T_I^2(L)\right)\left(T_J(L)+T_I(L)\right)\left(T_J(L)\right)\right]}{\left[\sum_{J=1}^{N} G_{IJ}\right] + \left[(SIGMA)\sum_{J=1}^{N} R_{IJ}\left(T_J^2(L)+T_I^2(L)\right)\left(T_J(L)+T_I(L)\right)\right]}$$

$$T(L+1) = D(X(L+1)) + (1-D)T(L)$$

where
L = 6, 1, 2 . . .Iteration count
D = Damping factor

and all other variables are defined as in the transient solution case.
The user may select different damping criteria for the diffusion and arithmetic node in his network. Radiation dominated problems require many iterations to reach steady state. It is suggested to use a D = .5-.7 in these cases.

References:

1. Smith, J. P., SINDA Users Manual, TRW Systems, 14690-H001-R0-00, April 1971.

2. Thermal Network Modeling Handbook, TRW Systems, 14690-H003-R0-00, January 1972.

TABLE XV

THERMAL NETWORK INPUT/OUTPUT SEQUENCE

CRT SYMBOL			DESCRIPTION/COMMENT
1.	a)	Is network stored on tape drive 10B	1 = Yes 2 = No
	b)	If the answer to part a) is yes, then input model file number	File # I ⟶ M where model is stored

NOTE: If the network is stored on tape the sequence continues at step 6.

2.	Input number of diffusion arithmetic and boundary node	I1, I2, I3
3.	Input for diffusion nodes 1 to I_1, initial temp. and thermal mass.	Input for each node at a time.
4.	Input for arithmetic nodes 1 to I_2, initial temp.	Input for each node at a time.
5.	Input for boundary node 1 to I_3, constant temp.	Input for each node at a time.
6.	Node Data Printout desired	1 = Yes Prints user node data 2 = No
7.	Input conductor data NA, NB, value	At this point, the user inputs each conductor one at a time.

The following rules apply to the conductor data:

a) Linear (conduction or convection). NA, NB are positive Node Numbers and the conduction value is positive

b) Mass Transfer - The upstream node NA or NB is flagged with a negative node number and the conduction value equals

c) Radiation Conductor - NA, NB are positive Node numbers and the

TABLE XV

THERMAL NETWORK INPUT/OUTPUT SEQUENCE
(CONCLUDED)

	CRT SYMBOL	DESCRIPTION/COMMENT
7.	c) continued conductor value is input as a negative σA. (The negative sign only serves as a flag to indicate radiation). d) An image of the user input is produced at the typewriter.	
8.	Detailed heat transfer path printout desired If yes, the printout shows all connections in the network.	1 = Yes 2 = No
9.	Source data input N, Value	N is the node (arithmetic or diffusion). Note that the value is added to the previously stored Q rate.
10.	Source data printout desired	1 = Yes 2 = No
11.	Make changes to network from demand node. The user can now (using the terminal) make changes to the network.	
12.	a) Is the network going to be saved on tape drive 10B	1 = Yes 2 = No
	b) If part A is Yes then input model file number	File # 1 → M

TABLE XVI

THERMAL NETWORK SOLUTION ROUTINE INPUTS

CRT SYMBOL	DESCRIPTION/COMMENT
1. Type of solution desired	1 = Forward differencing 2 = Steady state
2. Initial time	Problem start time
3. Output interval	Used only with forward differnce routine
4. Final time	Problem end time of the forward difference solution. Also used as the output time of the steady state solution
5. SIGMA	Stephan Baltzman Constant (A default of .1713E-8 $\frac{Btu}{hr\text{-}ft^2\text{-}°R^4}$ is obtained by inputing 0.).
6. Time step stability criteria	Used with forward difference solution to modify time step. (A default value of 1. is obtained by keying 0.)
7. Maximum number of interations	Used in the steady state solution routine
8. Arithmetic node relaxation criteria	Delta temperature between steady state iterations
9. Arithmetic Node damping factor	Used in the steady state routine
10. Diffusion node relaxation criteria	Same as arithmetic node
11. Diffusion node damping factor	Same as arithmetic node

SAMPLE PROBLEM: Two fins, one in convection and one in radiation with a fluid loop.

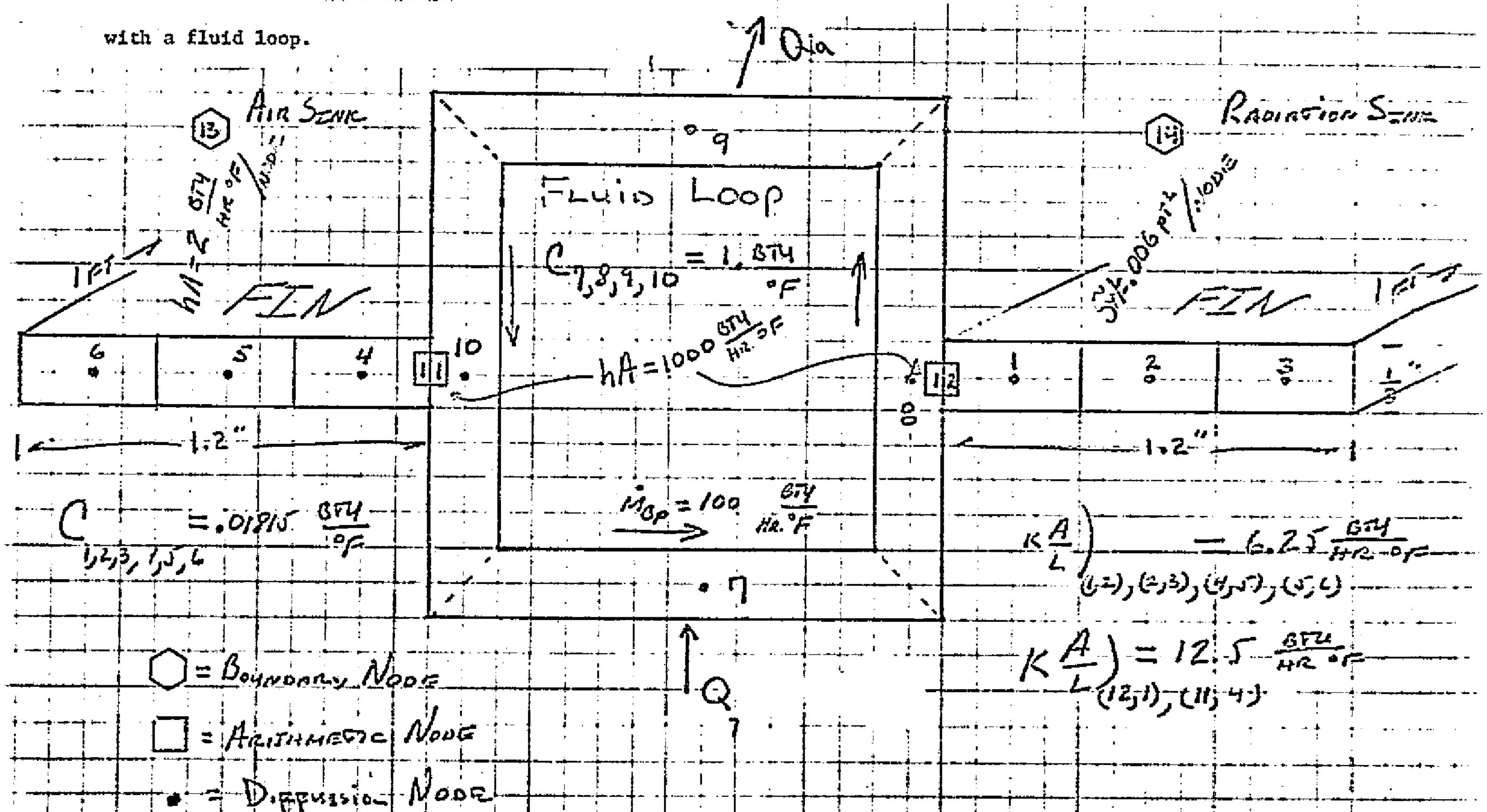

FIGURE 18 WINDA SAMPLE PROBLEM

PART A – $\dot{Q}_7 = 1000 \frac{Btu}{Hr}$ $\dot{Q}_9 = -200 \frac{Btu}{Hr}$

```
          MINI THERMAL ANALYZER PROGRAM
      LIMITED TO CONSTANT PROPERTY NETWORKS

   *** THERMAL NETWORK INPUTS ***

     NODE DATA BLOCK
   NODE  1 DIFF     INIT TEMP       40.00   CAP  1.815000E-02
   NODE  2 DIFF     INIT TEMP       40.00   CAP  1.815000E-02
   NODE  3 DIFF     INIT TEMP       40.00   CAP  1.815000E-02
   NODE  4 DIFF     INIT TEMP       70.00   CAP  1.815000E-02
   NODE  5 DIFF     INIT TEMP       70.00   CAP  1.815000E-02
   NODE  6 DIFF     INIT TEMP       70.00   CAP  1.815000E-02
   NODE  7 DIFF     INIT TEMP      100.00   CAP  1.000000E+00
   NODE  8 DIFF     INIT TEMP       50.00   CAP  1.000000E+00
   NODE  9 DIFF     INIT TEMP       65.00   CAP  1.000000E+00
   NODE 10 DIFF     INIT TEMP       60.00   CAP  1.000000E+00
   NODE 11 ARITH    INIT TEMP       70.00
   NODE 12 ARITH    INIT TEMP       40.00
   NODE 13 BOUN   CONST TEMP       100.00
   NODE 14 BOUN   CONST TEMP      -459.00
   NUMBER OF NODES DIFF   10 ARITH   2   BOUNDARY   2   TOTAL   14

     CONDUCTOR DATA BLOCK
              TYPE        NA          NB        CONDUCTOR VALUE
   *NEW*      LIN         12           1        1.250000E+01
   *NEW*      LIN          1           2        6.250000E+00
   *NEW*      LIN          2           3        6.250000E+00
   *NEW*      LIN         11           4        1.250000E+01
   *NEW*      LIN          4           5        6.250000E+00
   *NEW*      LIN          5           6        6.250000E+00
   *NEW*      LIN          8          12        1.000000E+03
   *NEW*      LIN         10          11        1.000000E+03
   *NEW*      LIN         -7           8        1.000000E+02
   *NEW*      LIN         -8           9        1.000000E+02
   *NEW*      LIN         -9          10        1.000000E+02
   *NEW*      LIN        -10           7        1.000000E+02
   *NEW*      RAD          1          14        6.000000E-03
   *NEW*      RAD          2          14        6.000000E-03
   *NEW*      RAD          3          14        6.000000E-03
   *NEW*      LIN          4          13        2.000000E+00
   *NEW*      LIN          5          13        2.000000E+00
   *NEW*      LIN          6          13        2.000000E+00
```

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OF POOR QUALITY

FIGURE 18 WINDA SAMPLE PROBLEM (CONTINUED)

NETWORK HEAT TRANSFER PATHS

EDIT	NO.	TYPE	NA(G1/R1)	NB(G2/R2)	VALUE(G/R)
G	1	LIN	12	1	1.250000E+01
G	2	LIN	1	12	1.250000E+01
G	3	LIN	1	2	6.250000E+00
G	4	LIN	2	1	6.250000E+00
G	5	LIN	2	3	6.250000E+00
G	6	LIN	3	2	6.250000E+00
G	7	LIN	11	4	1.250000E+01
G	8	LIN	4	11	1.250000E+01
G	9	LIN	4	5	6.250000E+00
G	10	LIN	5	4	6.250000E+00
G	11	LIN	5	6	6.250000E+00
G	12	LIN	6	5	6.250000E+00
G	13	LIN	8	12	1.000000E+03
G	14	LIN	12	8	1.000000E+03
G	15	LIN	10	11	1.000000E+03
G	16	LIN	11	10	1.000000E+03
G	17	LIN	8	7	1.000000E+02
G	18	LIN	9	8	1.000000E+02
G	19	LIN	10	9	1.000000E+02
G	20	LIN	7	10	1.000000E+02
G	21	LIN	4	13	2.000000E+00
G	22	LIN	13	4	2.000000E+00
G	23	LIN	5	13	2.000000E+00
G	24	LIN	13	5	2.000000E+00
G	25	LIN	6	13	2.000000E+00
G	26	LIN	13	6	2.000000E+00
R	1	RAD	1	14	6.000000E-03
R	2	RAD	14	1	6.000000E-03
R	3	RAD	2	14	6.000000E-03
R	4	RAD	14	2	6.000000E-03
R	5	RAD	3	14	6.000000E-03
R	6	RAD	14	3	6.000000E-03

NUMBER OF HEAT TRANSFER PATHS IN NETWORK 32 (26 LINEAR, 6 RADIATION)

SOURCE DATA BLOCK

NEW SOURCE 7 VALUE 1.000000E+03
NEW SOURCE 9 VALUE -2.000000E+02

NETWORK NET HEATING RATES ARRAY (Q)

NODE NO.	NET HEAT RATE				
1 - 5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
6 - 10	0.0000E+00	1.0000E+03	0.0000E+00	-2.0000E+02	0.0000E+00
11 - 15	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

NETWORK SAVED TO FILE 1 SUCCESSFULLY ← NOTE THAT NETWORK WAS SAVED

FIGURE 18 WINDA SAMPLE PROBLEM (CONTINUED)

```
*** CONTROL CONSTANTS INPUTS ***

FORWARD DIFFERENCE SOLUTION ROUTINE SELECTED (CNFRWD)
INITIAL TIME-TIMEO  0
OUTPUT INTERVAL-OUTPUT  1.00000000E-03
FINAL TIME-TIMEND  5.00000000E-03
RADIATION SIGMA 1.71300000E-09
TIME STEP STABILITY CRITERIA-CSGFAC  1
MAXIMUM NUMBER OF ITERATIONS-NLOOP  3
ARITHMETIC NODE RELAXATION CRITERIA-ARLXCA  1.00000000E-02
ARITHMETIC NODE DAMPING FACTOR-DAMPA  .9
DIFFUSION NODE RELAXATION CRITERIA-DRLXCA  100000000
DIFFUSION NODE DAMPING FACTOR-DAMPD  1

*** END OF INPUT SEQUENCE - BEGIN EXECUTION PHASE ***
```

TRANSIENT SOLUTION FOR .005 HRS.

TIMEN 0.0000 DTIMEU 8.30963E-04 CSGMIN 8.74698E-04 AT NODE 4

NODE NO.	TEMPERATURE (DEG F)				
1 - 5	40.00	40.00	40.00	70.00	70.00
6 - 10	70.00	100.00	50.00	45.00	60.00
11 - 15	70.00	40.00	100.00	-459.00	-460.00

TIMEN 0.0010 DTIMEU 8.30963E-04 CSGMIN 8.74698E-04 AT NODE 4

NODE NO.	TEMPERATURE (DEG F)				
1 - 5	40.63	39.96	39.96	72.60	73.25
6 - 10	73.25	97.16	46.70	45.22	66.70
11 - 15	66.77	46.62	100.00	-459.00	-460.00

TIMEN 0.0020 DTIMEU 8.30963E-04 CSGMIN 8.74698E-04 AT NODE 4

NODE NO.	TEMPERATURE (DEG F)				
1 - 5	44.42	40.32	39.94	71.89	75.77
6 - 10	76.14	95.11	51.57	45.24	64.66
11 - 15	64.75	51.46	100.00	-459.00	-460.00

TIMEN 0.0030 DTIMEU 8.30963E-04 CSGMIN 8.74698E-04 AT NODE 4

NODE NO.	TEMPERATURE (DEG F)				
1 - 5	47.81	41.61	40.09	71.38	77.16
6 - 10	78.55	93.07	55.74	45.73	62.84
11 - 15	62.95	55.65	100.00	-459.00	-460.00

TIMEN 0.0040 DTIMEU 8.30963E-04 CSGMIN 8.74698E-04 AT NODE 4

NODE NO.	TEMPERATURE (DEG F)				
1 - 5	50.99	43.21	40.63	70.72	78.11
6 - 10	80.37	91.05	59.30	46.57	61.27
11 - 15	61.39	59.19	100.00	-459.00	-460.00

TIMEN 0.0050 DTIMEU 8.30963E-04 CSGMIN 8.74698E-04 AT NODE 4

NODE NO.	TEMPERATURE (DEG F)				
1 - 5	53.88	44.98	41.53	70.07	78.72
6 - 10	81.69	89.08	62.30	47.67	59.95
11 - 15	60.09	62.19	100.00	-459.00	-460.00

FIGURE 18 WINDA SAMPLE PROBLEM (CONTINUED)

```
*** CONTROL CONSTANTS INPUTS ***

STEADY STATE SOLUTION ROUTINE SELECTED (CINDSS)
INITIAL TIME-TIMEO  1
OUTPUT INTERVAL-OUTPUT  0
FINAL TIME-TIMEND  100
RADIATION SIGMA 1.71300000E-09
TIME STEP STABILITY CRITERIA-CSGFAC  1
MAXIMUM NUMBER OF ITERATIONS-NLOOP  1000
ARITHMETIC NODE RELAXATION CRITERIA-ARLXCA  1.00000000E-03
ARITHMETIC NODE DAMPING FACTOR-DAMPA  .7
DIFFUSION NODE RELAXATION CRITERIA-DRLXCA  1.00000000E-03
DIFFUSION NODE DAMPING FACTOR-DAMPD  .7
```

STEADY STATE SOLUTION

```
*** END OF INPUT SEQUENCE - BEGIN EXECUTION PHASE ***


TIMEN       1.0000  DTIMEU  0.00000E+00  CSGMIN  0.00000E+00  AT NODE  0
NODE NO.                  TEMPERATURE  (DEG F)
  1 -  5        53.88        44.98        41.53        70.07        73.72
  6 - 10        81.69        89.08        62.30        47.67        59.95
 11 - 15        60.08        62.19       100.00      -459.00      -460.00

STEADY STATE IERATIONS PERFORMED  1000  NLOOP  1000

TIMEN     100.0000  DTIMEU  0.00000E+00  CSGMIN  0.00000E+00  AT NODE  0
NODE NO.                  TEMPERATURE  (DEG F)
  1 -  5       215.31       214.13       213.70       130.62       151.46
  6 - 10       138.93       218.52       216.32       214.17       208.67
 11 - 15       208.28       216.26       100.00      -459.00      -460.00
```

FIGURE 18 WINDA SAMPLE PROBLEM (CONTINUED)

FIGURE 18 WINDA SAMPLE PROBLEM (CONTINUED)

PART B - SAME NETWORK AS IN PART A

$\dot{Q}_7 = 500 \frac{Btu}{Hr}$

$\dot{Q}_9 = -400 \frac{Btu}{Hr}$

```
      MINI THERMAL ANALYZER PROGRAM
  LIMITED TO CONSTANT PROPERTY NETWORKS

 *** THERMAL NETWORK INPUTS ***

      MINI THERMAL ANALYZER PROGRAM
  LIMITED TO CONSTANT PROPERTY NETWORKS

 *** THERMAL NETWORK INPUTS ***

  NETWORK FROM FILE  1  WAS SUCCESSFULLY LOADED

  NODE DATA BLOCK
NUMBER OF NODES DIFF  10 ARITH  2  BOUNDARY  2  TOTAL  14

  CONDUCTOR DATA BLOCK
      TYPE       NA        NB      CONDUCTOR VALUE
NUMBER OF HEAT TRANSFER PATHS IN NETWORK  32  ( 26  LINEAR,  6  RADIATION)

  SOURCE DATA BLOCK
*NEW*  SOURCE  9  VALUE -2.000000E+02
*NEW*  SOURCE  7  VALUE -5.000000E+02

  NETWORK NET HEATING RATES ARRAY (Q)
 NODE NO.              NET HEAT RATE
   1 - 5    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
   6 - 10   0.0000E+00    5.0000E+02    0.0000E+00   -4.0000E+02    0.0000E+00
  11 - 15   0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00

 *** CONTROL CONSTANTS INPUTS ***

 FORWARD DIFFERENCE SOLUTION ROUTINE SELECTED (CNFRWD)
 INITIAL TIME-TIMEO  0
 OUTPUT INTERVAL-OUTPUT  1.00000000E-03
 FINAL TIME-TIMEND  5.00000000E-03
 RADIATION SIGMA 1.71300000E-09
 TIME STEP STABILITY CRITERIA-CSGFAC  1
 MAXIMUM NUMBER OF ITERATIONS-NLOOP  3
 ARITHMETIC NODE RELAXATION CRITERIA-ARLXCA  1.00000000E-02
 ARITHMETIC NODE DAMPING FACTOR-DAMPA  .9
 DIFFUSION NODE RELAXATION CRITERIA-DRLXCA  100000000
 DIFFUSION NODE DAMPING FACTOR-DAMPD  1

 *** END OF INPUT SEQUENCE - BEGIN EXECUTION PHASE ***
```

← NOTE THE NETWORK WAS LOADED FROM TAPE

← CHANGES IN $\dot{Q}$

} TRANSIENT SOLUTION FOR .005 HRS.

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```
TIMEN        0.0000  DTIMEU  8.30963E-04  CSGMIN  8.74698E-04  AT NODE  4
NODE NO.                    TEMPERATURE   (DEG F)
   1 - 5        40.00          40.00          40.00          70.00          70.00
   6 - 10       70.00         100.00          50.00          45.00          60.00
  11 - 15       70.00          40.00         100.00        -459.00        -460.00

TIMEN        0.0010  DTIMEU  8.30963E-04  CSGMIN  8.74698E-04  AT NODE  4
NODE NO.                    TEMPERATURE   (DEG F)
   1 - 5        40.63          39.96          39.96          72.60          73.25
   6 - 10       73.25          95.66          46.69          45.02          66.70
  11 - 15       66.77          46.62         100.00        -459.00        -460.00

TIMEN        0.0020  DTIMEU  8.30963E-04  CSGMIN  8.74698E-04  AT NODE  4
NODE NO.                    TEMPERATURE   (DEG F)
   1 - 5        44.41          40.32          39.94          71.88          75.77
   6 - 10       76.14          94.17          51.51          44.86          64.63
  11 - 15       64.72          51.42         100.00        -459.00        -460.00

TIMEN        0.0030  DTIMEU  8.30963E-04  CSGMIN  8.74698E-04  AT NODE  4
NODE NO.                    TEMPERATURE   (DEG F)
   1 - 5        47.77          41.61          40.09          71.36          77.16
   6 - 10       78.55          91.73          55.59          45.17          62.78
  11 - 15       62.89          55.49         100.00        -459.00        -460.00

TIMEN        0.0040  DTIMEU  8.30963E-04  CSGMIN  8.74698E-04  AT NODE  4
NODE NO.                    TEMPERATURE   (DEG F)
   1 - 5        50.89          43.20          40.63          70.63          78.10
   6 - 10       80.36          89.34          59.02          45.86          61.16
  11 - 15       61.28          58.92         100.00        -459.00        -460.00

TIMEN        0.0050  DTIMEU  8.30963E-04  CSGMIN  8.74698E-04  AT NODE  4
NODE NO.                    TEMPERATURE   (DEG F)
   1 - 5        53.69          44.94          41.52          70.00          78.70
   6 - 10       81.69          87.04          61.83          46.31          59.73
  11 - 15       59.91          61.73         100.00        -459.00        -460.00

*** CONTROL CONSTANTS INPUTS ***
```

FIGURE 18 WINDA SAMPLE PROBLEM (CONTINUED)

```
STEADY STATE SOLUTION ROUTINE SELECTED (CINDSS)
INITIAL TIME-TIMEO  1
OUTPUT INTERVAL-OUTPUT  0
FINAL TIME-TIMEND  100
RADIATION SIGMA 1.71300000E-09
TIME STEP STABILITY CRITERIA-CSGFAC  1
MAXIMUM NUMBER OF ITERATIONS-NLOOP  1000
ARITHMETIC NODE RELAXATION CRITERIA-ARLXCA  1.00000000E-03
ARITHMETIC NODE DAMPING FACTOR-DAMPA  .7
DIFFUSION NODE RELAXATION CRITERIA-DRLXCA  1.00000000E-03
DIFFUSION NODE DAMPING FACTOR-DAMPD  .7

*** END OF INPUT SEQUENCE - BEGIN EXECUTION PHASE ***
```

STEADY STATE SOLUTION

```
TIMEN       1.0000  DTIMEU  0.00000E+00  CSGMIN  0.00000E+00  AT NODE  0
NODE NO.                  TEMPERATURE  (DEG F)
  1 -  5       53.69        44.94        41.52        70.00        78.70
  6 - 10       81.69        77.04        61.88        46.81        59.73
 11 - 15       59.91        61.73       100.00      -459.00      -460.00

STEADY STATE IERATIONS PERFORMED  1000  NLOOP  1000

TIMEN     100.0000  DTIMEU  0.00000E+00  CSGMIN  0.00000E+00  AT NODE  0
NODE NO.                  TEMPERATURE  (DEG F)
  1 -  5       99.86        99.43        99.23        96.83        97.94
  6 - 10       98.42       100.78       100.23        96.19        95.81
 11 - 15       95.32       100.21       100.00      -459.00      -460.00
```

FIGURE 18 WINDA SAMPLE PROBLEM (CONCLUDED)

Table XVII

"WINDA" LISTING

```
10 REM          MINI THERMAL ANALYZER PROGRAM "WINDA"
20 DIM T(40),T1(40),C(40),Q(40),G1(250),G2(250),G(250),R1(250),R
2(250),R(250),X(40),Y(40):I8=40:G8,R8=250
30 SELECT PRINT 211(95):PRINT "       MINI THERMAL ANALYZER PROGR
AM":PRINT "  LIMITED TO CONSTANT PROPERTY NETWORKS":PRINT :PRINT
"*** THERMAL NETWORK INPUTS ***":PRINT
40 S5=0:S6=1:INPUT "IS NETWORK STORED ON TAPE DRIVE 10B (1=YES,0
=NO)",S5:IF S5=0 THEN 80
50 INPUT "NETWORK FILE NUMBER",S6:SELECT TAPE 10B:REWIND :IF S6=
1 THEN 60:SKIP (S6-1) F
60 DATA LOAD "MODEL":DATA LOAD I1,I2,I3,I9,G9,R9,T(),C(),Q(),G1(
),G2(),G(),R1(),R2(),R():IF END THEN 70
70 SELECT TAPE 10A:PRINT "  NETWORK FROM FILE ";S6;" WAS SUCCESS
FULLY LOADED":PRINT
80 PRINT "  NODE DATA BLOCK":IF S5=1 THEN 140:INPUT "NUMBER OF D
IFFUSION,ARITHMETIC,AND BOUNDARY NODES",I1,I2,I3
90 I9=I1+I2+I3:IF I9[=I8 THEN 100:PRINT "MAXIMUM NODE CAPABILITY
 ";I8;" EXCEEDED, WILL TERMINATE":GOTO 1320
100 SELECT PRINT 005:IF I1]0 THEN 110:PRINT "WARNING, THIS NETWO
RK DOES NOT HAVE ANY DIFFUSION NODES":GOTO 120
110 FOR I=1 TO I1:PRINT "DIFFUSION NODE ";I:INPUT "INITIAL TEMP,
CAPACITANCE",T(I),C(I):NEXT I
120 IF I2=0 THEN 130:FOR I=(I1+1) TO (I1+I2):SELECT PRINT 005:PR
INT "ARITHMETIC  NODE ";I:INPUT "INITIAL TEMP",T(I):NEXT I
130 IF I3=0 THEN 140:FOR I=(I1+I2+1) TO I9:SELECT PRINT 005:PRIN
T "BOUNDARY NODE ";I:INPUT "CONSTANT TEMP",T(I):NEXT I
140 SELECT PRINT 211(95):G0=0:INPUT "DETAILED NODE DATA PRINTOUT
 DESIRED (1=YES,0=NO)",G0:IF G0=0 THEN 200:IF I1=0 THEN 180:FOR
I=1 TO I1:PRINTUSING 150,I,T(I),C(I):NEXT I
150 %NODE ## DIFF   INIT TEMP -#####.##   CAP -#.######!!!!
160 %NODE ## ARITH  INIT TEMP -#####.##
170 %NODE ## BOUN  CONST TEMP -#####.##
180 IF I2=0 THEN 190:FOR I=(I1+1) TO (I1+I2):PRINTUSING 160,I,T(
I):NEXT I
190 IF I3=0 THEN 200:FOR I=(I1+I2+1) TO I9:PRINTUSING 170,I,T(I)
:NEXT I
200 PRINT "NUMBER OF NODES DIFF ";I1;"ARITH ";I2;" BOUNDARY ";I3
;" TOTAL ";I9
210 PRINT :PRINT "  CONDUCTOR DATA BLOCK":PRINTUSING 220
220 %        TYPE       NA        NB       CONDUCTOR VALUE
230 IF (R9+2)]R8 THEN 360:IF (G9+2)]G8 THEN 360:I=0:J=0:G0=0:INP
UT "CONDUCTOR DATA -NA,NB,GV- TO TERMINATE INPUT ENTER A ZERO NO
DE PAIR",I,J,G0
240 IF I=0 THEN 370:IF J=0 THEN 370:IF I]I9 THEN 330:IF J]I9 THE
N 330:IF ABS(I)=ABS(J) THEN 340:IF G0[0 THEN 270
250 IF I[0 THEN 260:G9=G9+1:G1(G9)=I:G2(G9)=ABS(J):G(G9)=G0
260 IF J[0 THEN 290:G9=G9+1:G1(G9)=J:G2(G9)=ABS(I):G(G9)=G0:GOTO
290
```

Table XVII

"WINDA" LISTING (continued)

```
270 IF I[0 THEN 350:IF J[0 THEN 350
280 R9=R9+1:R1(R9)=I:R2(R9)=J:R(R9)=ABS(G0):R9=R9+1:R1(R9)=J:R2(
R9)=I:R(R9)=ABS(G0):GOTO 300
290 PRINTUSING  310,I,J,G0:GOTO 230
300 PRINTUSING  320,I,J,ABS(G0):GOTO 230
310 %*NEW*  LIN      -##       -##       -#.######!!!!
320 %*NEW*  RAD      -##       -##       -#.######!!!!
330 SELECT PRINT 005:PRINT "NODE NUMBER NOT INPUT ,CONDUCTOR IGN
ORED":SELECT PRINT 211(95):GOTO 230
340 SELECT PRINT 005:PRINT "NA=NB, CONDUCTOR IGNORED" :SELECT PR
INT 211(95):GOTO 230
350 SELECT PRINT 005:PRINT "RADIATION CONDUCTORS CAN NOT BE ONE
WAY CONNECTIONS, CONDUCTOR IGNORED" :SELECT PRINT 211(95):GOTO 2
30
360 SELECT PRINT 005:PRINT "NUMBER OF LINEAR OR RADIATION HEAT T
RANSFER PATHS EXCEED PROGRAM LIMITS (";G8;R8;"), WILL TERMINATE"
 :GOTO 1320
370 G0=0:INPUT "DETAILED NETWORK PRINTOUT DESIRED (1=YES,0=NO)",
G0:IF G0=0 THEN 440
380 PRINT :PRINT "  NETWORK HEAT TRANSFER PATHS":PRINTUSING 390
390 %EDIT NO.  TYPE   NA(G1/R1)  NB(G2/R2)    VALUE(G/R)
400 %G    ###    LIN        ##           ##         -#.######!!!!
410 %R    ###    RAD        ##           ##         -#.######!!!!
420 IF G9=0 THEN 430:FOR I=1 TO G9:PRINTUSING 400,I,G1(I),G2(I),
G(I):NEXT I
430 IF R9=0 THEN 440:FOR I=1 TO R9:PRINTUSING 410,I,R1(I),R2(I),
R(I):NEXT I
440 PRINT "NUMBER OF HEAT TRANSFER PATHS IN NETWORK ";R9+G9;" ("
;G9;" LINEAR, ";R9;" RADIATION)"
450 PRINT :PRINT "  SOURCE DATA BLOCK"
460 I=0:INPUT "HEATING/COOLING RATES-NODE,QRATE-TO TERMINATE  IN
PUT A ZERO NODE ",I,Q0
470 IF I=0 THEN 510:IF I](I1+I2) THEN 480:Q(I)=Q(I)+Q0:GOTO 490

480 SELECT PRINT 005:PRINT "NODE NUMBER NOT RECOGNIZED ,SOURCE I
GNORED":SELECT PRINT 211(95):GOTO 460
490 PRINTUSING 500,I,Q0:GOTO 460
500 %*NEW*  SOURCE ##  VALUE -#.######!!!!
510 G0=0:INPUT "DETAILED NET HEATING RATE PRINTOUT DESIRED (1=YE
S,0=NO)",G0:IF G0=0 THEN 560:REM           END OF Q INPUTS
520 PRINT :PRINT "  NETWORK NET HEATING RATES ARRAY (Q)":PRINTUS
ING 530
530 % NODE NO.              NET HEAT RATE
540 %  ## - ##    -#.####!!!!    -#.####!!!!    -#.####!!!!    -#.##
##!!!!    -#.####!!!!
550 FOR I=1 TO (I1+I2) STEP 5:N1=I:N2=I+4:J1=Q(I):J2=Q(I+1):J3=Q
(I+2):J4=Q(I+3):J5=Q(I+4):PRINTUSING 540,N1,N2,J1,J2,J3,J4,J5:NE
XT I
560 STOP "MAKE CHANGES TO THIS NETWORK FROM DEMAND MODE, TO TERM
INATE PRESS CONTINUE"
570 S5=0:S6=1:INPUT "DO YOU WISH TO SAVE THIS NETWORK ON TAPE 10
B (1=YES,0=NO)",S5
```

Table XVII

"WINDA" LISTING (continued)

```
580 IF S5=0 THEN 610:INPUT "FILE NUMBER WHERE NETWORK IS TO BE S
AVED",S6:SELECT TAPE 10B:REWIND :IF S6=1 THEN 590:SKIP (S6-1)F
590 DATA SAVE OPEN "MODEL":DATA SAVE I1,I2,I3,I9,G9,R9,T(),C(),Q
(),G1(),G2(),G(),R1(),R2(),R():DATA SAVE END
600 SELECT TAPE 10A:PRINT :PRINT "  NETWORK SAVED TO FILE ";S6;"
 SUCCESSFULLY ":PRINT
610 FOR I=1 TO I9:T(I)=T(I)+460:T1(I)=T(I):NEXT I
620 PRINT :PRINT :PRINT "*** CONTROL CONSTANTS INPUTS ***":PRINT

630 S=0:INPUT "TYPE OF SOLUTION DESIRED,1=FORWARD DIFFERENCE(CNF
RWD) / 2=STEADY STATE(CINDSS)",S
640 IF S=1 THEN 650:IF S =2 THEN 650:GOTO 630
650 O1=0:INPUT "INITIAL TIME-TIMEO",O1
660 O2=0:INPUT "OUTPUT INTERVAL-OUTPUT",O2:IF S=1 THEN 670:O2=0

670 O3=O1+O2:INPUT "FINAL TIME-TIMEND",O3
680 R5=0:INPUT "RADIATION SIGMA",R5:IF R5]0 THEN 690:R5=.1713E-8

690 INPUT "TIME STEP STABILITY CRITERIA-CSGFAC",F1:IF F1]0 THEN
700:F1=1
700 INPUT "MAXIMUM NUMBER OF ITERATIONS-NLOOP",L1:IF L1]0 THEN 7
10:L1=1
710 INPUT "ARITHMETIC NODE RELAXATION CRITERIA-ARLXCA",A :IF A]0
 THEN 720:A=10!8
720 INPUT "ARITHMETIC NODE DAMPING FACTOR-DAMPA",A0:IF A0]0 THEN
730:A0=1
730 INPUT "DIFFUSION NODE RELAXATION CRITERIA-DRLXCA",D :IF D]0
THEN 740:D=10!8
740 INPUT "DIFFUSION NODE DAMPING FACTOR-DAMPD",D0:IF D0]0 THEN
750:D0=1
750 IF S=2 THEN 760:PRINT "FORWARD DIFFERENCE SOLUTION ROUTINE S
ELECTED (CNFRWD)":GOTO 770
760 PRINT "STEADY STATE SOLUTION ROUTINE SELECTED (CINDSS)"
770 PRINT "INITIAL TIME-TIMEO ";O1
780 PRINT "OUTPUT INTERVAL-OUTPUT ";O2
790 PRINT "FINAL TIME-TIMEND ";O3
800 PRINT "RADIATION SIGMA";R5
810 PRINT "TIME STEP STABILITY CRITERIA-CSGFAC ";F1
820 PRINT "MAXIMUM NUMBER OF ITERATIONS-NLOOP ";L1
830 PRINT "ARITHMETIC NODE RELAXATION CRITERIA-ARLXCA ";A
840 PRINT "ARITHMETIC NODE DAMPING FACTOR-DAMPA ";A0
850 PRINT "DIFFUSION NODE RELAXATION CRITERIA-DRLXCA ";D
860 PRINT "DIFFUSION NODE DAMPING FACTOR-DAMPD ";D0
870 PRINT :PRINT "*** END OF INPUT SEQUENCE - BEGIN EXECUTION PH
ASE ***":PRINT
880 SELECT PRINT 005:PRINT HEX(03):PRINT :PRINT :PRINT :PRINT :P
RINT :PRINT "MINI SINDA IS NOW IN ITS EXECUTION PHASE, PLEASE BE
 VERY PATIENT":SELECT PRINT 211(95)
890 O9=O1:O4=O1:F3,F2,F9=0:REM CALCULATE CSGMIN
900 IF S=2 THEN 970:IF O9=O1 THEN 910:IF R9=0 THEN 970
910 FOR I=1 TO I1:X(I)=0:IF G9=0 THEN 920:FOR J=1 TO G9:X(G1(J))
=X(G1(J))+C(J):NEXT J
```

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Table XVII

"WINDA" LISTING (continued)

```
920 IF R9=0 THEN 930:FOR J=1 TO R9:P1=T1(R1(J)):P2=T1(R2(J)):G0=
R5*R(J)*(P1+P2)*(P1*P1+P2*P2):X(R1(J))=X(R1(J))+G0:NEXT J
930 X(I)=C(I)/X(I):IF I]1 THEN 940:F2=X(1):F9=1
940 IF X(I)]F2 THEN 950:F2=X(I):F9=I
950 NEXT I:F3=F2:F2=.95*F2/F1
960 IF F2]0 THEN 970:PRINT : PRINT :PRINT "TIME STEP LESS THAN O
R EQUAL TO ZERO, WILL TERMINATE":GOSUB 1250:GOTO 1320
970 IF O9[]O4 THEN 990:GOSUB 1250:O4=O9+O2:IF O4[O3 THEN 980:O4=
O3
980 IF S=2 THEN 1060:IF O9=O3 THEN 1240
990 F=F2:IF (O9+F2)[O4 THEN 1000:F=O4-O9
1000 O9=O9+F:O8=O9-(.5*F): REM O8=TIMEM  VARBL1 OPS FOLLOW THIS
LINE
1010 REM      FORWARD DIFFERENCE DIFFUSION NODES
1020 FOR I=1 TO I1:X(I)=0.:IF G9=0 THEN 1040:FOR J=1 TO G9
1030 P1=G1(J):P2=G2(J):X(P1)=X(P1)+(G(J)*(T1(P2)-T1(P1))):NEXT J

1040 IF R9=0 THEN 1050:FOR J=1 TO R9:P1=T1(R1(J)):P2=T1(R2(J)):G
0=R5*R(J)*(P1+P2)*(P1*P1+P2*P2):X(R1(J))=X(R1(J))+(G0*(P2-P1)):N
EXT J
1050 X(I)=X(I)+Q(I):T(I)=T1(I)+(F*X(I)/C(I)):NEXT I:FOR I=1 TO I
1:T1(I)=T(I):NEXT I
1060 L=0:REM      STEADY STATE ITERATIONS
1070 L2=+1:IF (L+1)]L1 THEN 1220:L=L+1
1080 IF S=1 THEN 1150:REM       DIFFUSION NODES
1090 IF I1=0 THEN 1150:FOR I=1 TO I1:X(I)=0:Y(I)=0:IF G9=0 THEN
1110:FOR J=1 TO G9
1100 P1=G1(J):P2=G2(J):X(P1)=X(P1)+(T1(P2)*G(J)):Y(P1)=Y(P1)+G(J
):NEXT J
1110 IF R9=0 THEN 1120:FOR J=1 TO R9:P1=T1(R1(J)):P2=T1(R2(J)):G
0=R5*R(J)*(P1+P2)*(P1*P1+P2*P2):X(R1(J))=X(R1(J))+(G0*P2):Y(R1(J
))=Y(R1(J))+G0:NEXT J
1120 T(I)=(X(I)+Q(I))/Y(I):T(I)=D0*T(I)+((1-D0)*T1(I))
1130 IF ABS(T(I)-T1(I))[D THEN 1140:L2=-1
1140 NEXT I:FOR I=1 TO I1:T1(I)=T(I):NEXT I
1150 IF I2[=0 THEN 1220:REM     ARITHMETIC NODES
1160 FOR I=(I1+1) TO (I1+I2):X(I)=0:Y(I)=0:IF G9=0 THEN 1180:FOR
J=1 TO G9
1170 P1=G1(J):P2=G2(J):X(P1)=X(P1)+(T1(P2)*G(J)):Y(P1)=Y(P1)+G(J
):NEXT J
1180 IF R9=0 THEN 1190:FOR J=1 TO R9:P1=T1(R1(J)):P2=T1(R2(J)):G
0=R5*R(J)*(P1+P2)*(P1*P1+P2*P2):X(R1(J))=X(R1(J))+(G0*P2):Y(R1(J
))=Y(R1(J))+G0:NEXT J
1190 T(I)=(X(I)+Q(I))/Y(I):T(I)=A0*T(I)+((1-A0)*T1(I))
1200 IF ABS(T(I)-T1(I))[A THEN 1210:L2=-1
1210 NEXT I:FOR I=(I1+1) TO (I1+I2):T1(I)=T(I):NEXT I
1220 IF L2]0 THEN 1230:GOTO 1070:REM END OF ITERATION/TIME STEP
1230 IF S=1 THEN 900:PRINT :PRINT :PRINT "STEADY STATE IERATIONS
 PERFORMED ";L;" NLOOP ";L1:O9=O3:GOSUB 1250
1240 N0=0:INPUT "DO YOU WISH TO CONTINUE THE PROBLEM WITH THIS N
ETWORK AT THE FINAL TEMPERATURES (1=YES,0=NO)",N0:IF N0=1 THEN 6
```

Table XVII

"WINDA" LISTING (CONCLUDED)

```
20: SELECT PRINT 005:END
1250 REM OUTPUT SUBROUTINE
1260 SELECT PRINT 211(95)
1270 PRINT :PRINT :PRINTUSING 1280,09,F2,F3,F9:PRINTUSING 1290
1280 %TIMEN -#####.####  DTIMEU -#.######!!!!  CSGMIN -#.######!!!
!  AT NODE ##
1290 %NODE NO.                  TEMPERATURE  (DEG F)
1300 FOR I=1 TO I9 STEP 5:N1=I:N2=I+4:J1=T(I)-460:J2=T(I+1)-460:
J3=T(I+2)-460:J4=T(I+3)-460:J5=T(I+4)-460:PRINTUSING 1310,N1,N2,
J1,J2,J3,J4,J5:NEXT I:RETURN
1310%  ## - ##    -#####.##    -#####.##    -#####.##    -#####.
##    -#####.##
1320 REM ERROR TERMINATION OUTPUT
1330 SELECT PRINT 005
1340 END
```

APPENDIX A

ADJUSTED TEST DATA

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APPENDIX A

The raw test data was modified and corrected to produce the adjusted test data shown in Table A-1. The raw data was read and hand recorded from real time recording instruments during the test. Instrumentation and human factors combined to produce some readings that were in error, fortunately computer generated plots of the data were available and were used to eliminate the errors involved. The computer plots gave a better picture of when a particular test point had actually reached steady state conditions indicating the time when meaningful data could be taken. Computer generated plots also resolved an anomaly in the data involving the measured air outlet dew point, which was consistently higher than the measured outlet dry bulb temperatures; a condition which was impossible. If this condition did exist, then the water vapor would instantly condense and it would effectively be raining inside the ducting at the HX outlet. This was not observed to happen, therefore, there had to be a error somewhere. Checking the computer plots indicated that the outlet dew point reading was unstable and inaccurate and the air outlet dew point was then assumed to be equal to the dry bulb temperature for further analysis.

TABLE A-1

REDUCED TEST RESULTS

TEST POINT	AIR SIDE CONDITIONS					COOLANT SIDE CONDITIONS					
	FLOW (CFM)	T(°F)		TDP (°F)		[illegible] FLOW (LB/HR)	T(°F)		LiC FLOW (LB/HR)	T(°F)	
		IN	OUT	IN	OUT		IN	OUT		IN	OUT
1	100	79.1	42.04	45.5	42.04	750	42.0	47.8	-	-	-
2	142.3	73.93	45.60	47.0	45.60	"	45.42	52.37	-	-	-
3	199.25	78.7	45.2	46.5	45.2	"	44.50	54.40	-	-	-
4	294.50	80.0	46.4	47.5	46.4	"	44.2	58.80	-	-	-
5	100.00	82.6	44.85	52.9	44.85	"	44.8	51.60	-	-	-
6	191.50	77.4	46.1	54.0	46.1	"	45.0	56.00	-	-	-
7	298.70	82.50	49.8	54.0	49.8	"	46.50	61.80	-	-	-
8	99.70	82.5	45.6	65.0	45.6	"	45.50	54.90	-	-	-
9	199.80	79.0	46.70	59.0	46.70	"	45.0	58.86	-	-	-
10	299.7	84.0	53.8	61	53.8	"	49.0	66.30	-	-	-
11	298.70	84.0	54.15	54.4	54.14	350	45.0	72.00	-	-	-
12	297.80	84.0	49.05	52.00	49.05	750	46.0	62.10	-	-	-
13	297.50	84.0	52.5	53.00	52.50	400	45.0	70.2	-	-	-
14	297.60	84.0	50.25	54.0	50.25	600	45.0	65.10	-	-	-
15	99.90	84.0	44.03	45.50	44.03	-	-	-	750	44.0	49.9
16	192.40	77.8	45.25	46.0	45.25	-	-	-	750	44.7	53.92
17	297.5	82.10	46.9	47.5	46.9	-	-	-	750	44.8	57.70
18	100.4	84.0	44.55	55	45.55	-	-	-	750	44.5	52.30
19	198.8	77.7	45.6	51	45.6	-	-	-	750	44.5	55.25
20	296.4	81.8	48.1	51.5	48.1	-	-	-	750	45	60.60
21	100.3	84.0	44.25	61.5	44.25	-	-	-	750	44.2	53.10
22	191.6	82.5	47.0	61.0	47.0	-	-	-	750	45.25	60.25
23	297.6	84.0	55.0	62.0	55.0	-	-	-	750	50.25	67.00
24	290.5	83.8	52.20	53.0	50.2	-	-	-	400	45	69.90
25	290.5	82.8	49.1	51.5	49.1	-	-	-	600	45	63.60
26	100.0	82.5	45.03	47.0	45.03	375	45.0	52.7	375	45.0	48.70
27	200.0	80	45.4	45.5	45.4	"	45.0	57.0	"	45.0	52.50

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C-2

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TABLE A-1

REDUCED TEST RESULTS

TEST POINT	AIR SIDE CONDITIONS FLOW (CFM)	T(°F)		Tdp (°F)		COOLANT SIDE CONDITIONS PRI FLOW (LB/HR)	PRI T(°F)		SEC FLOW (LB/HR)	SEC T(°F)	
		IN	OUT	IN	OUT		IN	OUT		IN	OUT
28	300	82.5	48.9	48.9	48.9	375	47.0	64.50	375	47.0	59.00
29	102.5	82.5	44.65	52.0	44.65	"	44.6	53.30	"	44.6	49.80
30	194.9	77.2	45.6	52.5	45.6	"	44.0	57.25	"	45.0	54.25
31	299.6	82.5	49.3	52.0	49.3	"	46.0	63.50	"	46.9	59.90
32	97.6	83	45.04	61	45.04	"	45.0	56.05	"	45.0	51.90
33	199.3	80.0	47.15	60.0	47.15	"	45.2	61.4	"	45.2	57.8
34	299.3	82.5	55.6	62.0	55.6	"	51.0	68.8	"	51.0	65.0
35	295.5	82.7	50.15	52.0	50.15	250	44.0	67.9	250	45.0	64.5
36	295.5	83	50.7	53.0	50.7	300	45.8	66.8	300	47.0	63.0
37	295.5	83.3	50.8	52.5	50.8	400	48.4	64.4	400	49.0	60.4
38	187.2	79.4	45.75	53.0	45.75	375	45.0	57.9	375	45.0	54.6
39	189.25	78.8	45.55	53.0	45.55	"	44.0	57.20	"	45.0	54.50
40	102.25	82.5	44.54		46.25	750	44.5	50.25	-	-	-
41	190	78.5	45.55	53.5	45.55	375	44.0	57.6	375	44.9	54.30

APPENDIX B

DATA REDUCTION TECHNIQUE

B.1 General condensing HX solution and HA data provided by HSD

B.2 Listing of computer program used to reduce test data

B.3 Results of applying data reduction program to test points

APPENDIX B

B.1

Presented here is a description of the analytical method used to determine from the adjusted test data values for the hot side and cold side film coefficients for the RSECS condensing heat exchanger.

Analysis by Hamilton Standard produced two curves predicting values for both hot and cold side film coefficients as a function of flow rates as shown in Figures B2 and B3. Results of the procedure presented below were used to verify these predictions. The HX is imagined to be made up of two portions one wet and one dry. The wet portion is where all the condensing is assumed to occur and the dry portion is assumed to have no condensing. As air passes thru the HX the wall temperature drops until it equals the inlet dew point temperature (dry portion) and as the wall temperature continues to drop water condenses out of the air stream (wet portion) as shown in Figure B1. The point where the wall temperature reaches the inlet air dew point is called the heat exchanger Pinch Point and is the dividing line between wet and dry portions. The analysis starts by assuming that one of the predicted film coefficient surves is correct and proceeds to calculate the other curve.

Test results for a particular test point for air and coolant inlet and outlet temperatures and flow rates are combined with a value for film coefficient from curve B2 or B3 to find the air and coolant temps at the pinch point and the overall heat transfer coefficient for the dry portion of the heat exchanger.

The calculated condensate flow rate is then combined with the test data and the assumed film coefficient to find the overall heat transfer coefficient for the wet side only. These two coefficients are combined to form an overall heat transfer coefficient and then the hot side film coefficient is broken out of this overall number. This calculated value of hot side film coefficient is compared with the original assumption. If the value is the same then it is the final answer; otherwise, this new value is used as a new guess and the procedure is repeated until there is no change.

A similar procedure is followed for all the test points in order to generate a curve of air side film coefficient vs. flow rate. This calculated curve is then assumed correct and the procedure is repeated to generate a curve for coolant side film coefficient vs. flow. This process of assuming one curve correct and calculating the other continues until there was no change in the curve from one iteration to the next. The resulting two curves are then the ones to be used in the heat exchanger performance prediction procedure. (see Appendix C)

CONDENSING HX CALCULATION PROCEDURE:

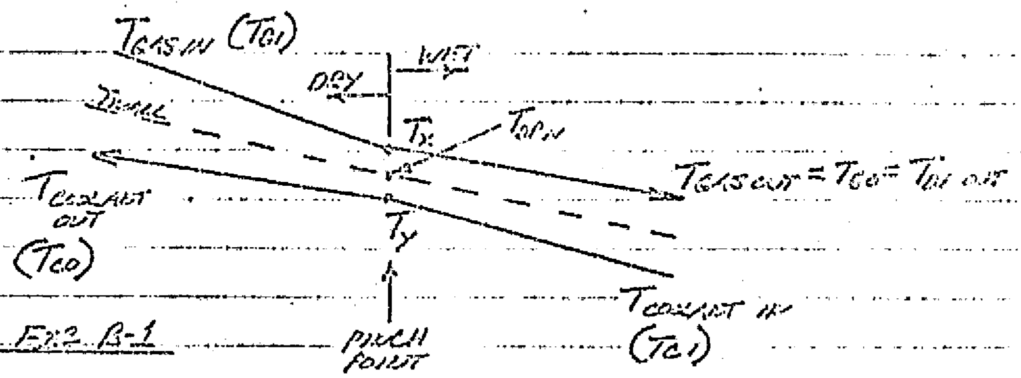

FIG B-1

OBTAIN hA_C (hA_H) FROM CHART (SEE NOTE #1)

ASSUME VALUE FOR hA_H (hA_C)

FIND AIR & COOLANT TEMPS AT PINCH POINT:

$$T_X = \frac{(\dot{w}c_p)_H (T_{GI}) + (\dot{w}c_p)_C \left[\frac{hA_H}{hA_C} T_{DPIN} - (T_{CO} - T_{DPIN})\right]}{\frac{hA_H}{hA_C} (\dot{w}c_p)_C + (\dot{w}c_p)_H}$$

(AIR)

$$T_Y = T_{DPIN} - \frac{hA_H}{hA_C}(T_X - T_{DPIN})$$

(COOLANT)

FIND $\mathcal{E}_{DRY}$, M_{DRY}, K_{DRY} AND $(UA)_{DRY}$:

$$\mathcal{E}_{DRY} = \frac{T_{GI} - T_X}{T_{GI} - T_Y}$$ (EFFECTIVENESS)

$$M_{DRY} = \frac{(\dot{w}c_p)_C}{(\dot{w}c_p)_H}$$ (HEAT FLOW RATIO)

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APPENDIX B.1

NOTE #2

TO FIND $\dot{W}$ CONDENSATE FOR A GIVEN TEST POINT FOLLOW PROCEDURE GIVEN HERE:

FROM STEAM TABLES FIND INLET AND OUTLET AIR STREAM SATURATION PRESSURES

$$P_{S\,IN} = f(T_{DPIN})$$
$$P_{S\,OUT} = f(T_{DPOUT}) = f(T_{GO})$$

THEN FIND ω_{IN}, ω_{OUT}

$$\omega_{IN} = \frac{(.622)\,P_{S\,IN}}{14.69 - P_{S\,IN}} \qquad \omega_{OUT} = \frac{(.622)\,P_{S\,OUT}}{14.69 - P_{S\,OUT}}$$

FIND AIR MASS FLOW

$$\dot{M}_{AIR} = \frac{P\dot{V}_{AIR}}{RT} = \frac{(14.69)(CFM)(144)(60)}{(53.3)(T_{GI}+460)} \left(\frac{LB}{HR}\right)$$

THEN:

$$\boxed{\dot{W}_{COND} = \dot{M}_{AIR}\,(\omega_{IN} - \omega_{OUT})}$$

APPENDIX B.1

NOTE #1

TO DETERMINE hA_c FOLLOW PROCEDURE DESCRIBED HERE:

SINGLE COOLANT LOOP

- FIND W/2 (W = TOTAL COOLANT SIDE FLOW)
- WITH W/2 READ h_c FROM CURVE B2

THEN:

$$hA_c = h_c \times \frac{27}{2} (.5408)$$

DOUBLE COOLANT LOOP

- FIND W/4
- WITH W/4 READ h_c FROM CURVE B2

THEN:

$$hA_c = h_c \times 27 (.5408)$$

TO DETERMINE hA_H DO THE FOLLOWING

SINGLE COOLANT LOOP:

- FIND VELOCITY = CFM/.8815 (CFM = FLOW IN CFM)
- WITH VELOCITY READ $\eta_o h_o$ FROM CURVE B3

THEN: $hA_H = \eta_o h_o (313)(.5408)(.7)$

DOUBLE COOLANT LOOP:

SAME AS ABOVE EXCEPT $hA_H = \eta_o h_o (313)(.5408)(.8)$

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UA_{DRY} – OVERALL HEAT TRANSFER COEFFICIENT DRY PORTION

UA_{WET} – OVERALL HEAT TRANSFER COEFFICIENT WET PORTION

Q_S – SENSIBLE HEAT WET PORTION

Q_L – LATENT " " "

Q_T – TOTAL " " "

UA^{SENS}_{WET} – OVERALL HEAT TRANSFER COEFFICIENT FOR WET SECTION FOR SENSIBLE HEAT TRANSFER ONLY

UA_{TOTAL} – OVERALL HEAT TRANSFER COEFFICIENT FOR COMBINED WET & DRY PORTIONS

DEFINITION OF SYMBOLS

TEST DATA INPUTS

T_{GI} – INLET GAS TEMPERATURE (°F)
T_{GO} – OUTLET " " (°F)
T_{DPIN} – INLET GAS DEW POINT (°F)
T_{DPOUT} – OUTLET " " " (°F)

T_{CI} – INLET COOLANT TEMP (°F)
T_{CO} – OUTLET " " (°F)

$(\dot{W}C_P)_C$ – COOLANT SIDE (FLOW RATE)·(SPECIFIC HEAT)
$(\dot{W}C_P)_H$ – AIR " " " " "

CALCULATED VALUES

T_X – AIR TEMP AT PINCH POINT (°F)
T_Y – COOLANT " " " " (°F)
hA_H – AIR SIDE FILM COEFFICIENT·AREA $\left(\frac{BTU}{HR\ °F}\right)$
hA_C – COOLANT " " " " "
ε_{DRY} – HX EFFECTIVENESS DRY PORTION
ε_{WET} – " " WET "
M_{DRY} – HEAT FLOW RATIO DRY PORTION
M_{WET} – " " " WET "
K_{DRY} – NTU FOR DRY PORTION
K_{WET} – " " WET "

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CHECK hA_H ASSUMPTION

$$\frac{1}{UA_{TOTAL}} = \frac{1}{hA_C} + \frac{1}{hA_H}$$

$$hA_H = \frac{1}{\frac{1}{UA_{TOTAL}} - \frac{1}{hA_C}}$$

CHECK THIS CALCULATED VALUE OF hA_H AGAINST INITIAL VALUE; IF THEY DO NOT AGREE THEN USE NEW VALUE OF hA_H AND REPEAT ENTIRE PROCESS. CONTINUE UNTIL AGREEMENT IS WITHIN ACCEPTABLE RANGE.

A SIMILAR APPROACH IS USED TO CALCULATE A VALUE FOR hA_C WHEN hA_H IS ASSUMED TO BE KNOWN.

FIND ε_{WET}, M_{WET}, K_{WET} AND $(UA)_{WET}$:

$$\varepsilon_{WET} = \frac{T_{CO} - T_{CI}}{T_X - T_{CI}}$$

$$M_{WET} = \frac{M_{DRY}}{Q_T / Q_S}$$

USE COUNTERFLOW HX EFFECTIVENESS CHARTS TO FIND VALUE OF K_{WET}

$$UA_{WET} = (wc_p)_H \left(\frac{Q_T}{Q_S}\right)(K_{WET})$$

FIND VALUE OF $UA_{SENS\ WET}$ AND UA_{TOTAL}

$$\frac{UA_{SENS\ WET}}{UA_{WET}} = \frac{1}{1 + \frac{hA_C}{hA_H}} + \frac{1}{Q_T/Q_S} \cdot \frac{hA_C/hA_H}{1 + hA_C/hA_H}$$

$$UA_{SENS\ WET} = (UA_{WET})\left(\frac{UA_{SENS\ WET}}{UA_{WET}}\right)$$

$$UA_{TOTAL} = UA_{DRY} + UA_{SENS}$$

USE COUNTER FLOW HX EFFECTIVENESS CHART (FIG 6?)
TO FIND VALUE OF $K_{DRY} \equiv NTU$ FOR HX

THEN FIND UA_{DRY}:

$$UA_{DRY} = (\dot{W}C_P)_H (K_{DRY})$$

THIS COMPLETES DRY SECTION ANALYSIS

WET SECTION

FIND $Q_{SENSIBLE}$, Q_{LATENT}, Q_{TOTAL} FOR WET SECTION

$$Q_S = (\dot{W}C_P)_H (T_X - T_{GO})$$

$$Q_L = (\dot{W}_{COND})(h_{fg})$$ (SEE NOTE #8 FOR CALCULATION OF $\dot{W}_{COND}$)

WHERE $\dot{W}_{COND}$ IS A FUNCTION OF AIR FLOW RATE PRESSURE AND TEMP. CHANGE FROM INLET TO OUTLET.

$$Q_T = Q_S + Q_L$$

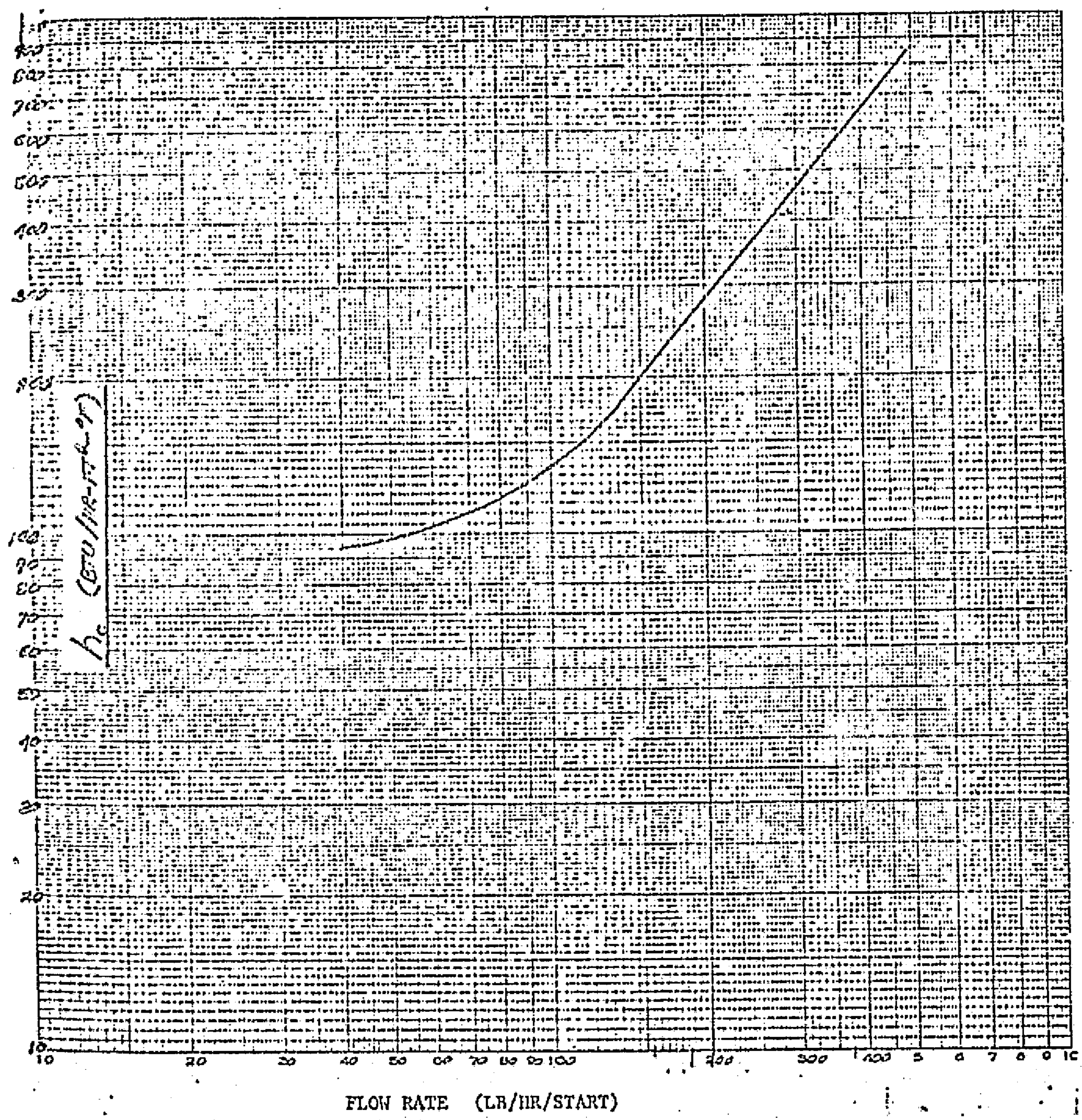


FIGURE B-2 350-M HEAT EXCHANGER PREDICTED COOLANT SIDE FILM COEFFICIENT VS FLOW

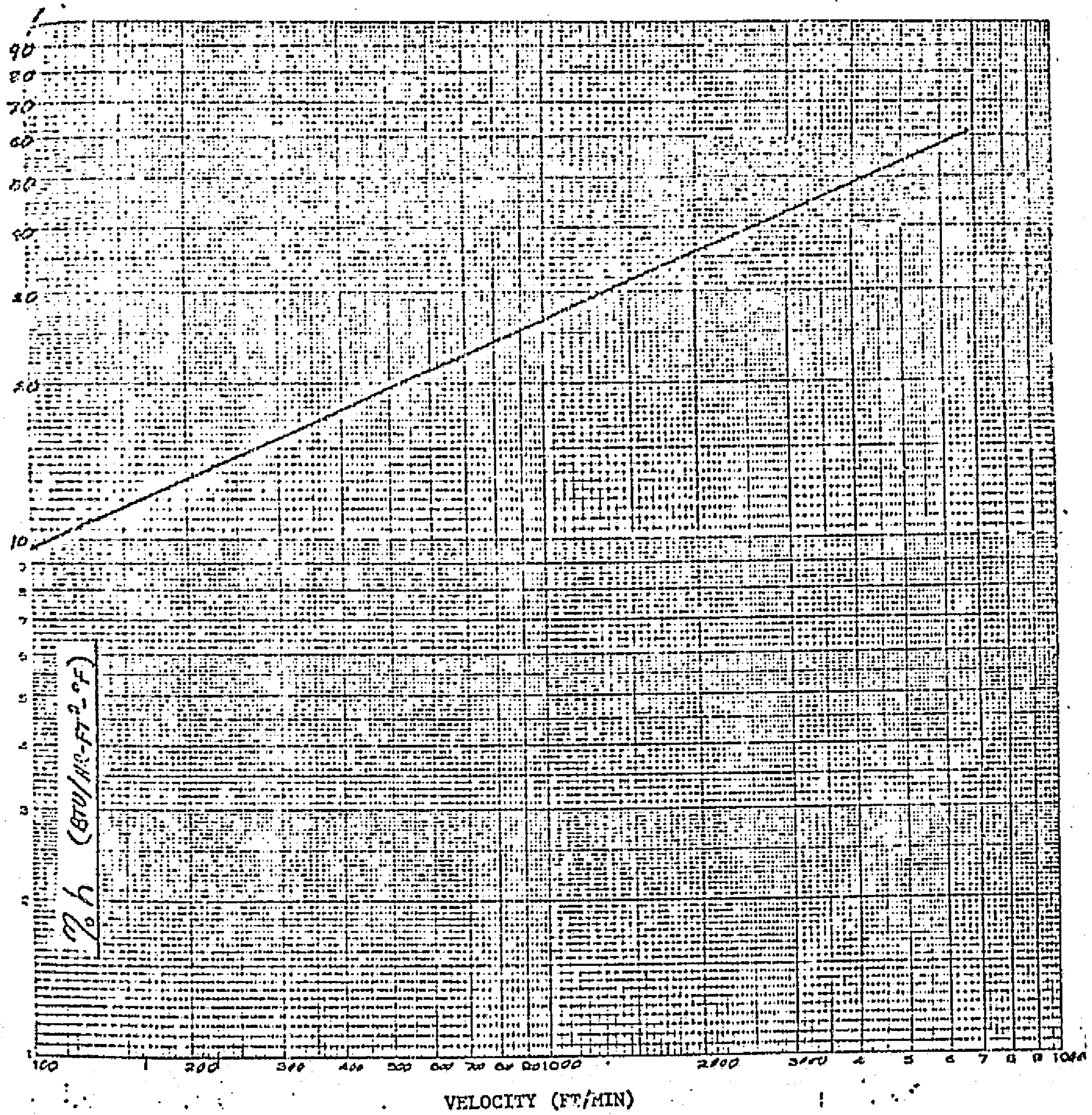


FIGURE B-3 350-M CONDENSING HEAT EXCHANGER AIR SIDE FILM COEFFICIENT VS AIR FLOW

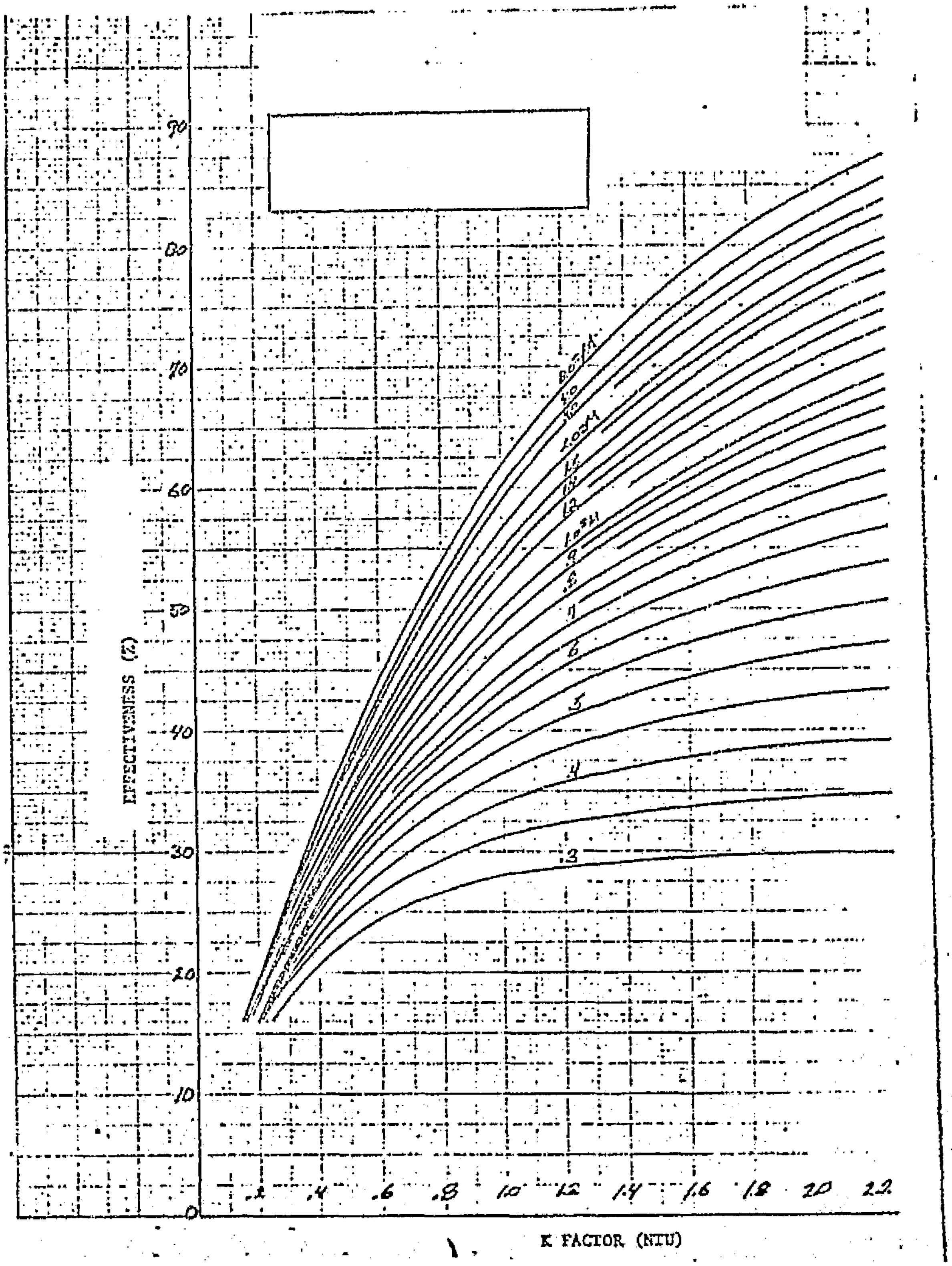
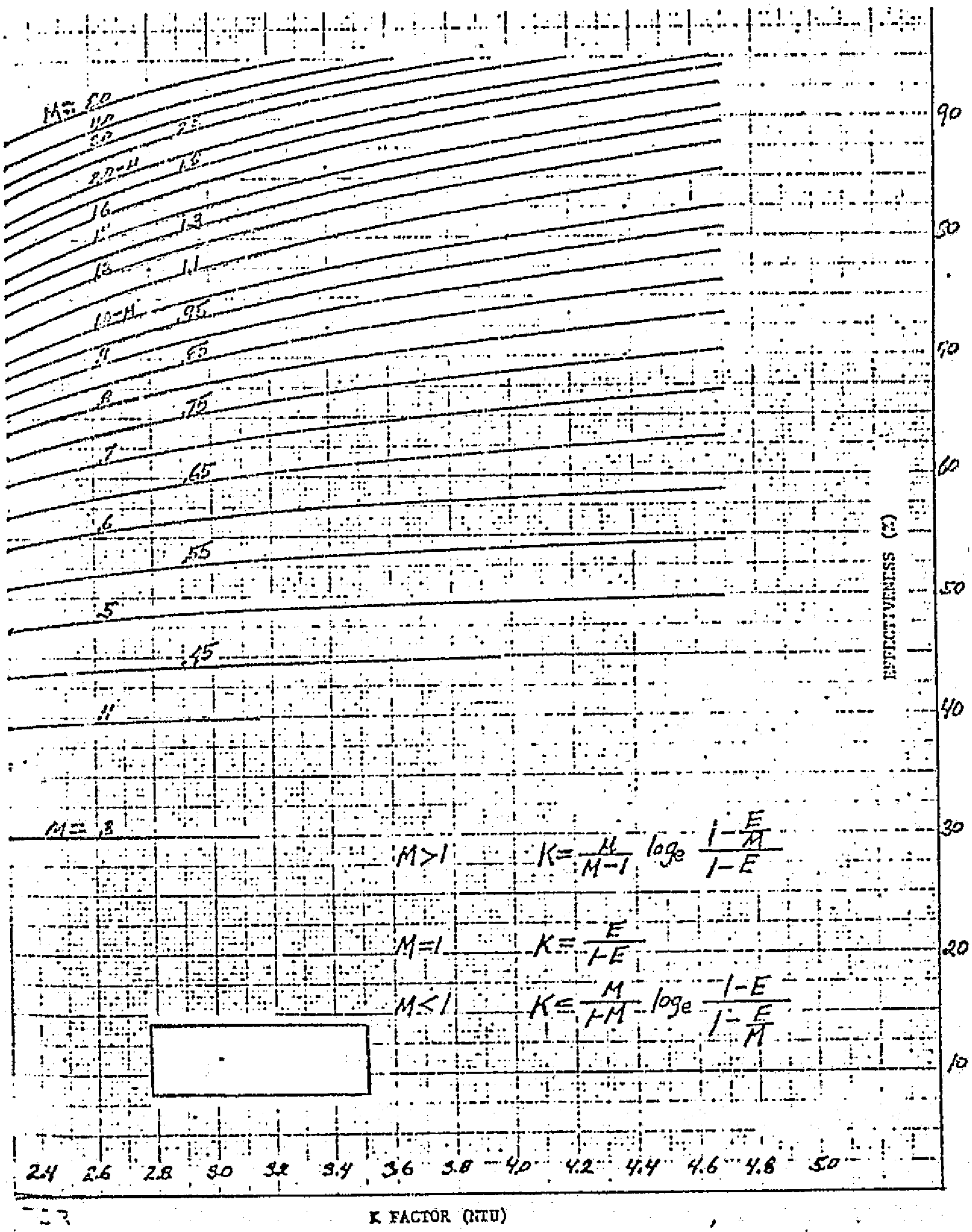


FIGURE B-4 EFFECTIVENESS CHART FOR COUNTER FLOW HEAT EXCHANGER



$M>1 \quad K=\frac{M}{M-1}\log_e\frac{1-\frac{E}{M}}{1-E}$

$M=1 \quad K=\frac{E}{1-E}$

$M<1 \quad K=\frac{M}{1-M}\log_e\frac{1-E}{1-\frac{E}{M}}$

FIGURE B-4 CONTINUED

APPENDIX B.2

LISTING OF COMPUTER PROGRAM USED IN DATA REDUCTION

```
10   REM - 350-M HX PERFORMANCE:
     DIM A(50,14),X(200),Y(3):
     IF Y(1)]1 THEN 150: Y(1)=1
20   REM - WATER VAPOR PROPERTIES - TEMPERATURE (1):
     DATA 32,34,36,38,40,42,44,46,48,50,52,54,56,58,60,62,64,66,
          68,70
30   REM - WATER VAPOR PROPERTIES - PRESSURE (21):
     DATA .08854,.09603,.10401,.11256,.1217 ,.1315 ,.14199,
          .15323,.16525,.17811,.19182,.20642,.222  ,.2386
40   DATA .2563 ,.2751 ,.2951 ,.3164 ,.339  ,.3631:
     REM - WATER VAPOR PROPERTIES - ENTHALPY (41):
     DATA 1075.8,1074.7,1073.6,1072.4,1071.3,1070.1,1068.9
50   DATA 1067.8,1066.7,1065.6,1064.4,1063.3,1062.2,1061  ,
          1059.9,1058.8,1057.6,1056.5,1055.5,1054.3:
     REM - WATER SIDE FILM COEFFICIENT (61)
60   DATA 9  ,0  ,100,150,200,250,300,350,400,450,500,134,198,
          282,370,463,560,655,765,860:
     REM - AIR SIDE FILM COEFFICIENT (81)
70   DATA 13  ,0   ,100 ,200 ,300 ,400 ,500 ,600 ,700 ,800 ,
          900 ,1000,1100,1200,1300,9.6 ,13.2,15.6,17.7,19.5,
          21.2,22.6,24  ,25.3,26.4,27.5,28.5,29.6
80   INPUT "# OF CASES      (1-50) = ",Y(2):
     INPUT "DATE                   = ",A$:
     INPUT "HT BAL (HOT=1/COLD=2)  = ",Y(3)
90   FOR Z=1 TO Y(2): SELECT PRINT 005:
     PRINT "CASE #                 = ";Z
100  INPUT "T "S-11 IN     (DEG F) = ",A(Z,1):
     INPUT "T "S-11 DEWPT  (DEG F) = ",A(Z,2):
     INPUT "T 350-M IN     (DEG F) = ",A(Z,3)
110  INPUT "T 350-M DEWPT  (DEG F) = ",A(Z,4):
     INPUT "T 350-° OUT    (DEG F) = ",A(Z,5):
     INPUT "ARS OUTLET FLOW (CFM)  = ",A(Z,6)
120  INPUT "RS-51 FLOW      (CFM)  = ",A(Z,7):
     INPUT "P CHAMBER     (IN HG)  = ",A(Z,8):
     INPUT "T PRI H2O IN  (DEG F)  = ",A(Z,9)
130  INPUT "T SEC H2O IN  (DEG F)  = ",A(Z,10):
     INPUT "T PRI H20 OUT (DEG F)  = ",A(Z,11):
     INPUT "T SEC H20 OUT (DEG F)  = ",A(Z,12)
140  INPUT "PRI H20 FLOW  (LB/HR)  = ",A(Z,13):
     INPUT "SEC H20 FLOW  (LB/HR)  = ",A(Z,14):
     NEXT Z
150  IF Y(1)[=Y(2) THEN 160P Y(1)=0: GOTO 610
160  FOR Z=1 TO 14: X(Z)=A(Y(1),Z): NEXT Z: X(17)=X(13)+X(14):
     X(15)=(X(9)*X(13)+X(10)*X(14))/(X(13)+X(14)):
     X(16)=(X(11)*X(13)+X(12)*X(14))y(X(13)+X(14))
170  X(18)=X(17)*(X(16)-T(15)): IF X(13)=0 THEN 180:
     IF X(14)=0 THEN 180: X(30)=X(17)/4: GOTO 190
h80  X(30)=X(17)/2
```

```
h90 RESTORE 61: FOR Z=101 TO 120P READ X(Z): NEXT Z:
    GOSUB '02(X(30),0): X(31)=Z1: IF X(13)=0 THEN 200:
    IF X(14)=0 THEN 200P X(19)=27*.5408*X(31): GOTO 210
200 X(19)=27*.5408*X(31)/2
210 X(20)=X(6)+X(7): IF X(2)]0 THEN 220P X(21)=X(4): GOTO 240
220 I X(4)z0 THEN 230: X(21)=X(2): GOTO 240
230 X(21)=(X(2)+X(4))/2
240 X(101)=20: X(102)=0: RESTORE 1: FOR Z=103 TO 142P READ X(Z):
    NEXT Z: GOSUB '02(X(5),0): P1=Z1: GOSUB '02(X(21),0): P2=Z1:
    X(22)=144*60*(X(8)*.4912)*X(20)/53.35/(X(1)+459.6)
250 X(23)=.24*X(22)*(X(3)-X(5)): A3=.622*P1/(X(8)*.4912-P1):
    A2=.622*P2/(X(8)*.4912-P2): X(24)=1065*X(22)*(A2-A3):
    X(25)=(X(23)+X(24))/X(18): X(26)=X(20)y.8015
260 "ESTORE 31: FOR Z=101 TO 128: READ X(Z): NEXT Z:
    GOSUB '02(X(26),0): X(29)=Z1: X(27)=313*.5408*X(29)
270 IF X(13)=0 THEN 280: IF X(14)=0 THEN 280:
    X(27)=.8*X(27): GOTO 290
280 T(27)=.7*X(27)
290 H1=X(19): H2=X(27)
300 ON Y(3) GOTO 310,320
310 X(27)=H2: GOTO 330
320 X(19)=H1
330 H=X(27)/X(19):
    T1=(.24*X(22)*X(3)+X(17)*(H*X(21)+X(21)-X(16)))/
       (H*X(17)+.24*X(22))
340 Q1=.24*X(22)*(T1-X(5)): Q2=Q1+X(24): IF Q2ZX(18) THEN 350:
    U1=0: T2=X(16): T1=X(3): Q1=X(23): Q2=X(13): GOTO 360
350 T2=X(21)-H*(T1-X(21)): E1=(X(3)-T1)/(X(3)-T2):
    M1=X(17)/(.24*X(22)): GOSUB '01(E1,M1):
    U1=.24*X(22)*K
360 E2=(T1-X(5))/(T1-X(15)): M2=X(17)*Q1/(.24*X(22))/Q2:
    GOSUB '01(E2,M2): U2=.24*X(22)*K*Q2/Q1:
    U3=((1/H)/(1+1/H))*Q1/Q2+(1/(1+1/H)): X(28)=U1+U2*U3
370 ON Y(3) GOTO 380,400
380 H2=1/(1/X(28)-1/X(19)): IF ABS((X(27)-H2)/X(27))]=.5E-3
    THEN 300: T(29)=X(27)/313/.5408: IF X(13)=0 THEN 390:
    IF X(14)=0 THEN 390: X(29)=X(29)/.8: GOTO 420
390 X(29)=X(29)/.7: GOTO 420
000 H1=1/(1/X(28)-1/X(27)): IF ABS((X(19)-H1)/X(19))]=.5E-3
    THEN 300P IF X(13)=0 THEN 410: IF X(14)=0 THEN 410:
    X(31)=X(19)/27/.5408: GOTO 420
410 T(31)=2*X(19)/27/.5408
420 SELECT PRINT 211(156): PRINT HEX(0D0E):
    ON Y(3) JOTO 430,440
```

```
430 PRINT "RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE":
    PRINT HEX(0A):
    GOTO 450
440 PRINT "RSECS 350-M HX PERFORMANCE / COLD SIDE BALANCE":
    PRINT HEX(0A)
050 PRINT "CASE #: ";Y(1):
    PRINT "DATE  :  ";A$: PRINT HEX(0I):
    PRINT "INPUT DATA -"
460 PRINTUSING 510,X(1),X(2),X(3):
    PRINTUSING 520,X(4),X(5),X(6):
    PRINTUSING 530,X(7),X(8),X(9)
470 PRINTUSING 540,X(10),X(11),X(12):
    PRINTUSING 550,X(13),X(14):
    PRINT HEX(0A)
080 PRINT "OUTPUT DATA -":
    PRINTUSING 560,X(17),X(30),X(20):
    PRINTUSING 570,X(22),X(26),X(28)
490 PRINTUSING 580,X(19),X(31),X(27):
    PRINTUSING 590,X(29),X(23),X(24):
    PRINTUSING 600,X(18),X(25)
500 PRINT HEX(0A0I0A0I0A):
    Y(1)=Y(1)+1: GOTO 150
510 %T RS-11 INLET      =-#####.##   T RS-11 DEWPT      =-#####.##   T
 350-M INLET      =-#####.##
520 %T 350-° DEWPT      =-#####.##   T 350-° OUTLET     =-@####.##   A
RS OUTLET FLOW  =-#####.##
530 %RS-51 FLOW         =-@####.##   CHAMBER PRESSURE =-#####.##   T
 PRI H2O INLET   =-#####.##
540 %T SEC H2O INLET    =-#####.##   T PRI H2O OUTLET =-@####.##   T
 SEC H2O OUTLET =-@####.##
550 %PRI H2O FLOW       =-#####.##   SEC H2O FLOW       =-@####.##
560 %TOTAL H2O FLOW     =-#####.##   H2S FLOW/START     =-#####.##   T
OTAL AIR FLOW   =-#####.##
570 %AIR WEIGHT FLOW    =-#####.##   AIR VELOCITY       =-#####.##   T
STAL HX UA        =-#####.##
580 %COLD SIDE HA       =-#####.##   COLD FILM COEFF  =-@####.##   H
ST SIDE HA        =-#####.##
590 %HOT +ILM COEFF     =-@####.##   Q SENSIBLE         =-#####.##   Q
 HATENT            =-#####.##
600 %Q TOTAL            =-#####.##   HEAT BALANCE       =-####.###
610 END
620 DEFFN'01(E3,M3)
630 IF M3=1 THEN 640: IF M3]1 THEN 650P
    K=M3/(1-M3)*LOG((1-E3)/(1-E3/M3)): GOTO 660
640 K=E3/(1-E3): GOTO 660
650 K=M3/(M3-1)*LOG((1-E3/M3)/(1-E3))
660 RETURN
670 DEFFN'02(C1,D1)
680 DIM A1(6),X1(6),Yh(6)
690 I1=101: N=3: N2=2
```

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OF POOR QUALITY

```
500 IF X(I1)=3 THEN 740: IF X(I1)]3 THEN 750P
    IF X(I1)[0 THEN 770: IF X(I1)=0 THEN 740:
    IF X(I1)=2 THEN 720: IF X(I1)]2 THEN 740
510 N=1: GOTO 730
520 N=2
730 N2=1
740 I1=I1+1
750 N1=N+1
760 L=I1: IF X(L)]0 THEN 780
770 K1=-1: Z1=0: GOTO 1050
780 N9=X(L):
    IF X(L+1)[0 THEN 770: IF X(L+1)]0 THEN 800
590 N8=0: GOTO 810
800 N8=X(L+1)
810 K1=0: K8=0: C2=C1: J1=I1+2: J2=N9+I1+1:
    IF C2[X(J1) THEN 850P IF C2=X(J1) THEN 860
820 +OR J=J1 TO J2P IF C2Z=X(J) THEN 870: NEXT J
830 K1=2: C2=T(J2)
840 J9=J2-N: GOTO 880
850 K1=1: C2=X(J1)
860 J9=J1: GOTO 880
870 IF J-J1Z1 THEN 850: IF J-J1=1 THEN 860P
    IF J=J2 THEN 840: IF J]J2 THEN 830:
    J9=J-N2
880 C3=C2: IF N8]0 THEN 890: FOR L=1 TO N1: X1(L)=X(J9):
    L6=J9+N9: Y1(L)=T(L8): J9=J9+1: NEXT L: I=1: GOTO 970
890 J1=J1+N9P J2=J2+N6: D2=E1: IF D2[X(Jh) THEN 920P
    IF D2=X(J1) THEN 930: FOR J=J1 TO J2:
    IF D2[=X(J) THEN 940: NEXT J
900 K8=6P D2=X(J2)
910 J8=J2-N: GOTO 950
920 K8=3: D2=X(J1)
930 J8=J1: GOTO 950
940 IF J-J1[1 THEN 920P IF J-J1=1 THEN 930:
    IF J=J2 THEN 910: IF J]J2 THEN 900P J8=J-N2
950 J7=J9: L8=J8+N8¢(J7-I1-1): L7=H8: FOR L=1 TO N1:
    X1(L)=X(J7): Y1(L)=X(L7): L7=L7+N8: J7=J7+1: NEXT L:
    I=0P GOTO 970
960 Y1(1)=Z1: FOR I=1 TO N: L7=L8+I: Y1(I+1)=0P FOR M=1 TO N1:
    Y1(I+1)=Y1(I+1)+X(L7)*X1(M): L7=L7+N8: NEXT M: NEXT I:
    FOR L=1 TO N1: X1(L)=X(J8): J8=J8+1: NEXT L: C3=E2: I=1
970 D=1: X1(N+2)=X1(h): X1(N+3)=X1(2): FOR J=1 TO N1:
    A1(J+1)=T1(J+1)-X1(J): C4=C3-X1(J): IF C4[]0 THEN 990
    Zh=Y1(J): X1(1)=0: X1(2)=0: X1(3)=0P X1(4)=0
980 X1(J)=1: GOTO 1040
990 D=D*C4: ON N GOTO 1000,1010,1020
1000 X1(J)=C4/A1(J+1): GOTO 1030
h010 X1(J)=-C4: GOTO 1030
1020 X1(J)=(X1(J+2)-X1(J))*C4
1030 NEXT J: A1(1)=A1(N+2): Z1=0: FOR J=1 TO N1:
     X1(J)=D/(A1(J)*A1(J+1)*X1(J)): Z1=Z1+Y1(J)*X1(J):
     NEXT J
1040 IF I[=0 THEN 960
1050 K1=K1+K8:
     RETURN
```

APPENDIX B.3

RESULTS OF DATA REDUCTION PROGRAM

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 1
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET	=	77.30	T RS-11 DEWPT	=	45.50	T 350-M INLET	=	79.10
T 350-M DEWPT	=	45.50	T 350-M OUTLET	=	42.04	ARS OUTLET FLOW	=	92.50
RS-51 FLOW	=	7.50	CHAMBER PRESSURE	=	30.00	T PRI H2O INLET	=	42.00
T SEC H2O INLET	=	0.00	T PRI H2O OUTLET	=	47.30	T SEC H2O OUTLET	=	0.00
PRI H2O FLOW	=	750.00	SEC H2O FLOW	=	0.00			

OUTPUT DATA -

TOTAL H2O FLOW	=	750.00	H2O FLOW/START	=	375.00	TOTAL AIR FLOW	=	100.00
AIR WEIGHT FLOW	=	444.49	AIR VELOCITY	=	113.44	TOTAL HX UA	=	926.47
COLD SIDE HA	=	4429.30	COLD FILM COEFF	=	606.68	HOT SIDE HA	=	1171.88
HOT FILM COEFF	=	9.89	Q SENSIBLE	=	3953.50	Q LATENT	=	379.79
Q TOTAL	=	4350.00	HEAT BALANCE	=	0.996			

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 2
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET	=	77.30	T RS-11 DEWPT	=	47.00	T 350-M INLET	=	78.98
T 350-M DEWPT	=	47.00	T 350-M OUTLET	=	45.60	ARS OUTLET FLOW	=	137.00
RS-51 FLOW	=	5.30	CHAMBER PRESSURE	=	30.00	T PRI H2O INLET	=	45.42
T SEC H2O INLET	=	0.00	T PRI H2O OUTLET	=	52.37	T SEC H2O OUTLET	=	0.00
PRI H2O FLOW	=	750.00	SEC H2O FLOW	=	0.00			

OUTPUT DATA -

TOTAL H2O FLOW	=	750.00	H2O FLOW/START	=	375.00	TOTAL AIR FLOW	=	142.33
AIR WEIGHT FLOW	=	632.51	AIR VELOCITY	=	161.42	TOTAL HX UA	=	107[illegible].36
COLD SIDE HA	=	4429.30	COLD FILM COEFF	=	60[illegible].6[illegible]	HOT SIDE [illegible]	=	1411.53
HOT FILM COEFF	=	11.91	Q SENSIBLE	=	5067.19	Q LATENT	=	233.66
Q TOTAL	=	5212.50	HEAT BALANCE	=	1.017			

```
RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #:  3
DATE  :  7/8/75

INPUT DATA -
T RS-11 INLET     =    77.30  T RS-11 DEWPT     =    46.50  T 350-M INLET      =    73.70
T 350-M DEWPT     =    46.50  T 350-M OUTLET    =    45.20  ARS OUTLET FLOW    =   191.00
RS-51 FLOW        =     8.25  CHAMBER PRESSURE  =    30.00  T PRI H2O INLET    =    44.50
T SEC H2O INLET   =     0.00  T PRI H2O OUTLET  =    54.40  T SEC H2O OUTLET   =     0.00
PRI H2O FLOW      =   750.00  SEC H2O FLOW      =     0.00

OUTPUT DATA -
TOTAL H2O FLOW    =   750.00  H2O FLOW/START    =   375.00  TOTAL AIR FLOW     =   199.25
AIR WEIGHT FLOW   =   885.65  AIR VELOCITY      =   226.03  TOTAL HX UA        =  1193.25
COLD SIDE HA      =  4429.30  COLD FILM COEFF   =   606.63  HOT SIDE HA        =  1633.32
HOT FILM COEFF    =    13.78  Q SENSIBLE        =  7120.65  Q LATENT           =   305.57
Q TOTAL           =  7425.00  HEAT BALANCE      =    1.000
```

```
RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #:  4
DATE  :  7/8/75

INPUT DATA -
T RS-11 INLET     =    78.50  T RS-11 DEWPT     =    47.50  T 350-M INLET      =    30.00
T 350-M DEWPT     =    47.50  T 350-M OUTLET    =    46.40  ARS OUTLET FLOW    =   287.00
RS-51 FLOW        =     7.50  CHAMBER PRESSURE  =    30.00  T PRI H2O INLET    =    44.20
T SEC H2O INLET   =     0.00  T PRI H2O OUTLET  =    58.30  T SEC H2O OUTLET   =     0.00
PRI H2O FLOW      =   750.00  SEC H2O FLOW      =     0.00

OUTPUT DATA -
TOTAL H2O FLOW    =   750.00  H2O FLOW/START    =   375.00  TOTAL AIR FLOW     =   294.50
AIR WEIGHT FLOW   =  1306.11  AIR VELOCITY      =   334.03  TOTAL HX UA        =  1361.79
COLD SIDE HA      =  4429.30  COLD FILM COEFF   =   606.68  HOT SIDE HA        =  1966.29
HOT FILM COEFF    =    16.59  Q SENSIBLE        = 10532.50  Q LATENT           =   395.93
Q TOTAL           = 10950.00  HEAT BALANCE      =    0.998
```

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 5
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET	= 79.10	T RS-11 DEWPT	= 52.90	T 350-M INLET	= 82.60
T 350-M DEWPT	= 52.90	T 350-M OUTLET	= 44.85	ARS OUTLET FLOW	= 92.50
RS-51 FLOW	= 7.50	CHAMBER PRESSURE	= 30.00	T PRI H2O INLET	= 44.33
T SEC H2O INLET	= 0.00	T PRI H2O OUTLET	= 51.60	T SEC H2O OUTLET	= 0.00
PRI H2O FLOW	= 750.00	SEC H2O FLOW	= 0.00		

OUTPUT DATA -

TOTAL H2O FLOW	= 750.00	H2O FLOW/START	= 375.00	TOTAL AIR FLOW	= 100.00
AIR WEIGHT FLOW	= 443.00	AIR VELOCITY	= 113.44	TOTAL HX UA	= 931.86
COLD SIDE HA	= 4429.30	COLD FILM COEFF	= 696.63	HOT SIDE HA	= 1180.66
HOT FILM COEFF	= 9.96	Q SENSIBLE	= 4013.65	Q LATENT	= 1052.09
Q TOTAL	= 5100.00	HEAT BALANCE	= 0.993		

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 6
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET	= 75.50	T RS-11 DEWPT	= 54.00	T 350-M INLET	= 77.40
T 350-M DEWPT	= 54.00	T 350-M OUTLET	= 46.10	ARS OUTLET FLOW	= 184.00
RS-51 FLOW	= 7.50	CHAMBER PRESSURE	= 30.00	T PRI H2O INLET	= 45.00
T SEC H2O INLET	= 0.00	T PRI H2O OUTLET	= 56.30	T SEC H2O OUTLET	= 0.00
PRI H2O FLOW	= 750.00	SEC H2O FLOW	= 0.00		

OUTPUT DATA -

TOTAL H2O FLOW	= 750.00	H2O FLOW/START	= 375.00	TOTAL AIR FLOW	= 191.50
AIR WEIGHT FLOW	= 854.06	AIR VELOCITY	= 217.24	TOTAL HX UA	= 1178.70
COLD SIDE HA	= 4429.30	COLD FILM COEFF	= 696.63	HOT SIDE HA	= 1696.58
HOT FILM COEFF	= 13.55	Q SENSIBLE	= 5415.[illegible]	Q LATENT	= 2070.98
Q TOTAL	= 8250.00	HEAT BALANCE	= 1.023		

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RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 7
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET	= 80.60	T RS-11 DEWPT	= 54.00	T 350-M INLET	= 82.50
T 350-M DEWPT	= 54.00	T 350-M OUTLET	= 49.80	ARS OUTLET FLOW	= 291.00
RS-51 FLOW	= 7.70	CHAMBER PRESSURE	= 30.00	T PRI H2O INLET	= 46.50
T SEC H2O INLET	= 0.00	T PRI H2O OUTLET	= 61.50	T SEC H2O OUTLET	= 0.00
PRI H2O FLOW	= 750.00	SEC H2O FLOW	= 0.00		

OUTPUT DATA -

TOTAL H2O FLOW	= 750.00	H2O FLOW/START	= 375.00	TOTAL AIR FLOW	= 298.70
AIR WEIGHT FLOW	= 1319.59	AIR VELOCITY	= 338.85	TOTAL HX UA	= 1336.87
COLD SIDE HA	= 4429.30	COLD FILM COEFF	= 606.68	HOT SIDE HA	= 1915.29
HOT FILM COEFF	= 16.16	Q SENSIBLE	= 10356.15	Q LATENT	= 1804.51
Q TOTAL	= 11475.00	HEAT BALANCE	= 1.059		

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 8
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET	= 79.00	T RS-11 DEWPT	= 65.00	T 350-M INLET	= 82.50
T 350-M DEWPT	= 65.00	T 350-M OUTLET	= 45.60	ARS OUTLET FLOW	= 92.00
RS-51 FLOW	= 7.70	CHAMBER PRESSURE	= 30.00	T PRI H2O INLET	= 45.50
T SEC H2O INLET	= 0.00	T PRI H2O OUTLET	= 54.90	T SEC H2O OUTLET	= 0.00
PRI H2O FLOW	= 750.00	SEC H2O FLOW	= 0.00		

OUTPUT DATA -

TOTAL H2O FLOW	= 750.00	H2O FLOW/START	= 375.00	TOTAL AIR FLOW	= 99.70
AIR WEIGHT FLOW	= 441.76	AIR VELOCITY	= 113.10	TOTAL HX UA	= 934.97
COLD SIDE HA	= 4429.30	COLD FILM COEFF	= 606.63	HOT SIDE HA	= 1185.31
HOT FILM COEFF	= 10.00	Q SENSIBLE	= 3912.23	Q LATENT	= 3168.36
Q TOTAL	= 7050.00	HEAT BALANCE	= 1.004		

```
RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 9
DATE  : 7/8/75

INPUT DATA -
T RS-11 INLET    =    76.80  T RS-11 DEWPT      =    59.00  T 350-M INLET     =    79.00
T 350-M DEWPT    =    59.00  T 350-M OUTLET     =    46.70  ARS OUTLET FLOW   =   192.00
RS-51 FLOW       =     7.60  CHAMBER PRESSURE   =    30.00  T PRI H20 INLET   =    45.00
T SEC H20 INLET  =     0.00  T PRI H20 OUTLET   =    58.36  T SEC H20 OUTLET  =     0.00
PRI H20 FLOW     =   750.00  SEC H20 FLOW       =     0.00

OUTPUT DATA -
TOTAL H20 FLOW   =   750.00  H20 FLOW/START     =   375.00  TOTAL AIR FLOW    =   199.80
AIR WEIGHT FLOW  =   838.92  AIR VELOCITY       =   226.65  TOTAL HX UA       =  1201.74
COLD SIDE HA     =  4429.30  COLD FILM COEFF    =   606.68  HOT SIDE HA       =  1649.36
HOT FILM COEFF   =    13.91  Q SENSIBLE         =  6390.95  Q LATENT          =  3695.92
Q TOTAL          = 10395.00  HEAT BALANCE       =    1.018
```

```
RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 10
DATE  : 7/8/75

INPUT DATA -
T RS-11 INLET    =    82.70  T RS-11 DEWPT      =    61.00  T 350-M INLET     =    84.00
T 350-M DEWPT    =    61.00  T 350-M OUTLET     =    53.80  ARS OUTLET FLOW   =   292.00
RS-51 FLOW       =     7.70  CHAMBER PRESSURE   =    30.00  T PRI H20 INLET   =    49.00
T SEC H20 INLET  =     0.00  T PRI H20 OUTLET   =    66.30  T SEC H20 OUTLET  =     0.00
PRI H20 FLOW     =   750.00  SEC H20 FLOW       =     0.00

OUTPUT DATA -
TOTAL H20 FLOW   =   750.00  H20 FLOW/START     =   375.00  TOTAL AIR FLOW    =   299.79
AIR WEIGHT FLOW  =  1313.88  AIR VELOCITY       =   339.98  TOTAL HX UA       =  1345.59
COLD SIDE HA     =  4429.30  COLD FILM COEFF    =   606.63  HOT SIDE HA       =  1929.51
HOT FILM COEFF   =    16.28  Q SENSIBLE         =  9559.25  Q LATENT          =  3712.76
Q TOTAL          = 12975.00  HEAT BALANCE       =    1.022
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HAMILTON STANDARD
Division of UNITED TECHNOLOGIES

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 11
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET =	82.60	T RS-11 DEWPT =	54.50	T 350-M INLET =	84.00
T 350-M DEWPT =	54.50	T 350-M OUTLET =	54.15	ARS OUTLET FLOW =	291.00
RS-51 FLOW =	7.70	CHAMBER PRESSURE =	30.00	T PRI H2O INLET =	45.00
T SEC H2O INLET =	0.00	T PRI H2O OUTLET =	72.00	T SEC H2O OUTLET =	0.00
PRI H2O FLOW =	350.00	SEC H2O FLOW =	0.00		

OUTPUT DATA -

TOTAL H2O FLOW =	350.00	H2O FLOW/START =	175.00	TOTAL AIR FLOW =	298.79
AIR WEIGHT FLOW =	1314.72	AIR VELOCITY =	338.85	TOTAL HX UA =	912.13
COLD SIDE HA =	1741.24	COLD FILM COEFF =	238.50	HOT SIDE HA =	1915.87
HOT FILM COEFF =	16.16	Q SENSIBLE =	9418.68	Q LATENT =	162.22
Q TOTAL =	9450.00	HEAT BALANCE =	1.013		

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 12
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET =	82.20	T RS-11 DEWPT =	52.00	T 350-M INLET =	84.00
T 350-M DEWPT =	52.00	T 350-M OUTLET =	49.05	ARS OUTLET FLOW =	290.00
RS-51 FLOW =	7.80	CHAMBER PRESSURE =	30.00	T PRI H2O INLET =	46.00
T SEC H2O INLET =	0.00	T PRI H2O OUTLET =	62.10	T SEC H2O OUTLET =	0.00
PRI H2O FLOW =	750.00	SEC H2O FLOW =	0.00		

OUTPUT DATA -

TOTAL H2O FLOW =	750.00	H2O FLOW/START =	375.00	TOTAL AIR FLOW =	297.80
AIR WEIGHT FLOW =	1311.73	AIR VELOCITY =	337.83	TOTAL HX UA =	1353.23
COLD SIDE HA =	4429.30	COLD FILM COEFF =	606.68	HOT SIDE HA =	1948.39
HOT FILM COEFF =	16.44	Q SENSIBLE =	11002.79	Q LATENT =	1204.38
Q TOTAL =	12075.00	HEAT BALANCE =	1.010		

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 13
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET =	82.40	T RS-11 DEWPT =	53.00	T 350-M INLET =	84.00
T 350-M DEWPT =	53.00	T 350-M OUTLET =	52.50	ARS OUTLET FLOW =	290.00
RS-51 FLOW =	7.50	CHAMBER PRESSURE =	30.00	T PRI H2O INLET =	45.00
T SEC H2O INLET =	0.00	T PRI H2O OUTLET =	70.20	T SEC H2O OUTLET =	0.00
PRI H2O FLOW =	400.00	SEC H2O FLOW =	0.00		

OUTPUT DATA -

TOTAL H2O FLOW =	400.00	H2O FLOW/START =	200.00	TOTAL AIR FLOW =	297.50
AIR WEIGHT FLOW =	1309.92	AIR VELOCITY =	337.49	TOTAL HX UA =	994.13
COLD SIDE HA =	2058.82	COLD FILM COEFF =	282.00	HOT SIDE HA =	1922.79
HOT FILM COEFF =	16.22	Q SENSIBLE =	9903.03	Q LATENT =	215.99
Q TOTAL =	10080.00	HEAT BALANCE =	1.004		

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 14
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET =	82.20	T RS-11 DEWPT =	54.00	T 350-M INLET =	84.00
T 350-M DEWPT =	54.00	T 350-M OUTLET =	50.25	ARS OUTLET FLOW =	290.00
RS-51 FLOW =	7.60	CHAMBER PRESSURE =	30.00	T PRI H2O INLET =	45.00
T SEC H2O INLET =	0.00	T PRI H2O OUTLET =	65.10	T SEC H2O OUTLET =	0.00
PRI H2O FLOW =	600.00	SEC H2O FLOW =	0.00		

OUTPUT DATA -

TOTAL H2O FLOW =	600.00	H2O FLOW/START =	300.00	TOTAL AIR FLOW =	297.60
AIR WEIGHT FLOW =	1310.84	AIR VELOCITY =	337.60	TOTAL HX UA =	1226.52
COLD SIDE HA =	3380.27	COLD FILM COEFF =	463.00	HOT SIDE HA =	1925.27
HOT FILM COEFF =	16.24	Q SENSIBLE =	10617.88	Q LATENT =	1611.99
Q TOTAL =	12060.00	HEAT BALANCE =	1.014		

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RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 15
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET =	79.90	T RS-11 DEWPT =	45.50	T 350-M INLET =	84.00
T 350-M DEWPT =	45.50	T 350-M OUTLET =	44.33	ARS OUTLET FLOW =	92.50
RS-51 FLOW =	7.40	CHAMBER PRESSURE =	33.00	T PRI H2O INLET =	0.00
T SEC H2O INLET =	44.00	T PRI H2O OUTLET =	0.00	T SEC H2O OUTLET =	49.90
PRI H2O FLOW =	0.00	SEC H2O FLOW =	750.00		

OUTPUT DATA -

TOTAL H2O FLOW =	750.00	H2O FLOW/START =	375.00	TOTAL AIR FLOW =	99.90
AIR WEIGHT FLOW =	441.90	AIR VELOCITY =	113.32	TOTAL HX UA =	963.42
COLD SIDE HA =	4429.30	COLD FILM COEFF =	606.68	HOT SIDE HA =	1231.00
HOT FILM COEFF =	10.38	Q SENSIBLE =	4239.14	Q LATENT =	186.07
Q TOTAL =	4425.00	HEAT BALANCE =	0.995		

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 16
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET =	75.90	T RS-11 DEWPT =	46.00	T 350-M INLET =	77.80
T 350-M DEWPT =	46.00	T 350-M OUTLET =	45.25	ARS OUTLET FLOW =	183.00
RS-51 FLOW =	7.40	CHAMBER PRESSURE =	30.00	T PRI H2O INLET =	0.00
T SEC H2O INLET =	44.70	T PRI H2O OUTLET =	0.00	T SEC H2O OUTLET =	53.90
PRI H2O FLOW =	0.00	SEC H2O FLOW =	750.00		

OUTPUT DATA -

TOTAL H2O FLOW =	750.00	H2O FLOW/START =	375.00	TOTAL AIR FLOW =	192.40
AIR WEIGHT FLOW =	857.44	AIR VELOCITY =	218.26	TOTAL HX UA =	1179.77
COLD SIDE HA =	4429.30	COLD FILM COEFF =	606.69	HOT SIDE HA =	1698.14
HOT FILM COEFF =	13.57	Q SENSIBLE =	6698.33	Q LATENT =	159.38
Q TOTAL =	6900.00	HEAT BALANCE =	0.995		

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 17
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET	=	81.00	T RS-11 DEWPT	=	47.50	T 350-M INLET	=	82.10
T 350-M DEWPT	=	47.50	T 350-M OUTLET	=	46.90	ARS OUTLET FLOW	=	293.00
RS-51 FLOW	=	7.50	CHAMBER PRESSURE	=	30.00	T PRI H2O INLET	=	0.00
T SEC H2O INLET	=	44.80	T PRI H2O OUTLET	=	0.00	T SEC H2O OUTLET	=	59.70
PRI H2O FLOW	=	0.00	SEC H2O FLOW	=	750.00			

OUTPUT DATA -

TOTAL H2O FLOW	=	750.00	H2O FLOW/START	=	375.00	TOTAL AIR FLOW	=	297.50
AIR WEIGHT FLOW	=	1313.31	AIR VELOCITY	=	337.49	TOTAL HX UA	=	1339.86
COLD SIDE HA	=	4429.30	COLD FILM COEFF	=	606.63	HOT SIDE HA	=	1921.47
HOT FILM COEFF	=	16.21	Q SENSIBLE	=	11094.90	Q LATENT	=	219.03
Q TOTAL	=	11175.00	HEAT BALANCE	=	1.012			

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 18
DATE : 7/6/75

INPUT DATA -

T RS-11 INLET	=	80.60	T RS-11 DEWPT	=	55.00	T 350-M INLET	=	84.00
T 350-M DEWPT	=	55.00	T 350-M OUTLET	=	44.55	ARS OUTLET FLOW	=	92.50
RS-51 FLOW	=	7.90	CHAMBER PRESSURE	=	30.00	T PRI H2O INLET	=	0.00
T SEC H2O INLET	=	44.50	T PRI H2O OUTLET	=	0.00	T SEC H2O OUTLET	=	52.53
PRI H2O FLOW	=	0.00	SEC H2O FLOW	=	750.00			

OUTPUT DATA -

TOTAL H2O FLOW	=	750.00	H2O FLOW/START	=	375.00	TOTAL AIR FLOW	=	133.49
AIR WEIGHT FLOW	=	443.54	AIR VELOCITY	=	113.83	TOTAL HX UA	=	551.47
COLD SIDE HA	=	4429.30	COLD FILM COEFF	=	696.63	HOT SIDE HA	=	1211.42
HOT FILM COEFF	=	10.22	Q SENSIBLE	=	4199.48	Q LATENT	=	1411.56
Q TOTAL	=	5625.00	HEAT BALANCE	=	9.997			

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RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 19
DATE : 7/3/75

INPUT DATA -

T RS-11 INLET =	76.00	T RS-11 DEWPT =	51.00	T 350-M INLET =	77.70
T 350-M DEWPT =	51.00	T 350-M OUTLET =	45.60	ARS OUTLET FLOW =	131.00
RS-51 FLOW =	7.80	CHAMBER PRESSURE =	30.00	T PRI H2O INLET =	44.50
T SEC H2O INLET =	0.00	T PRI H2O OUTLET =	55.25	T SEC H2O OUTLET =	0.00
PRI H2O FLOW =	750.00	SEC H2O FLOW =	0.00		

OUTPUT DATA -

TOTAL H2O FLOW =	750.00	H2O FLOW/START =	375.00	TOTAL AIR FLOW =	193.80
AIR WEIGHT FLOW =	885.79	AIR VELOCITY =	225.52	TOTAL HX UA =	1173.77
COLD SIDE HA =	4429.30	COLD FILM COEFF =	606.68	HOT SIDE HA =	1696.39
HOT FILM COEFF =	13.55	Q SENSIBLE =	6824.18	Q LATENT =	1382.62
Q TOTAL =	8062.50	HEAT BALANCE =	1.017		

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 20
DATE : 7/3/75

INPUT DATA -

T RS-11 INLET =	79.40	T RS-11 DEWPT =	51.50	T 350-M INLET =	81.80
T 350-M DEWPT =	51.50	T 350-M OUTLET =	48.19	ARS OUTLET FLOW =	289.00
RS-51 FLOW =	7.40	CHAMBER PRESSURE =	30.00	T PRI H2O INLET =	45.00
T SEC H2O INLET =	0.00	T PRI H2O OUTLET =	60.60	T SEC H2O OUTLET =	0.00
PRI H2O FLOW =	750.00	SEC H2O FLOW =	0.00		

OUTPUT DATA -

TOTAL H2O FLOW =	750.00	H2O FLOW/START =	375.00	TOTAL AIR FLOW =	296.40
AIR WEIGHT FLOW =	1312.34	AIR VELOCITY =	336.24	TOTAL HX UA =	1335.52
COLD SIDE HA =	4429.30	COLD FILM COEFF =	606.63	HOT SIDE HA =	1912.55
HOT FILM COEFF =	16.14	Q SENSIBLE =	10614.25	Q LATENT =	1356.03
Q TOTAL =	11700.00	HEAT BALANCE =	1.023		

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 21
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET	82.40	T RS-11 DEWPT	61.50	T 350-M INLET	84.00
T 350-M DEWPT	61.50	T 350-M OUTLET	44.25	ARS OUTLET FLOW	92.50
RS-51 FLOW	7.80	CHAMBER PRESSURE	30.00	T PRI H2O INLET	44.20
T SEC H2O INLET	0.00	T PRI H2O OUTLET	53.10	T SEC H2O OUTLET	0.00
PRI H2O FLOW	750.00	SEC H2O FLOW	0.00		

OUTPUT DATA -

TOTAL H2O FLOW	750.00	H2O FLOW/START	375.00	TOTAL AIR FLOW	100.30
AIR WEIGHT FLOW	441.63	AIR VELOCITY	113.73	TOTAL HX UA	992.57
COLD SIDE HA	4429.30	COLD FILM COEFF	606.68	HOT SIDE HA	1279.15
HOT FILM COEFF	10.79	Q SENSIBLE	4213.16	Q LATENT	2592.37
Q TOTAL	6675.00	HEAT BALANCE	1.019		

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 22
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET	79.20	T RS-11 DEWPT	61.00	T 350-M INLET	82.50
T 350-M DEWPT	61.00	T 350-M OUTLET	47.00	ARS OUTLET FLOW	134.00
RS-51 FLOW	7.60	CHAMBER PRESSURE	30.00	T PRI H2O INLET	45.25
T SEC H2O INLET	0.00	T PRI H2O OUTLET	60.25	T SEC H2O OUTLET	0.00
PRI H2O FLOW	750.00	SEC H2O FLOW	0.00		

OUTPUT DATA -

TOTAL H2O FLOW	750.00	H2O FLOW/START	375.00	TOTAL AIR FLOW	191.60
AIR WEIGHT FLOW	848.64	AIR VELOCITY	217.35	TOTAL HX UA	1154.92
COLD SIDE HA	4429.30	COLD FILM COEFF	606.68	HOT SIDE HA	1562.49
HOT FILM COEFF	13.18	Q SENSIBLE	7230.46	Q LATENT	4179.39
Q TOTAL	11250.00	HEAT BALANCE	1.014		

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 23
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET =	83.50	T RS-11 DEWPT =	62.00	T 350-M INLET =	84.00
T 350-M DEWPT =	62.00	T 350-M OUTLET =	55.00	ARS OUTLET FLOW =	290.30
RS-11 FLOW =	7.60	CHAMBER PRESSURE =	30.05	T PRI H2O INLET =	50.25
T SEC H2O INLET =	0.00	T PRI H2O OUTLET =	67.00	T SEC H2O OUTLET =	0.00
PRI H2O FLOW =	750.00	SEC H2O FLOW =	0.00		

OUTPUT DATA -

TOTAL H2O FLOW =	750.00	H2O FLOW/START =	375.00	TOTAL AIR FLOW =	297.60
AIR WEIGHT FLOW =	1307.71	AIR VELOCITY =	337.60	TOTAL HX UA =	1325.40
COLD SIDE HA =	4429.30	COLD FILM COEFF =	606.63	HOT SIDE HA =	1891.84
HOT FILM COEFF =	15.96	Q SENSIBLE =	9101.67	Q LATENT =	3703.93
Q TOTAL =	12562.50	HEAT BALANCE =	1.019		

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 24
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET =	81.40	T RS-11 DEWPT =	53.00	T 350-M INLET =	93.80
T 350-M DEWPT =	53.00	T 350-M OUTLET =	52.20	ARS OUTLET FLOW =	283.00
RS-51 FLOW =	7.50	CHAMBER PRESSURE =	30.00	T PRI H2O INLET =	45.00
T SEC H2O INLET =	0.00	T PRI H2O OUTLET =	69.90	T SEC H2O OUTLET =	0.00
PRI H2O FLOW =	400.00	SEC H2O FLOW =	0.00		

OUTPUT DATA -

TOTAL H2O FLOW =	400.00	H2O FLOW/START =	200.00	TOTAL AIR FLOW =	290.50
AIR WEIGHT FLOW =	1281.46	AIR VELOCITY =	329.55	TOTAL HX UA =	1009.37
COLD SIDE HA =	2058.82	COLD FILM COEFF =	282.00	HOT SIDE HA =	1930.15
HOT FILM COEFF =	16.71	Q SENSIBLE =	9718.65	Q LATENT =	341.09
Q TOTAL =	9960.00	HEAT BALANCE =	1.010		

HAMILTON STANDARD
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RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 25
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET	=	80.90	T RS-11 DEWPT	=	51.50	T 350-M INLET	=	82.80
T 350-M DEWPT	=	51.50	T 350-M OUTLET	=	49.10	ARS OUTLET FLOW	=	283.00
RS-51 FLOW	=	7.50	CHAMBER PRESSURE	=	30.00	T PRI H2O INLET	=	45.00
T SEC H2O INLET	=	0.00	T PRI H2O OUTLET	=	63.60	T SEC H2O OUTLET	=	0.00
PRI H2O FLOW	=	600.00	SEC H2O FLOW	=	0.00			

OUTPUT DATA -

TOTAL H2O FLOW	=	600.00	H2O FLOW/START	=	300.00	TOTAL AIR FLOW	=	290.50
AIR WEIGHT FLOW	=	1282.65	AIR VELOCITY	=	329.55	TOTAL HX UA	=	1228.79
COLD SIDE HA	=	3330.27	COLD FILM COEFF	=	463.00	HOT SIDE HA	=	1930.21
HOT FILM COEFF	=	16.29	Q SENSIBLE	=	10374.10	Q LATENT	=	950.99
Q TOTAL	=	11160.00	HEAT BALANCE	=	1.014			

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 26
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET	=	79.10	T RS-11 DEWPT	=	47.00	T 350-M INLET	=	82.50
T 350-M DEWPT	=	47.00	T 350-M OUTLET	=	45.03	ARS OUTLET FLOW	=	92.50
RS-51 FLOW	=	7.50	CHAMBER PRESSURE	=	30.00	T PRI H2O INLET	=	45.00
T SEC H2O INLET	=	45.00	T PRI H2O OUTLET	=	52.70	T SEC H2O OUTLET	=	48.70
PRI H2O FLOW	=	375.00	SEC H2O FLOW	=	375.00			

OUTPUT DATA -

TOTAL H2O FLOW	=	750.00	H2O FLOW/START	=	187.50	TOTAL AIR FLOW	=	100.00
AIR WEIGHT FLOW	=	443.00	AIR VELOCITY	=	113.44	TOTAL HX UA	=	996.05
COLD SIDE HA	=	3796.41	COLD FILM COEFF	=	260.00	HOT SIDE HA	=	1350.35
HOT FILM COEFF	=	9.97	Q SENSIBLE	=	3983.38	Q LATENT	=	232.96
Q TOTAL	=	4275.00	HEAT BALANCE	=	0.986			

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 27
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET	=	75.00	T RS-11 DEWPT	=	45.50	T 350-M INLET	=	80.00
T 350-M DEWPT	=	45.50	T 350-M OUTLET	=	45.40	ARS OUTLET FLOW	=	192.50
RS-51 FLOW	=	7.50	CHAMBER PRESSURE	=	30.00	T PRI H2O INLET	=	45.00
T SEC H2O INLET	=	45.00	T PRI H2O OUTLET	=	57.00	T SEC H2O OUTLET	=	52.50
PRI H2O FLOW	=	375.00	SEC H2O FLOW	=	375.00			

OUTPUT DATA -

TOTAL H2O FLOW	=	750.00	H2O FLOW/START	=	187.50	TOTAL AIR FLOW	=	200.00
AIR WEIGHT FLOW	=	892.81	AIR VELOCITY	=	226.83	TOTAL HX UA	=	1223.32
COLD SIDE HA	=	3796.41	COLD FILM COEFF	=	260.00	HOT SIDE HA	=	1304.73
HOT FILM COEFF	=	13.32	Q SENSIBLE	=	7413.91	Q LATENT	=	23.37
Q TOTAL	=	7312.50	HEAT BALANCE	=	1.017			

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 28
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET	=	75.00	T RS-11 DEWPT	=	48.90	T 350-M INLET	=	82.50
T 350-M DEWPT	=	48.90	T 350-M OUTLET	=	48.90	ARS OUTLET FLOW	=	292.50
RS-51 FLOW	=	7.50	CHAMBER PRESSURE	=	30.00	T PRI H2O INLET	=	47.00
T SEC H2O INLET	=	47.00	T PRI H2O OUTLET	=	64.50	T SEC H2O OUTLET	=	59.00
PRI H2O FLOW	=	375.00	SEC H2O FLOW	=	375.00			

OUTPUT DATA -

TOTAL H2O FLOW	=	750.00	H2O FLOW/START	=	187.50	TOTAL AIR FLOW	=	300.00
AIR WEIGHT FLOW	=	1339.21	AIR VELOCITY	=	340.32	TOTAL HX UA	=	1421.01
COLD SIDE HA	=	3796.41	COLD FILM COEFF	=	260.00	HOT SIDE HA	=	2270.44
HOT FILM COEFF	=	16.76	Q SENSIBLE	=	10799.45	Q LATENT	=	0.00
Q TOTAL	=	11062.50	HEAT BALANCE	=	0.976			

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 29
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET	77.90	T RS-11 DEWPT	52.00	T 350-M INLET	82.59
T 350-M DEWPT	52.00	T 350-M OUTLET	44.65	ARS OUTLET FLOW	95.03
RS-51 FLOW	7.50	CHAMBER PRESSURE	30.00	T PRI H2O INLET	44.60
T SEC H2O INLET	44.60	T PRI H2O OUTLET	53.39	T SEC H2O OUTLET	49.80
PRI H2O FLOW	375.00	SEC H2O FLOW	375.00		

OUTPUT DATA -

TOTAL H2O FLOW	750.00	H2O FLOW/START	187.50	TOTAL AIR FLOW	102.59
AIR WEIGHT FLOW	455.09	AIR VELOCITY	116.27	TOTAL HX UA	999.74
COLD SIDE HA	3796.41	COLD FILM COEFF	260.00	HOT SIDE HA	1337.36
HOT FILM COEFF	10.02	Q SENSIBLE	4134.19	Q LATENT	965.45
Q TOTAL	5212.50	HEAT BALANCE	0.978		

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 30
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET	76.10	T RS-11 DEWPT	52.50	T 350-M INLET	77.20
T 350-M DEWPT	52.50	T 350-M OUTLET	45.60	ARS OUTLET FLOW	187.00
RS-51 FLOW	7.90	CHAMBER PRESSURE	30.00	T PRI H2O INLET	44.90
T SEC H2O INLET	45.00	T PRI H2O OUTLET	57.25	T SEC H2O OUTLET	54.25
PRI H2O FLOW	375.00	SEC H2O FLOW	375.00		

OUTPUT DATA -

TOTAL H2O FLOW	750.00	H2O FLOW/START	187.50	TOTAL AIR FLOW	194.90
AIR WEIGHT FLOW	863.25	AIR VELOCITY	221.10	TOTAL HX UA	1255.59
COLD SIDE HA	3796.41	COLD FILM COEFF	260.00	HOT SIDE HA	1373.35
HOT FILM COEFF	13.87	Q SENSIBLE	6584.87	Q LATENT	1775.93
Q TOTAL	8437.50	HEAT BALANCE	0.991		

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RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 31
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET	79.80	T RS-11 DEWPT	52.00	T 350-M INLET	82.50
T 350-M DEWPT	52.00	T 350-M OUTLET	49.30	ARS OUTLET FLOW	292.00
RS-51 FLOW	7.60	CHAMBER PRESSURE	30.00	T PRI H2O INLET	46.00
T SEC H2O INLET	46.90	T PRI H2O OUTLET	63.60	T SEC H2O OUTLET	59.30
PRI H2O FLOW	375.00	SEC H2O FLOW	375.00		

OUTPUT DATA -

TOTAL H2O FLOW	750.00	H2O FLOW/START	187.50	TOTAL AIR FLOW	299.60
AIR WEIGHT FLOW	1325.53	AIR VELOCITY	339.87	TOTAL HX UA	1393.57
COLD SIDE HA	3796.41	COLD FILM COEFF	260.00	HOT SIDE HA	2214.51
HOT FILM COEFF	16.35	Q SENSIBLE	10561.32	Q LATENT	1116.42
Q-TOTAL	11475.00	HEAT BALANCE	1.017		

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 32
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET	80.50	T RS-11 DEWPT	61.00	T 350-M INLET	88.00
T 350-M DEWPT	61.00	T 350-M OUTLET	45.04	ARS OUTLET FLOW	90.00
RS-51 FLOW	7.60	CHAMBER PRESSURE	30.00	T PRI H2O INLET	45.00
T SEC H2O INLET	45.00	T PRI H2O OUTLET	56.05	T SEC H2O OUTLET	51.90
PRI H2O FLOW	375.00	SEC H2O FLOW	375.00		

OUTPUT DATA -

TOTAL H2O FLOW	750.00	H2O FLOW/START	187.50	TOTAL AIR FLOW	97.60
AIR WEIGHT FLOW	431.25	AIR VELOCITY	110.72	TOTAL HX UA	1045.33
COLD SIDE HA	3796.41	COLD FILM COEFF	260.00	HOT SIDE HA	1442.24
HOT FILM COEFF	10.65	Q SENSIBLE	4446.41	Q LATENT	2349.50
Q TOTAL	6731.25	HEAT BALANCE	1.009		

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 33
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET	= 77.20	T RS-11 DEWPT	= 60.00	T 350-M INLET	= 80.30
T 350-M DEWPT	= 60.00	T 350-M OUTLET	= 47.15	ARS OUTLET FLOW	= 192.00
RS-51 FLOW	= 7.30	CHAMBER PRESSURE	= 30.00	T PRI H2O INLET	= 45.2?
T SEC H2O INLET	= 45.20	T PRI H2O OUTLET	= 61.40	T SEC H2O OUTLET	= 57.30
PRI H2O FLOW	= 375.00	SEC H2O FLOW	= 375.00		

OUTPUT DATA -

TOTAL H2O FLOW	= 750.00	H2O FLOW/START	= 187.50	TOTAL AIR FLOW	= 199.39
AIR WEIGHT FLOW	= 886.04	AIR VELOCITY	= 226.03	TOTAL HX UA	= 1211.24
COLD SIDE HA	= 3796.41	COLD FILM COEFF	= 260.01	HOT SIDE HA	= 1779.45
HOT FILM COEFF	= 13.14	Q SENSIBLE	= 6935.54	Q LATENT	= 3944.63
Q TOTAL	= 10800.00	HEAT BALANCE	= 1.012		

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 34
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET	= 81.20	T RS-11 DEWPT	= 62.00	T 350-M INLET	= 82.50
T 350-M DEWPT	= 62.00	T 350-M OUTLET	= 55.60	ARS OUTLET FLOW	= 292.00
RS-51 FLOW	= 7.30	CHAMBER PRESSURE	= 30.00	T PRI H2O INLET	= 51.00
T SEC H2O INLET	= 51.00	T PRI H2O OUTLET	= 68.80	T SEC H2O OUTLET	= 65.00
PRI H2O FLOW	= 375.00	SEC H2O FLOW	= 375.00		

OUTPUT DATA -

TOTAL H2O FLOW	= 750.00	H2O FLOW/START	= 187.50	TOTAL AIR FLOW	= 299.39
AIR WEIGHT FLOW	= 1320.77	AIR VELOCITY	= 339.53	TOTAL HX UA	= 1393.53
COLD SIDE HA	= 3796.41	COLD FILM COEFF	= 260.00	HOT SIDE HA	= 2202.33
HOT FILM COEFF	= 16.26	Q SENSIBLE	= 8526.92	Q LATENT	= 3457.40
Q TOTAL	= 11925.00	HEAT BALANCE	= 1.064		

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 35
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET =	81.20	T RS-11 DEWPT =	52.00	T 350-M INLET =	82.70
T 350-M DEWPT =	52.00	T 350-M OUTLET =	50.15	ARS OUTLET FLOW =	288.00
RS-51 FLOW =	7.50	CHAMBER PRESSURE =	30.00	T PRI H2O INLET =	44.00
T SEC H2O INLET =	45.00	T PRI H2O OUTLET =	67.90	T SEC H2O OUTLET =	64.50
PRI H2O FLOW =	250.00	SEC H2O FLOW =	250.00		

OUTPUT DATA -

TOTAL H2O FLOW =	500.00	H2O FLOW/START =	125.00	TOTAL AIR FLOW =	295.50
AIR WEIGHT FLOW =	1304.00	AIR VELOCITY =	335.22	TOTAL HX UA =	1152.01
COLD SIDE HA =	2372.76	COLD FILM COEFF =	162.50	HOT SIDE HA =	2239.05
HOT FILM COEFF =	16.53	Q SENSIBLE =	10136.89	Q LATENT =	764.26
Q TOTAL =	10850.00	HEAT BALANCE =	1.009		

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 36
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET =	81.80	T RS-11 DEWPT =	53.00	T 350-M INLET =	83.00
T 350-M DEWPT =	53.00	T 350-M OUTLET =	50.70	ARS OUTLET FLOW =	288.00
RS-51 FLOW =	7.50	CHAMBER PRESSURE =	30.00	T PRI H2O INLET =	45.80
T SEC H2O INLET =	47.00	T PRI H2O OUTLET =	66.80	T SEC H2O OUTLET =	63.00
PRI H2O FLOW =	300.00	SEC H2O FLOW =	300.00		

OUTPUT DATA -

TOTAL H2O FLOW =	600.00	H2O FLOW/START =	150.00	TOTAL AIR FLOW =	295.50
AIR WEIGHT FLOW =	1302.56	AIR VELOCITY =	335.22	TOTAL HX UA =	1258.41
COLD SIDE HA =	2391.11	COLD FILM COEFF =	198.00	HOT SIDE HA =	2227.24
HOT FILM COEFF =	16.44	Q SENSIBLE =	10097.45	Q LATENT =	973.24
Q TOTAL =	11100.00	HEAT BALANCE =	0.997		

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RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 37
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET	= 81.20	T RS-11 DEWPT	= 52.50	T 350-M INLET	= 83.30
T 350-M DEWPT	= 52.50	T 350-M OUTLET	= 50.80	ARS OUTLET FLOW	= 288.00
RS-51 FLOW	= 7.50	CHAMBER PRESSURE	= 30.00	T PRI H2O INLET	= 43.40
T SEC H2O INLET	= 49.00	T PRI H2O OUTLET	= 64.40	T SEC H2O OUTLET	= 60.40
PRI H2O FLOW	= 400.00	SEC H2O FLOW	= 400.00		

OUTPUT DATA -

TOTAL H2O FLOW	= 800.00	H2O FLOW/START	= 200.00	TOTAL AIR FLOW	= 295.50
AIR WEIGHT FLOW	= 1304.00	AIR VELOCITY	= 335.22	TOTAL HX UA	= 1448.33
COLD SIDE HA	= 4117.65	COLD FILM COEFF	= 232.00	HOT SIDE HA	= 2234.94
HOT FILM COEFF	= 16.49	Q SENSIBLE	= 10171.25	Q LATENT	= 715.45
Q TOTAL	= 10960.00	HEAT BALANCE	= 0.993		

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 38
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET	= 77.80	T RS-11 DEWPT	= 53.00	T 350-M INLET	= 79.40
T 350-M DEWPT	= 53.00	T 350-M OUTLET	= 45.75	ARS OUTLET FLOW	= 184.00
RS-51 FLOW	= 3.20	CHAMBER PRESSURE	= 30.00	T PRI H2O INLET	= 45.50
T SEC H2O INLET	= 45.00	T PRI H2O OUTLET	= 57.90	T SEC H2O OUTLET	= 54.60
PRI H2O FLOW	= 375.00	SEC H2O FLOW	= 375.00		

OUTPUT DATA -

TOTAL H2O FLOW	= 750.00	H2O FLOW/START	= 187.50	TOTAL AIR FLOW	= 187.20
AIR WEIGHT FLOW	= 831.31	AIR VELOCITY	= 212.35	TOTAL HX UA	= 1405.47
COLD SIDE HA	= 3796.41	COLD FILM COEFF	= 260.91	HOT SIDE HA	= 2231.03
HOT FILM COEFF	= 16.47	Q SENSIBLE	= 6713.72	Q LATENT	= 1807.40
Q TOTAL	= 8437.50	HEAT BALANCE	= 1.099		

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RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 39
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET	= 76.60	T RS-11 DEWPT	=	53.00	T 350-M INLET	=	78.80
T 350-M DEWPT	= 53.00	T 350-M OUTLET	=	45.55	ARS OUTLET FLOW	=	184.00
RS-51 FLOW	= 5.25	CHAMBER PRESSURE	=	30.00	T PRI H2O INLET	=	44.00
T SEC H2O INLET	= 45.00	T PRI H2O OUTLET	=	57.20	T SEC H2O OUTLET	=	54.59
PRI H2O FLOW	= 375.00	SEC H2O FLOW	=	375.00			

OUTPUT DATA -

TOTAL H2O FLOW	= 750.00	H2O FLOW/START	=	187.50	TOTAL AIR FLOW	=	183.25
AIR WEIGHT FLOW	= 842.30	AIR VELOCITY	=	214.69	TOTAL HX UA	=	1223.64
COLD SIDE HA	= 3796.41	COLD FILM COEFF	=	260.00	HOT SIDE HA	=	1313.96
HOT FILM COEFF	= 13.43	Q SENSIBLE	=	6721.57	Q LATENT	=	1875.69
Q TOTAL	= 8512.50	HEAT BALANCE	=	1.009			

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 40
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET	= 79.70	T RS-11 DEWPT	=	46.25	T 350-M INLET	=	82.50
T 350-M DEWPT	= 46.25	T 350-M OUTLET	=	44.54	ARS OUTLET FLOW	=	95.00
RS-51 FLOW	= 7.50	CHAMBER PRESSURE	=	30.00	T PRI H2O INLET	=	44.50
T SEC H2O INLET	= 0.00	T PRI H2O OUTLET	=	50.25	T SEC H2O OUTLET	=	0.00
PRI H2O FLOW	= 750.00	SEC H2O FLOW	=	0.00			

OUTPUT DATA -

TOTAL H2O FLOW	= 750.00	H2O FLOW/START	=	375.00	TOTAL AIR FLOW	=	102.50
AIR WEIGHT FLOW	= 453.57	AIR VELOCITY	=	116.27	TOTAL HX UA	=	944.85
COLD SIDE HA	= 4429.30	COLD FILM COEFF	=	606.68	HOT SIDE HA	=	1201.23
HOT FILM COEFF	= 10.13	Q SENSIBLE	=	4132.28	Q LATENT	=	202.67
Q TOTAL	= 4312.50	HEAT BALANCE	=	1.005			

RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

CASE #: 41
DATE : 7/8/75

INPUT DATA -

T RS-11 INLET	= 76.90	T RS-11 DEWPT	=	53.50	T 350-M INLET	=	73.50
T 350-M DEWPT	= 53.50	T 350-M OUTLET	=	45.55	ARS OUTLET FLOW	=	180.00
RS-51 FLOW	= 10.00	CHAMBER PRESSURE	=	30.00	T PRI H2O INLET	=	44.00
T SEC H2O INLET	= 44.90	T PRI H2O OUTLET	=	57.60	T SEC H2O OUTLET	=	54.30
PRI H2O FLOW	= 375.00	SEC H2O FLOW	=	375.00			

OUTPUT DATA -

TOTAL H2O FLOW	= 750.00	H2O FLOW/START	=	187.50	TOTAL AIR FLOW	=	190.00
AIR WEIGHT FLOW	= 845.16	AIR VELOCITY	=	215.54	TOTAL HX UA	=	1227.62
COLD SIDE HA	= 3796.41	COLD FILM COEFF	=	269.30	HOT SIDE HA	=	1314.65
HOT FILM COEFF	= 13.42	Q SENSIBLE	=	6683.38	Q LATENT	=	2025.72
Q TOTAL	= 8625.00	HEAT BALANCE	=	1.009			

APPENDIX C

PERFORMANCE PREDICTION TECHNIQUE

C.1 General condensing HX performance prediction analysis

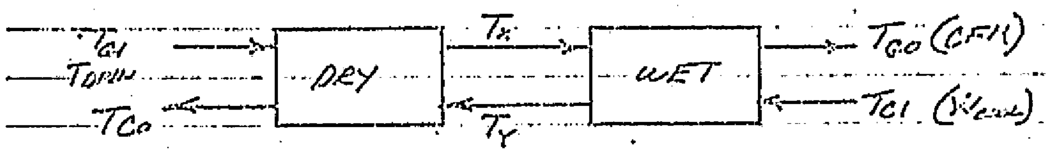
C.2 Modification to account for anomaly in coolant outlet temp with both coolant loops flowing

C.3 Listing of computer program used to predict HX performance

APPENDIX C.1

Presented here is the procedure followed to predict thermal performance for a condensing heat exchanger. This technique divides the HX into a wet and dry portion as described in Appendix B, and assumes as value for the air stream outlet temperature to start the procedure. The performance prediction is based on known values for air and coolant inlet temperatures and flow rates which in combination with the film coefficient curves from Appendix B is used to predicted values for the air side and coolant side outlet temperatures. If this calculated value for air outlet temperature agrees with the initial value the prediction is finished. If not, then the procedure is repeated using the calculated outlet temperature as the new guess. This procedure continues until the guess and final prediction agree within some desired tolerance.

CONDENSING HX PERFORMANCE PREDICTION PROCEDURE



WITH AIR FLOW CFM FIND UA_H FROM FIG B-3 (SEE NOTE#1 APP B.1)
WITH COOLANT FLOW FIND UA_C FROM FIG B-2 (NOTE#1 B.1)

$$UA_{TOT} = \frac{1}{\frac{1}{UA_C} + \frac{1}{UA_H}}$$

ASSUME INITIAL VALUE FOR $T_{GO} = (T_{C1} + .1)$

FIND Q_S, Q_L, Q_T, T_{CO}

$$Q_S = (WC_P)_H (T_{G1} - T_{GO})$$

$$Q_L = h_{fg} (\omega_{IN} - \omega_{OUT}) \dot{W}_{AIR} \quad \text{(SEE NOTE\#1 APP C-1)}$$

$$Q_T = Q_S + Q_L$$

$$T_{CO} = \frac{Q_T}{(WC_P)_C} + T_{C1}$$

FIND T_X, T_Y

$$T_X = \frac{(WC_P)_H T_{G1} + (WC_P)_C \left[\frac{UA_H}{UA_C} T_{DPIN} - (T_{CO} - T_{DPIN})\right]}{\frac{UA_H}{UA_C} (WC_P)_C + (WC_P)_H}$$

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$$T_Y = T_{DPIN} - \frac{UA_H}{UA_C}(T_X - T_{DPIN})$$

FIND ϵ_{DRY}, M_{DRY}, UA_{DRY}

$$\epsilon_{DRY} = \frac{T_{GI} - T_X}{T_{GI} - T_Y}$$

$$M_{DRY} = \frac{(WCP)_C}{(WCP)_H}$$

FROM COUNTERFLOW HX CHART FIND K (SEE FIG B-4)

THEN:

$$UA_{DRY} = (WCP)_H K$$

FIND $UA_{SENS\ WET}$, $Q_{TOT\ WET}$, $Q_{LAT\ WET}$, $Q_{SENS\ WET}$, UA_{WET}

$$UA_{SENS\ WET} = UA_{TOTAL} - UA_{DRY}$$

$$Q_{TOTAL\ WET} = Q_T - (WCP)_C(T_{CO} - T_Y)$$

$$Q_{LAT\ WET} = Q_L$$

$$Q_{SENS\ WET} = Q_{TOTAL\ WET} - Q_L$$

$$M_{WET} = \frac{M_{DRY}}{Q_{TOTAL\ WET}/Q_{SENS\ WET}}$$

$$UA_{WET} = \frac{UA_{THIS\ WET}}{\left[\frac{1}{1+\frac{\eta A_C}{\eta A_H}} + \frac{\eta A_C/\eta A_H}{\frac{Q_{TOTAL}}{Q_S}\left(1+\frac{\eta A_C}{\eta A_H}\right)}\right]}$$

$$K_{WET} = \frac{UA_{WET}}{\left((WC_p)_H \frac{Q_{TOT\ WET}}{Q_{SENS\ WET}}\right)}$$

WITH M_{WET} AND K_{WET} GO TO COUNTERFLOW HX CHARTS TO FIND $\mathcal{E}_{WET}$ (SEE FIG B-4)

THEN:

$$T_{GO} = T_X - \mathcal{E}_{WET}(T_X - T_{CIN})$$

IF THIS VALUE FOR T_{CO} AGREES WITHIN DESIRED RANGE WITH INITIAL GUESS THEN ANALYSIS IS FINISHED. OTHERWISE USE THIS VALUE FOR NEW GUESS AND REPEAT PROCEDURE

WHEN SOLUTION HAS CONVERGED THEN PREDICTED OUTPUT VALUES ARE:

T_{GO} AND T_{CO}

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APPENDIX C.1

NOTE #1

CALCULATIONS OF W_{IN} AND W_{OUT} ARE AS SHOWN IN APPENDIX B.1 NOTE #2.

IN ADDITION THE VALUE OF h_{fg} USED IS CONSIDERED TO BE THE AVERAGE VALUE FOR THE HX.

$h_{fg_{T_{OUT}}} = 1075.8 - .56(T_{60} - 32)$

$h_{fg_{IN}} = 1075.8 - .56(T_{81} - 32)$

$$h_{fg} = h_{fg_{AVG}} = \frac{h_{fg_{OUT}} + h_{fg_{IN}}}{2}$$

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Appendix C.2 Modifications to Heat Exchanger Performance Prediction to Account for Coolant Outlet Temp Anomaly

Table C.2-1 presents data for test points #26 thru 37 which shows how the split in heat rejection between loops varied with air flow rate, inlet inlet dewpoint, inlet coolout temperature and coolant flow rate.

A regression analysis program was used with the Wang minicomputer to generate an empirical function that gives the percent of total heat transferred by the HX which was picked up by the secondary coolant loop. The primary loop picks up 1 minus this percentage. This percentage was expressed as a function of difference between air dewpoint in and secondary coolant temperature in and air flow rate (cfm). This percent vs $T_{DPin} - T_{SECin}$ and air flow curve is shown in figure C.2-1. The same regression analysis program was then used to generate a curve of correction factor as a function of coolant flow rate. (figure C.2-2) The value of percent found from figure C.2-1 is multiplied by this correction factor to obtain the actual percent of total heat that was picked up by the secondary loop and also the heat picked up by the primary loop. Knowing the inlet temperature and flow and the heat in each loop it is then a simple step to find the outlet temperature for each loop.

This procedure is incorporated into the heat exchanger perfromance prediction program and is activated automatically if both coolout loops are flowing.

TP	AIR W	DP IN	P I %	SEC %	PRI Ẇ	SEC Ẇ	TDP-TC	PRI DT	SEC DT
26	100.0	47.00	67.54	32.45	375	375	2.00	2.00	2.00
27	200.0	45.50	61.53	38.46	375	375	0.50	0.50	0.50
28	300.0	48.90	59.32	40.67	375	375	1.90	1.90	1.90
29	102.5	52.00	62.58	37.41	375	375	7.40	7.40	7.40
30	194.9	52.50	58.88	41.11	375	375	8.00	8.50	7.50
31	299.6	52.00	57.51	42.48	375	375	5.55	6.00	5.10
32	97.6	61.00	61.55	38.44	375	375	16.00	16.00	16.00
33	199.3	60.00	56.25	43.75	375	375	14.80	14.80	14.80
34	299.3	62.00	55.97	44.02	375	375	11.00	11.00	11.00
35	295.5	52.00	55.06	44.93	250	250	7.50	8.00	7.00
36	295.5	53.00	56.75	43.24	300	300	6.60	7.20	6.00
37	295.5	52.50	58.39	41.60	400	400	3.80	4.10	3.50

TABLE C.2-1

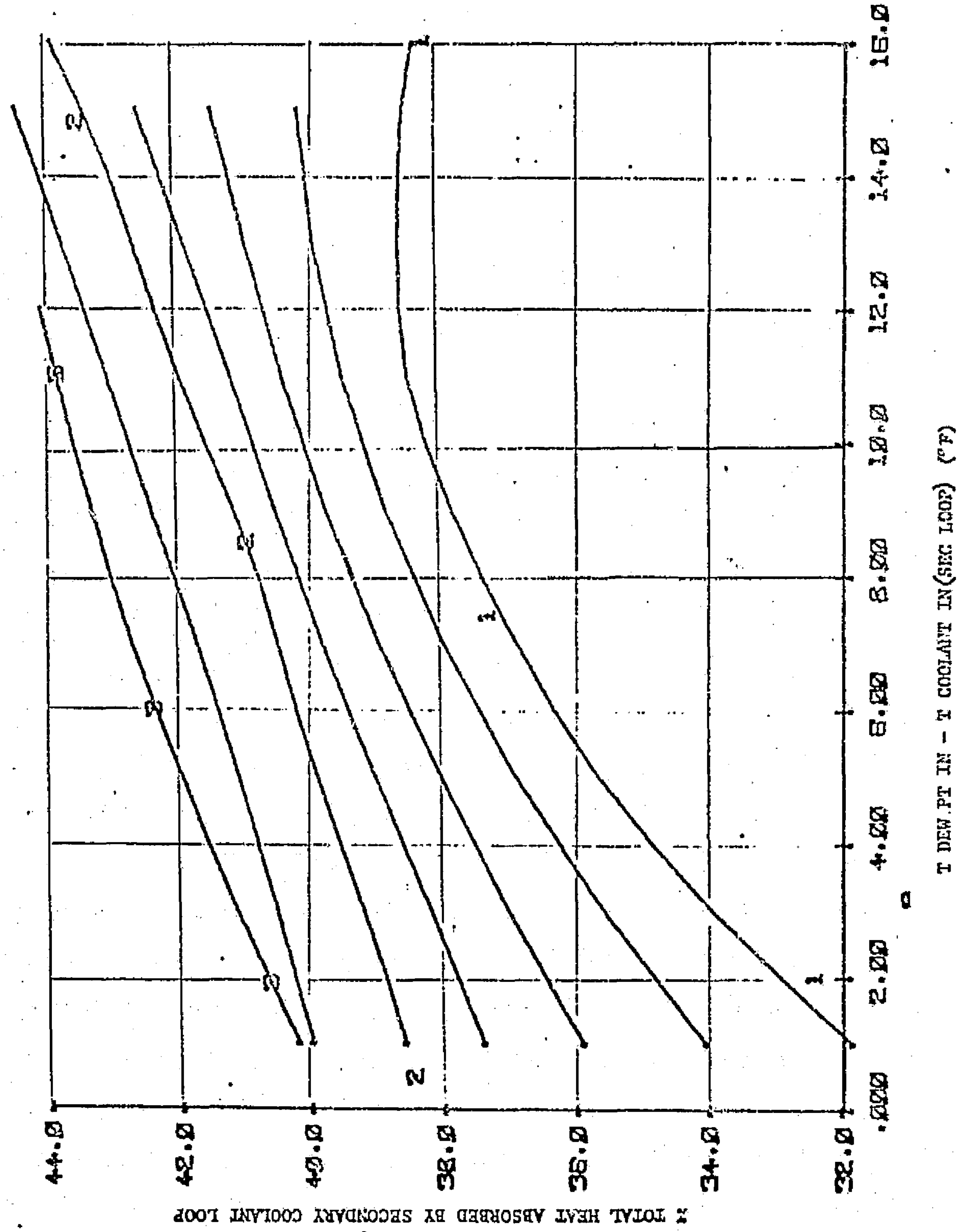

FIGURE C.2-1 HEAT LOAD SPLIT BETWEEN COOLANT LOOPS FOR 350-M HX
(FUNCTION OF DEWPOINT AND AIR FLOW RATE)

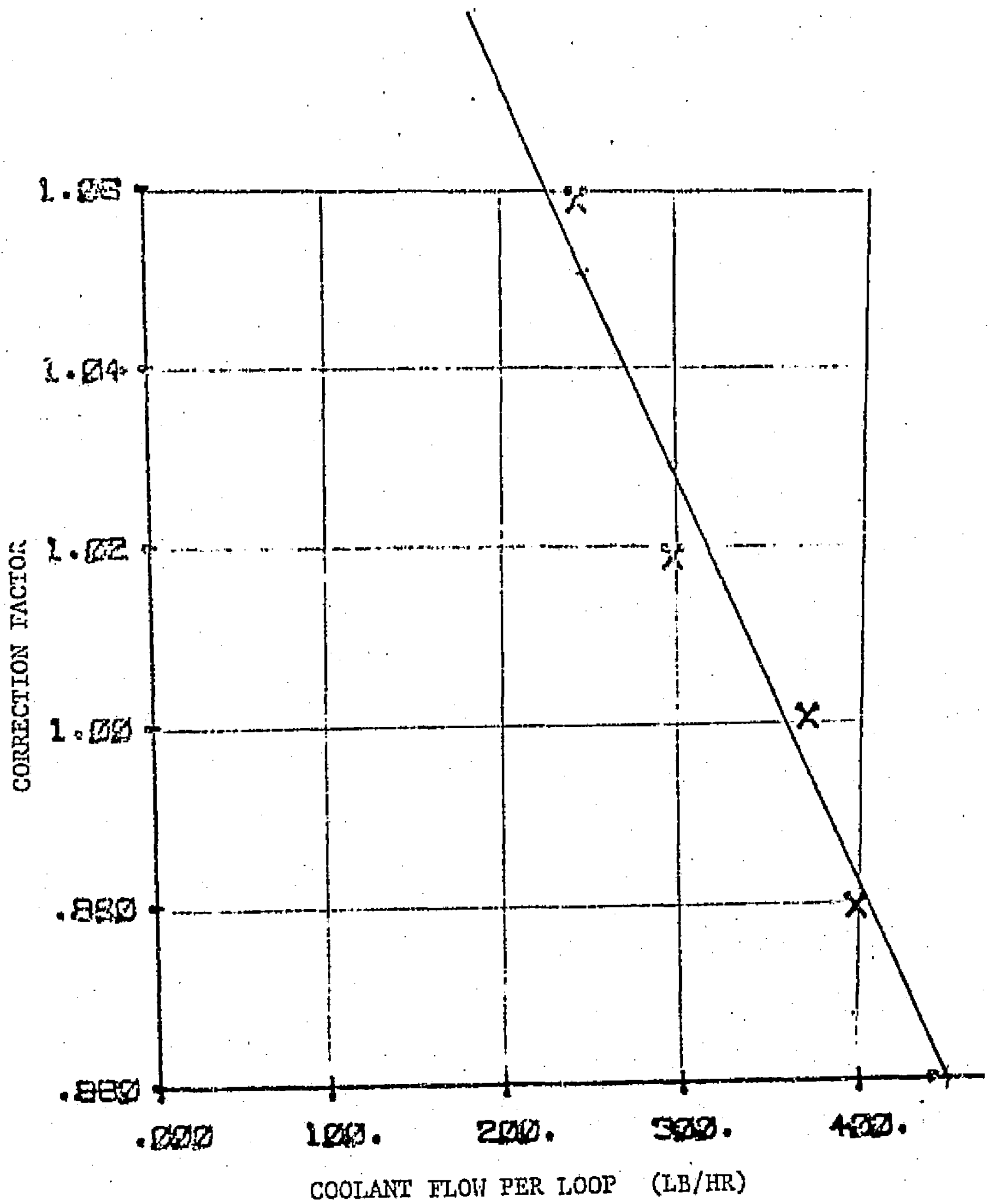

FIGURE C.2-2 HEAT LOAD SPLIT BETWEEN COOLANT LOOPS FOR 350-M HX
(FUNCTION OF COOLANT FLOW RATE)

APPENDIX C.3

LISTING OF CONDENSING HEAT EXCHANGER PERFORMANCE PREDICTION COMPUTER PROGRAM

```
 L)  REM - 350-M HX PERFORMANCE PREDICTION PROGRAM
  - GIVEN TIN FOR GAS AND COOLANT  FIND TOUT AND Q -
20 DIM X(50)
30 DEFFN1(X)=3.10719762E-02+2.71331473E-04*X+4.56164060E-05*X!2
   -7.17044935E-08*X!3+4.01962030E-09*X!4+1.04575064E-11*X!5
40 DEFFN2(X)=106.7019036671-.79!56288304O7*X+1.42137844E-02*X!2
   -4.03702990E-05*X!3+6.35142232E-08*X!4-4.04697326E-11*X!5
50 DEFFN3(X)=7.304894511852+3.19172743E-02*X-1.83198194E-05*X!2
   +6.78877362E-09*X!3-1.19293620E-12*X!4+7.52444916E-17*X!5
60 FOR I=1 TO 50:X(I)=0:NEXT I
70 PRINT HEX(03):PRINT "INPUT AIR SIDE CONDITIONS"
80 INPUT "AIR FLOW RATE (TOTAL CFM)  = ",X5
90 INPUT "INTERNAL BYPASS (%) = ",B4: X(20)=(100-B4)/100*X5:
   INPUT "AIR TEMP IN (F)      = ",X(3) :
   INPUT "AIR DEW POINT IN (F)= ",X(2):PRINT
100 PRINT "INPUT PRI COOLANT LOOP CONDITIONS"
110 INPUT "PRI LOOP FLOW (LByHR) = ",X(13):
    INPUT "PRI LOOP TEMP IN (F)  = ",X(9):PRINT
120 PRINT "INPUT SEC COOLANT LOOP CONDITIONS"
130 INPUT "SEC LOOP FLOW (LB/HR) = ",X(14):
    INPUT "SEC LOOP TEMP IN (F)  = ",X(10):PRINT
140 PRINT HEX(03):PRINT :PRINT :PRINT :
    PRINT "    ****  COND HX PROGRAM IS RUNNING  ****"
h50 PRINT :PRINT "                         T CALC       T GUESS "
160 X(17)=X(13)+X(14)
170 X(15)=(X(9)*X(13)+X(10)*X(14))/(X(13)+X(14))
180 K9=(X(3)-X(h5))/2PX(5)=X(15)+K9
190 IF X(13)=0 THEN 210
200 IF T(14)=0 THEN 210:X(30)=X(17)/4:GOTO 220
210 X(30)=X(17)/2
220 X(8)=30:X(1)=X(3)
230 X(31)=FN2(X(30)):
     IF X(13)=0 THEN 240:
     IF X(14)=0 THEN 240: X(19)=27*·5408¢X(31): GOTO 250
240 X(19)=27*·5408*X(31)/2
250 X(21)=X(2):X(26)=X(20)/.8815
260 X(29)=FN3(X(26)): X(27)=313*·5408¢X(29)
270 IF X(13)=0 THEN 280: IF X(14)=0 THEN 280:
    X(27)=.8*X(27): GOTO 290
280 X(27)=.7*X(27)
290 H1=X(19): H2=X(27)
300 N=H1*H2/(H1+H2)
310 P1=FN1(X(5)):P2=FN1(X(21)):
    X(22)=144*60*(X(8)*·4912)*X(20)/53.35/(X(1)+459.6)
```

FIGURE C.3-1 350-M HX PERFORMANCE PREDICTION PROGRAM

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```
320 L=1
330 IF T(2)zX(15)THEN 340:X(24)=0:L=0:GOTO 630
340 X(23)=.24*X(22)*(X(3)-X(5))
350 I3=.622*P1/(X(8)*.4912-P1):
    A2=.622*P2/(X(8)*.4912-P2): X(24)=1065*X(22)*(A2-A3)
260 IF X(24)]0 THEN 370:X(18)=X(23):X(24)=0:GOTO 380
370 X(18)=X(23)+X(24)
380 T(16)=(X(23)+X(24))/X(17)+X(15)
390 H=X(27)/X(19)
400 M1=X(17)/(.24*X(22))
410 IF X(2)[X(3) THEN 420:T1=X(3):T2=X(16):U1=0PGOTO 490
420 T1=(.24*X(22)*X(3)+X(17)*(H*X(21)+X(21)-X(16)))/
      (H*X(17)+.24*X(22))
430 T2=X(21)-H*(T1-X(21))
440 IF T2]X(15) THEN 450:GOTO 630
450 E1=(X(3)-T1)/(X(3)-T2)
460 IF E1[1.0 THEN 470:E1=.99
470 GOSUB '01(E1,M1):U1=.24*X(22)*K
480 IF U1[U THEN 490:GOTO 630
490 U2=U-N1
500 Q7=X(18)-X(17)*(X(16)-T2)
510 Q8=Q7-X(24)
520 M2=M1*Q8/Q7
530 K1=1/(1+1/H)+1/H*Q8/Q7/(1+1/H)
540 U3=U2/K1
550 K2=U3*Q8/Q7/(.24*X(22))
560 GOSUB '02(M2,K2)
570 T0=T1-E1*(T1-X(15))
580 Q1=X(18):Q2=X(24)+.24*X(22)*(X(3)-T0)
590 IF ABS(Q1-Q2)[.20 THEN 730PPRINT ,T0,X(5)
600 IF Q1]Q2 THEN 620
610 T(5)=X(5)-K9:K9=K9/2PX(5)=T(5)+K9:GOTO 310
620 T(5)=X(5)+K9:K9=K9/2:X(5)=X(5)-K9:GOTO 310
630 °2=X(17)/(X(22)*.24)
640 K2=U/(X(22)*.24)
650 GOSUB '02(M2,K2)
660 IF L=1 THEN 670P X(5)=X(3)-E1*(X(3)-X(15)):GOTO 690
670 T0=X(3)-E1*(X(3)-T(15))
680 IF T0]=X(2) THEN 700:GOTO 580
690 IF X(5)]=X(2) THEN 700:GOTO 580
500 IF L=0 THEN 710:X(5)=T0
710 X(18)=X(22)*.24*(X(3)-X(5)):X(23)=X(18):X(24)=0
720 X(16)=X(18)/X(17)+X(15)
730 PRINT PPRINT :PRINT : GOSUB 1040:
    INPUT "LOCATION SF OUTPUT  (1=CRT,2=PRINTER)",B
740 SELECT PRINT 005:IF B=1 THEN 750:SELECT PRINT 211(64)
750 PRINT HEX(03),"      ****  RESULTS  ****"
```

FIGURE C.3-1 (continued)

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OF POOR QUALITY

```
760 JOSUB 1420:IF X(13)=0 THEN 580
770  PRINT " PRI COOLANT FLOW (LB/HR) ";X(13) :
     PRINT " PRI TIN = ";X(9);"  PRI TOUT = "; X6
780 IF X(14)=0 THEN 800
590  PRINT " SEC COOLANT FLOW (LB/HR) ";X(14) P
     PRINT " SEC TIN = ";T(10);"  SEC TOUT = "; X7
800 PRINT
810  PRINT " AIR FLOW RATE (TOTAL CFM) = ";X(20)/(100-B4)*100;"
     BYPASS CFM = ";X(20)/(100-B4)*B4                :
         PRINT " HX TIN = ";T(3);" HX TDP IN = ";T(2)
820 PRINT " HX TOUT = ";X(5);"  HX TDP OUT = "      ;X(5)
830 PRINT " MIX TOUT = ";T;  "  MIX TDP OUT = ";D
840 PRINT
850 PRINT "Q LATENT = "pX(24):
    PRINT "Q SENS   = ";X(23):
    PRINT "Q TOTAL  = ";X(18)
860 PRINTUSING 870,X(19),X(27),U;
870% HAC = -#####.##   HAH = -#####.##   UA = -@####.##
880 SELECT PRINT 005
890 GOTO 1030
900 DEFFN'01(E1,M1)
910 IF E1[ Mh THEN 920:E1=M1-.01
920 IF °1]1 THEN 930: IF M1[1 THEN 940PGOTO 950
930 K=M1/(M1-1)*LOG((1-E1/M1)/(1-E1)):GOTO 960
940 K=M1/(1-M1)*LOG((1-E1)/(1-E1/M1)):GOTO 960
950 K=E1/(1-E1)
960 "ETURN
970 DEFFN'02(M2,K2)
980 IF M2]1 THEN 990:IF M2[ 1 THEN 1000:GOTO 1010
990 C1=EXP(K2¢(M2-1)/M2):E1=(1-C1)/(1/M2-C1):GOTO 1020
1000 C1=EXP(K2*(1-M2)/M2):E1=(1-C1)/(1-C1/M2):GOTO 1020
1010 Eh=K2/(1+K2)
1020 RETURN
1030 STOP "FOR NEXT CASE KEY KONTINUE":GOTO 60
1040 EEFFNA(T)=1.28996377E-02+2.00639183E-03¢T-2.02793661E-05¢T!
2      +1.19988908E-06*T!3-9.17383683E-09*T!4+8.06114440E-11*T!5
       -1.49070697E-13¢T!6
1050 EEFFNB(P)=101.6990348998+33.443410892*LOG(P)+2.312198303256
*   (LOG(P))!2+.2681769374251*(LOG(P))!3+.1055287919424*(LOG(P))!
4   +3.63241174E-02*(LOG(P))!5+4.87666468E-03*(LOG(P))!6
1060 DEFFNC(P1)=.622¢P1/(h4.69-P1)
1070 DEFFND(T)=1061.542592593+.4348148148148*T
1080 M=.001:N=.001:K=1.
h090 A1=X(20)
1100 T1=X(5):D1=X(5)
1110 A2=X(20)/(100-B4)*B4
1120 T2=X(3):D2=X(2)
1130 W1=14.7*144*A1*60/53.3/(T1+460)
1140 W2=14.7*144*A2¢60/53.3/(T2+460)
1150 S1=FNA(D1):S2=FNA(D2)
```

FIGURE C.3-1 (continued)

```
1160 V1=FNC(S1):V2=FNC(S2)
1170 V1=V1*W1:V2=•2*W2
1180 W=W1+W2:V=V1+V2
1190 H1=FND(T1):H2=FND(T2)
1200 H=((W1-V1)*•24*T1+V1*H1)+((W2-V2)*•24*T2+V2*H2)
1210 T=(W1*•24*T1+W2*•24*T2)/(W1*•24+W2*•24):Z=T
1220 H0=(W-•)*•24*T+V*FND(T)
1230 PRINT H,H0,T
1240 IF ABS(H-H0)[=° THEN 1380
1250 Y=Z
1260 Z=T
h270 IF H0]H+N THEN 1330
1280 T=T+K
1290 IF Y[]T THEN 1220
1300 K=K/2
1310 T=T-K
1320 JOTO 1220
1330 T=T-K
1340 IF Y[]T THEN 1220
1350 K=K/2
1360 T=T+K
1370 GOTO 1220
1380 P=V*14.69/(V+W*•622)
1390 D=FNB(P)
1400 REM
1410 RETURN
1420 EEFFN6(X)=15.96522137769+•1858021306397*X-4.01064465E-04*X!
2    +1.51909722E-07*X!3
1430 DEFFN7(X)=3.303588188936-2.68317973E-02*X+6.01984427E-05*X!
2    -5.12152777E-09*X!3
1440 DEFFN8(X)=-.161759673865+1.49855664E-03*X-3.39129732E-06*X!
2    +1.73611111E-10*X!3
1450 DEFFN9(X)=A+B*X+C*X!2
1460 DEFFN5(X)=1.13931368132-5.08131868E-04*X
1470 IF X(13)=0 THEN 1480:IF X(14)=0 THEN 1480PGOTO 1490
h480  ,X7=X(h6):GOTO 1510
       =FN6(X5):B=+N7(X5):C=FN8(X5):F2=FN9(X(2)-T(h0)):
       F2=F2*FN5(X(13))
1500 X6=(100-F2)/100*X(18)/X(13)+X(9):X7=F2/100*X(18)/X(14)+X(10
)
1510 RETURN
```

FIGURE C.3-1 (continued)