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ABSTRACT

SHUTTLE ENVIRONMENTAL AND THERMAL
CONTROL/LIFE SUPPORT SYSTEM COMPUTER
PROGRAM

by

WILLIAM J. AYOTTE

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 Systems 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 SPOZ73, "Users Manual, Space Shuttle Atmospheric Revitalization Subsystem/Active Thermal Control Subsystem Computer Program" covered the work performed under this contract during calendar year 1973; SVSRSR 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.
RS6CS STEADY STATE COMPUTER PROGRAM

RUN #: SAMPLE CASE 1 - M" LOAD 29000 P/L SYS
DATE: 7/3/76

INPUT DATA -
T RS-20 SETPT = 70.00 O CHAMBER-S = 0.00 O CHAMBER-L = 1269.00
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 = 335.00
RS-251 FLOW = 778.00 RS-251 POWER = 73.00 H2O BYPASS FLOW = 281.00
Q H2O AVIONICS = 1110.00 T RS-261 F21 IN = 35.50 W RS-361 F21 = 2587.00

GAS LOOP OUTPUT DATA -
T CHAMBER = 70.00 TOTAL AIR FLOW = 1413.04 O RS-11 = 3311.5°F
T DEPREP = 50.06 HCP RS-11 = 345.21 O RS-50 -S = 0.00
T RS-11 OUT = 70.00 HCP 350-M = 90.68 O RS-50 -L = 0.00
T RS-50 IN = 70.50 350-M = 73.27 O RS-50 -L = 631.5°F
T 350-M IN = 70.50 350-M = 333.72 O 350-M -S = 396.17
T 350-M OUT = 36.10 H COMPRESS = 1.19 O 350-M -L = 1260.0°F
T RS-51 OUT = 64.10 H A 350-M = 796.27 O 350-M -TOT = 5211.1°F

COOLANT LOOP OUTPUT DATA -
T RS-261 H20 OUT = 35.00 T 350-M H2O IN = 35.00 T 350-M H2O OUT = 46.4°F
T RS-251 H2O IN = 54.68 T AVION H2O IN = 55.00 T RS-261 H2O IN = 60.27
T RS-261 F21 IN = 61.47 W RS-261/350-M = 608.00 O H2O FNSTR = 0.00
O RS-261 = 260.22 O RS-261 = 16568.39

FIGURE 1 RS6CS STEADY STATE COMPUTER PROGRAM SAMPLE CASE
INPUT DATA -

| T RS-20 SHTT  | 73.00 | 0 CHARTER-S | 6352.00 | 0 CHARTER-L | 2769.00 |
| T CIRCUIT AVIONICS | 4187.00 | CO2 T/L MT FLOW | 0.76 | RS-11 FLOW | 317.00 |
| RS-11 POWER | 970.00 | RS-51 FLOW | 10.00 | RS-51 POWER | 135.00 |
| RS-251 FLOW | 687.00 | RS-251 POWER | 60.00 | H20 BYPASS FLOW | 0.00 |
| RS-261 F21 F21 T | 36.20 | T RS-261 F21 T | 138.33 | T 350-2 T | 17254.17 |

CIRCUIT LOOP OUTPUT DATA -

| T RS-261 T20 OUT | 42.40 | T 350-2 H20 IN | 42.40 | T 350-2 H20 OUT | 67.55 |
| T RS-251 H20 T | 67.55 | T AVIONICS H20 T | 67.89 | T RS-261 H20 IN | 105.20 |
| T RS-261 F21 OUT | 97.24 | T RS-261/350-T | 667.00 | T H20 P'TS' | -146.00 |
| Q RS-251 | 235.56 | Q RS-261 | 3630.70 |

FIGURE 1. RSEGS STEADY STATE COMPUTER PROGRAM SAMPLE CASE (CONCLUDED)
TO CHAMBER AIR DISTRIBUTION SYSTEM

FROM CHAMBER AIR DISTRIBUTION SYSTEM

AVIONICS SIMULATOR

RS-11 FAN

RS-50 LION ASSEMBLY

350-M HEAT EXCHANGER

H₂O

COOLANT LOOP

TO CHAMBER

RS-51 SEPARATOR

TO CONDENSATE COLLECTION

FIGURE 9: RSNGS ARS GAS LOOP SCHEMATIC
FIGURE 3  RSXCS WATER LOOP SCHEMATIC
<table>
<thead>
<tr>
<th>CRT SYMBOL</th>
<th>PRINTED SYMBOL</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td># of cases</td>
<td>not printed</td>
<td>number of cases to be run (1 - 10)</td>
</tr>
<tr>
<td>date</td>
<td>date</td>
<td>Time identification (16 characters, max)</td>
</tr>
</tbody>
</table>
| 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 ($^\circ$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)**

<table>
<thead>
<tr>
<th>CRT SYMBOL</th>
<th>PRINTED SYMBOL</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>RS-251 power</td>
<td>RS-251 power</td>
<td>RS-251 pump input power (watts)</td>
</tr>
<tr>
<td>bypass flow</td>
<td>H₂O bypass flow</td>
<td>RS-251 pump package bypass flow rate (Lb/Hz)</td>
</tr>
<tr>
<td>Q simulator</td>
<td>Q H₂O avionics</td>
<td>sensible heat supplied by the H₂O loop avionics simulator (Btu/Hr)</td>
</tr>
<tr>
<td>T 350M H₂O in</td>
<td>not printed</td>
<td>desired 350-M HX H₂O inlet temp. If &gt; 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 H₂O heat sink Q will be set at 0 and the RS-261 HX outlet temp. will be used (°F)</td>
</tr>
<tr>
<td>T 261 H₂O in</td>
<td>not printed</td>
<td>desired RS-261 HX H₂O inlet temp. must be &gt; 0 if T 350M H₂O in is &gt; 0; / or must = 0 if T 350M H₂O in = 0 (°F)</td>
</tr>
<tr>
<td>T 261 F₂1 in</td>
<td>T RS-261 F₂1 IN</td>
<td>RS-261 HX cold side inlet temperature (°F)</td>
</tr>
<tr>
<td>261 F₂1 flow</td>
<td>W RS-261 F₂1</td>
<td>RS-261 HX cold side flow rate (Lb/Hz)</td>
</tr>
</tbody>
</table>
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
   - 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

<table>
<thead>
<tr>
<th>PRINTED SYMBOL</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>T chamber</td>
<td>steady state chamber temperature (°F)</td>
</tr>
<tr>
<td>total air flow</td>
<td>air weight flow at the RS-11 fans (Lb/HR)</td>
</tr>
<tr>
<td>Q RS-11</td>
<td>sensible heat generated by the RS-11 fans (Btu/HR)</td>
</tr>
<tr>
<td>T dewpoint</td>
<td>chamber dewpoint temperature (°F)</td>
</tr>
<tr>
<td>WCP RS-11</td>
<td>air weight flow X specific heat at the RS-11 fans (Btu/HR - °F)</td>
</tr>
<tr>
<td>Q RS-50-S</td>
<td>sensible heat generated by the LiOH/CO₂ reaction (Btu/HR)</td>
</tr>
<tr>
<td>T RS-11 in</td>
<td>RS-11 fans inlet temperature (°F)</td>
</tr>
<tr>
<td>WCP 350-M</td>
<td>air weight flow X specific heat through the 350-M HX (Btu/HR - °F)</td>
</tr>
<tr>
<td>Q RS-50-L</td>
<td>latent heat generated by the LiOH/CO₂ reaction (Btu/HR)</td>
</tr>
<tr>
<td>T RS-50 in</td>
<td>RS-50 LiOH assembly inlet temperature (°F)</td>
</tr>
<tr>
<td>V 350-M</td>
<td>air flow rate exiting the 350-M HX (cfm)</td>
</tr>
<tr>
<td>Q RS-51</td>
<td>sensible heat generated by the RS-51 separator (Btu/HR)</td>
</tr>
<tr>
<td>T 350-M in</td>
<td>350-M HX air inlet temperature (°F)</td>
</tr>
<tr>
<td>V bypass</td>
<td>air flow rate through the 350-M HX bypass (cfm)</td>
</tr>
<tr>
<td>Q 350-M-S</td>
<td>350-M HX sensible heat load (Btu/HR)</td>
</tr>
<tr>
<td>T 350-M out</td>
<td>350-M HX air outlet temperature (°F)</td>
</tr>
<tr>
<td>W condensate</td>
<td>condensate flow rate exiting the RS-51 separator (Lb/HR)</td>
</tr>
<tr>
<td>Q 350-M-L</td>
<td>350-M HX latent heat load (Btu/HR)</td>
</tr>
</tbody>
</table>
Table II
OUTPUT DATA DEFINITION (CONCLUDED)

<table>
<thead>
<tr>
<th>PRINTED SYMBOL</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>T RS-51 out</td>
<td>RS-51 separator air outlet temperature (°F)</td>
</tr>
<tr>
<td>UA 350-M</td>
<td>350-M HX UA (Btu/HR - °F)</td>
</tr>
<tr>
<td>Q 350-M -TOT</td>
<td>350-M HX total heat load (Btu/HR)</td>
</tr>
<tr>
<td>T RS-261 H2O out</td>
<td>RS-261 HX H2O outlet temperature (°F)</td>
</tr>
<tr>
<td>T 350-M H2O in</td>
<td>350-M HX H2O inlet temperature (°F)</td>
</tr>
<tr>
<td>T 350-M H2O out</td>
<td>350-M H2O outlet temperature (°F)</td>
</tr>
<tr>
<td>T RS-251 H2O in</td>
<td>RS-251 pump inlet temperature (°F)</td>
</tr>
<tr>
<td>T avion H2O in</td>
<td>H2O loop avionics simulator inlet temperature (°F)</td>
</tr>
<tr>
<td>T RS-261 H2O in</td>
<td>RS-261 HX H2O inlet temperature (°F)</td>
</tr>
<tr>
<td>T PS-261 F21 out</td>
<td>RS-261 HX cold side outlet temperature</td>
</tr>
<tr>
<td>W RS-261/350-M</td>
<td>RS-261/350-M HX H2O flow rate (Lb/HR)</td>
</tr>
<tr>
<td>Q H2O HTSINK</td>
<td>H2O loop heat sink load (Btu/HR)</td>
</tr>
<tr>
<td>Q RS-251</td>
<td>heat generated by the RS-251 pump</td>
</tr>
<tr>
<td>Q RS-261</td>
<td>RS-261 HX heat load (Btu/HR)</td>
</tr>
</tbody>
</table>
FIGURE 4  RS-11 FAN PERFORMANCE MAP
1 COOLANT CIRCUIT:
VELOCITY = cfm / 8815
\[ h_H = 118.4892 + \eta \cdot h_o \]

2 COOLANT CIRCUITS:
VELOCITY = cfm / 8815
\[ h_H = 135.4153 + \eta \cdot h_o \]
1 COOLANT CIRCUIT:
FLOW RATE / START
= TOTAL FLOW / 2
\[ h_a = 7.3008 \cdot h_c \]

2 COOLANT CIRCUITS:
FLOW RATE / START
= TOTAL FLOW / 4
\[ h_a = 14.6016 \cdot h_c \]

FLOW RATE / START - lb / hr

FIGURE C: B3ECZ 350-M HEAT EXCHANGER PERFORMANCE
FIGURE 7: NSCS N-1 HEAT EXCHANGER PERFORMANCE
COLD SIDE FLUID: 62.5% GLYCOL / 37.5% WATER, T_{\text{IN}} 40°F

HOT SIDE FLUID: WATER

HOT SIDE FLOW RATE - lb / hr

COLD SIDE FLOW RATE - lb / hr

FIGURE 3: R-100S-2.1 HEAT EXCHANGER PERFORMANCE

ORIGINAL PAGE IS OF POOR QUALITY
HAMILTON STANDARD

COLD SIDE FLUID: WATER, $T_{in} = 40^\circ F$
HOT SIDE FLUID: WATER

FIGURE 9 RSECS 261 HEAT EXCHANGER PERFORMANCE
### Table III

**INTERNAL DATA SUMMARY**

<table>
<thead>
<tr>
<th>STORAGE LOCATION</th>
<th>DATA DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-25</td>
<td>Freon temperatures, 0-240°F in 10°F increments</td>
</tr>
<tr>
<td>26-50</td>
<td>Freon enthalpy, Btu/Lb, corresponding to temperatures in locations 1-25</td>
</tr>
<tr>
<td>51-70</td>
<td>Water vapor temperatures, 32-70°F in 20°C increments</td>
</tr>
<tr>
<td>71-90</td>
<td>Water vapor pressure, PSIA, corresponding to temperatures in locations 51-70</td>
</tr>
<tr>
<td>91-118</td>
<td>350-M HX air side film coefficient curve, $\eta_{h_0}$ 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: $\eta_{h_0},$ Btu/HR-Ft², corresponding to air velocities in locations 93-103</td>
</tr>
<tr>
<td>119-138</td>
<td>350-M HX H₂O 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-Ft², corresponding to flow/start in locations 121-129</td>
</tr>
<tr>
<td>139-211</td>
<td>RS-261 HX effectiveness map; H₂O/F₂₁, T F₂₁ = in = 40°F 139: # of X values (8) 140: # of Y values (7) 141-148: H₂O 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: X₁, Y₁, X₂, Y₂, X₃Y₇, X₂Y₁, X₂Y₇, X₈Y₇</td>
</tr>
</tbody>
</table>
Table IV
DATA ARRAY

- Provides storage for individual case calculations

<table>
<thead>
<tr>
<th>ARRAY LOCATION</th>
<th>DATA DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RS-20 temperature controller set point</td>
</tr>
<tr>
<td>2</td>
<td>Non-RSECS sensible heat added to the chamber</td>
</tr>
<tr>
<td>3</td>
<td>Non-RSECS latent heat added to the chamber</td>
</tr>
<tr>
<td>4</td>
<td>Cabin avionics simulator heat load</td>
</tr>
<tr>
<td>5</td>
<td>CO₂ injection flow rate to chamber</td>
</tr>
<tr>
<td>6</td>
<td>RS-11 fans total volumetric flow rate</td>
</tr>
<tr>
<td>7</td>
<td>RS-11 fans power requirement</td>
</tr>
<tr>
<td>8</td>
<td>RS-51 separator volumetric flow rate</td>
</tr>
<tr>
<td>9</td>
<td>RS-51 separator power requirement</td>
</tr>
<tr>
<td>10</td>
<td>RS-251 pump total mass flow rate</td>
</tr>
<tr>
<td>11</td>
<td>RS-251 pump power requirement</td>
</tr>
<tr>
<td>12</td>
<td>H₂O bypass mass flow rate</td>
</tr>
<tr>
<td>13</td>
<td>H₂O loop avionics simulator heat load</td>
</tr>
<tr>
<td>14</td>
<td>350-M HX H₂O inlet temperature</td>
</tr>
<tr>
<td>15</td>
<td>RS-261 HX H₂O inlet temperature</td>
</tr>
<tr>
<td>16</td>
<td>RS-261 HX F21 inlet temperature</td>
</tr>
<tr>
<td>17</td>
<td>RS-261 HX F21 mass flow rate</td>
</tr>
<tr>
<td>18</td>
<td>Chamber temperature</td>
</tr>
<tr>
<td>19</td>
<td>RS-11 fan heat load</td>
</tr>
<tr>
<td>20</td>
<td>Sensible heat generated by the CO₂/LiOH reaction</td>
</tr>
</tbody>
</table>
Table IV

DATA ARRAY (CONTINUED)

- Provides storage for individual case calculations

<table>
<thead>
<tr>
<th>ARRAY LOCATION</th>
<th>DATA DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>Latent heat generated by the CO$_2$/LiOH reaction</td>
</tr>
<tr>
<td>22</td>
<td>RS-51 separator heat load</td>
</tr>
<tr>
<td>23</td>
<td>Sensible heat at the 350-M HX inlet - air side</td>
</tr>
<tr>
<td>24</td>
<td>350-M HX total sensible heat</td>
</tr>
<tr>
<td>25</td>
<td>350-M HX total latent heat</td>
</tr>
<tr>
<td>26</td>
<td>350-M HX total heat load</td>
</tr>
<tr>
<td>27</td>
<td>RS-251 pump heat load</td>
</tr>
<tr>
<td>28</td>
<td>H$_2$O loop sink heat load</td>
</tr>
<tr>
<td>29</td>
<td>RS-261 HX heat load</td>
</tr>
<tr>
<td>30</td>
<td>RS-261/350-M HX's H$_2$O mass flow rate</td>
</tr>
<tr>
<td>31</td>
<td>RS-261 HX H$_2$O outlet temperature</td>
</tr>
<tr>
<td>32</td>
<td>RS-261 HX F21 outlet temperature</td>
</tr>
<tr>
<td>33</td>
<td>350-M HX H$_2$O outlet temperature</td>
</tr>
<tr>
<td>34</td>
<td>RS-251 pump H$_2$O inlet temperature</td>
</tr>
<tr>
<td>35</td>
<td>H$_2$O loop avionics simulator inlet temperature</td>
</tr>
<tr>
<td>36</td>
<td>RS-11 fan air mass flow rate X specific heat</td>
</tr>
<tr>
<td>37</td>
<td>350-M HX air mass flow rate X specific heat</td>
</tr>
<tr>
<td>38</td>
<td>RS-11 fan inlet temperature</td>
</tr>
<tr>
<td>39</td>
<td>RS-11 fan air mass flow rate</td>
</tr>
<tr>
<td>40</td>
<td>Chamber temperature from previous iteration</td>
</tr>
</tbody>
</table>
### Table IV

**DATA ARRAY (CONCLUDED)**

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

INPUT DATA ARRAY

- Provides input data storage for a maximum of 10 cases

<table>
<thead>
<tr>
<th>ARRAY LOCATION</th>
<th>DATA DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,1 - 1,17</td>
<td>Case #1 input data: corresponds to X-array locations 1-17</td>
</tr>
<tr>
<td>2,1 - 2,17</td>
<td>Case #2 input data</td>
</tr>
<tr>
<td>10,1 - 10,17</td>
<td>Case #10 input data</td>
</tr>
</tbody>
</table>

Table VI

LOGIC KEY ARRAY

- Provides storage for program keys

<table>
<thead>
<tr>
<th>ARRAY LOCATION</th>
<th>DATA DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Case # being run</td>
</tr>
<tr>
<td>2</td>
<td>Max # of cases to be run</td>
</tr>
<tr>
<td>3</td>
<td>Flow chart key</td>
</tr>
<tr>
<td>4</td>
<td>Print-out key</td>
</tr>
</tbody>
</table>

Table VII

SCALAR VARIABLES SUMMARY LIST

<table>
<thead>
<tr>
<th>B$</th>
<th>M2</th>
<th>U2</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>Q1</td>
<td>U3</td>
</tr>
<tr>
<td>E2</td>
<td>Q2</td>
<td>W1</td>
</tr>
<tr>
<td>H</td>
<td>T1</td>
<td>Z</td>
</tr>
<tr>
<td>H1</td>
<td>T2</td>
<td>Z1</td>
</tr>
<tr>
<td>H2</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td>N1</td>
<td>U1</td>
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</table>
Table VIII

SUBROUTINE DESCRIPTIONS

<table>
<thead>
<tr>
<th>SUBROUTINE NUMBER</th>
<th>SUMMARY</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Interpolates data curves that have been transferred to the X-array in locations 101-200. Array must be set-up in following order:</td>
</tr>
<tr>
<td></td>
<td>X(101) : # of X-values (N)</td>
</tr>
<tr>
<td></td>
<td>X(102) : # of Y-values (M)</td>
</tr>
<tr>
<td></td>
<td>X(103) - X(102 + N) : X-values in ascending order</td>
</tr>
<tr>
<td></td>
<td>X(102 + N + 1) - X(102 + N + M) : Y-values in ascending order, omit if M = 0</td>
</tr>
<tr>
<td></td>
<td>X(102 + N + M + 1) - X(200) : Z-values in following order -- Z(N1, M1), Z(N1, M2), ----Z(N1, M)</td>
</tr>
<tr>
<td></td>
<td>Z(N2, M1), ----Z(N2, M), ----Z(N, M)</td>
</tr>
<tr>
<td></td>
<td>Array and scalar variables used:</td>
</tr>
<tr>
<td></td>
<td>A1(6)</td>
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<tr>
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<td>X1(6)</td>
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<tr>
<td></td>
<td>Y1(6)</td>
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<tr>
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<td>C1</td>
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<td></td>
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<tr>
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<td>N2</td>
</tr>
<tr>
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<td>N8</td>
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</tbody>
</table>
Table VIII

SUBROUTINE DESCRIPTIONS (CONTINUED)

<table>
<thead>
<tr>
<th>SUBROUTINE NUMBER</th>
<th>SUMMARY</th>
</tr>
</thead>
<tbody>
<tr>
<td>N9 Z1</td>
<td>Calculates air flow rate X Cp by iterating 350-M HX air outlet temperature and chamber dewpoint</td>
</tr>
<tr>
<td></td>
<td>Scalar variables: B</td>
</tr>
<tr>
<td>02</td>
<td>Calculates air dewpoint at 350-M HX inlet</td>
</tr>
<tr>
<td></td>
<td>Scalar variables: A2, C, P2, Z1</td>
</tr>
<tr>
<td>03</td>
<td>Calculates 350-M HX hA hot and UA</td>
</tr>
<tr>
<td></td>
<td>Scalar variables: E, H1, H2, V1, Z1</td>
</tr>
<tr>
<td>04</td>
<td>Calculates 350-M HX NTU's</td>
</tr>
<tr>
<td></td>
<td>Scalar variables: E3, K, M3</td>
</tr>
<tr>
<td>05</td>
<td>Calculates chamber dewpoint</td>
</tr>
<tr>
<td></td>
<td>Scalar variables: A2, F, P2, Z1</td>
</tr>
</tbody>
</table>
Table VIII

SUBROUTINE DESCRIPTIONS (CONCLUDED)

<table>
<thead>
<tr>
<th>SUBROUTINE NUMBER</th>
<th>SUMMARY</th>
</tr>
</thead>
</table>
| 07                | Calculates air weight flow and Cp by iterating RS-11 fan inlet temperature  
Scalar variables:  
C3  
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 |
10 REM RSEC'S ARS/H2O LOOP PERFORMANCE
20 COM X(200),A(10,17),AS(1n64),B$,Y(4)
30 IF Y(1) THEN 250; Y(1)=1
40 REM FREON PROPERTIES - TEMPERATURE (1):
   DATA 0 ,10 ,20 ,30 ,40 ,50 ,60 ,70 ,80 ,90 ,100,110,120,
   130,140,150,160,170,180,190,200,210,220,230,240
50 REM FREON PROPERTIES - ENTHALPY (26):
   DATA 9.44,11.81,14.21,16.61,19.04,21.49,23.93,26.49,29.99,33,
   31.59,34.18,36.79,39.46,42.13,44.86,47.62,50.43,53.2
60 DATA 56 ,59 ,62 ,65 ,68 ,71 ,74
70 REM WATER VAPOR PROPERTIES - TEMPERATURE (51):
   DATA 32,34,36,38,40,42,44,46,48,50,52,54,56,58,60,62,64,66,68,70,
80 REM WATER VAPOR PROPERTIES - PRESSURE (71):
   DATA .0385,.0603,.1001,.1336,.1615,.1899,.2183,.2467,.2662,.2856
90 DATA .2951,.3164,.3381,.3631
100 REM 350-M IN AIR SIDE FILM COEFFICIENT (91):
   DATA 13 ,0 ,100 ,200 ,300 ,400 ,500 ,600 ,700 ,800 ,900 ,1000 ,1100 ,1200 ,1300
110 DATA 9.6 ,17.2 ,15.6 ,17.7 ,19.5 ,21.3 ,22.6 ,24.5 ,23.3 ,24.6 ,27.5 ,28.5 ,29.6
120 REM 350-M IN%20 SIDE FILM COEFFICIENT (119):
   DATA 9 ,0 ,100 ,150 ,200 ,250 ,300 ,350 ,400 ,450 ,500 ,550 ,600 ,650 ,700 ,750
130 REM 261 IN% EFFECTIVITY MAP - P21/120, T=P21=AF (130):
   DATA .77 ,200 ,300 ,400 ,500 ,600 ,700 ,800
140 DATA 900 ,1000 ,1100 ,1200 ,1300
150 DATA .118 ,.218 ,.328 ,.438 ,.548 ,.658 ,.768 ,.878 ,.988
160 DATA .0282 ,.9635 ,.981 ,.1132 ,.5496 ,.6797 ,.7914 ,.8739 ,.9266
170 DATA .9577
170 INPUT "B OF CASES " (1-10) "$Y(2);
   INPUT "INPUT "B=$": "$Y(2);
180 INPUT "ARC FLOW" CARTS DISTINGUISH, (YES=1/NO=2) "$Y(3);
190 PRINT "TS PRINT OUT DICT."
   INPUT "YES/NO 005"
   PRINT "CASE; /= " $Y(4); 
   IL-PIT "H= DISCRIMINATION": "$Y(2);
190 INPUT "T R=NO 005" "$Y(2)= "$Y(2);
   T-PIT "$A=005" "$Y(2)= "$Y(2);
190 INPUT "T R=NO 005" "$Y(2)= "$Y(2);
   T-PIT "$A=005" "$Y(2)= "$Y(2);
200 INPUT "A=005" "$Y(2)= "$Y(2);
   T-PIT "B=005" "$Y(2)= "$Y(2);
   T-PIT "C=005" "$Y(2)= "$Y(2);
   T-PIT "D=005" "$Y(2)= "$Y(2);
   T-PIT "E=005" "$Y(2)= "$Y(2);
   T-PIT "PA=005" "$Y(2)= "$Y(2); 
   T-PIT "PS=16 FLOU" "$Y(2)= "$Y(2);
   T-PIT "PA=15 FLOU" "$Y(2)= "$Y(2);
HAMILTON STANDARD

Table IX

PROGRAM LISTING (CONTINUED)

```
210 INPUT "PS-11 POWER (WATTS) =", A(7,7):
211 INPUT "PS-51 FLOW (CFM) =", A(7,6):
212 INPUT "PS-31 POWER (WATTS) =", A(7,9):
220 INPUT "PS-251 FLOW (LB/H) =", A(7,10):
221 INPUT "PS-251 POWER (WATTS) =", A(7,11):
222 INPUT "BYPASS FLOW (LB/H) =", A(7,12):
230 INPUT "0 STIMULATOR (BTC/H) =", A(7,13):
231 INPUT "T 350M H20 IN (DEG F) =", A(7,14):
232 INPUT "T 261 H20 II (DEG F) =", A(7,15):
240 INPUT "261 F21 III (BTC F) =", A(7,16):
241 INPUT "261 F21 FLOW (LB/H) =", A(7,17):
250 NEXT Z:
```

```
250 IF Y(1)=Y(2) THEN GOTO 260: Y(1)=0: RESTORE: GOTO 340
251 FOR Z=1 TO 17: X(Z)=A(Y(1),Z): NEXT Z: X(18)=X(1):
252 X(19)=3.41*A(7,7)*X(5): X(20)=427.5*X(5):
253 X(21)=3.41*A(7,6)*X(4)+X(19)+X(20):
254 X(22)=X(26)+X(27)+X(25):
255 X(23)=X(27)=3.414*X(11):
256 X(24)=X(30)-X(10)-X(12):
257 RESTORE 130: FOR Z=101 TO 173: READ X(Z): NEXT Z
258 GOSUB '01(X(30),X(17)): E1=E1: IF X(15)=0 THEN 290:
259 X(31)=X(15)-E1*X(15)-X(16):
260 X(29)=X(30)*X(15)-X(31):
261 X(29)=X(30)*X(31)-X(14)!
```

```
300 NEXT Z: FOR Z=101 TO 173: READ X(Z): NEXT Z
301 RESTORE 26: FOR Z=101 TO 127: READ X(Z): NEXT Z
302 RESTOR 1: FOR Z=128 TO 153: READ X(Z): NEXT Z
303 RESTORE 26: FOR Z=101 TO 127: READ X(Z): NEXT Z
304 RESTOR 1: FOR Z=128 TO 153: READ X(Z): NEXT Z
305 RESTORE 26: FOR Z=101 TO 127: READ X(Z): NEXT Z
```

```
310 GOSUB '01(X(11),0): H1=H1+X(29)/X(17):
311 GOSUB '02(X(11),0): H2=H2+X(29)/X(17):
312 GOSUB '03(X(11),0): H=H2/H1:
```

```
340 X(65)=X(45)+X(44)+X(24)/X(37):
341 X(13)=X(44)/X(23)/X(36): GOSUB '02: GOSUB '10: GOSUB '11:
342 IF X(45)=X(14) THEN 360
```

```
343 X(34)=X(34)+X(27)/X(10):
344 X(40)=X(40)+X(41)+X(42)-50:
345 X(43)=X(43)+X(26)+X(27)/X(10):
346 X(36)=X(36)+X(37)/X(36):
347 V1=X(36)/X(36):
```

```
348 V1=X(37)/X(37):
349 IF X(45)=X(45)+1: X(45)=X(45)+X(24)/X(37):
350 IF X(45)=X(45)+1: X(45)=X(45)+X(24)/X(37):
```

```
360 IF X(45)=X(14) THEN 360
370 Q1=X(37)/X(44)+X(37): Q2=X(25): IF Q2(X(26) THEN 380:
380 T2=X(31): T3=X(31): Q1=X(26)!
```

```
390 T2=X(44)-X(44)-X(44)-X(44)-X(44)-X(44): IF T2=T1 THEN 510:
```

```
T1=(X(37)-X(37))/X(37):
```

```
370 Q1=X(37)/X(44)+X(37): Q2=X(25): IF Q2(X(26) THEN 380:
380 T2=X(31): T3=X(31): Q1=X(26)!
390 T2=X(44)-X(44)-X(44)-X(44)-X(44)-X(44): IF T2=T1 THEN 510:
```

```
T1=(X(37)-X(37))/X(37):
```

```
370 Q1=X(37)/X(44)+X(37): Q2=X(25): IF Q2(X(26) THEN 380:
380 T2=X(31): T3=X(31): Q1=X(26)!
390 T2=X(44)-X(44)-X(44)-X(44)-X(44)-X(44): IF T2=T1 THEN 510:
```

```
T1=(X(37)-X(37))/X(37):
```

```
370 Q1=X(37)/X(44)+X(37): Q2=X(25): IF Q2(X(26) THEN 380:
380 T2=X(31): T3=X(31): Q1=X(26)!
390 T2=X(44)-X(44)-X(44)-X(44)-X(44)-X(44): IF T2=T1 THEN 510:
```

```
T1=(X(37)-X(37))/X(37):
```

```
370 Q1=X(37)/X(44)+X(37): Q2=X(25): IF Q2(X(26) THEN 380:
380 T2=X(31): T3=X(31): Q1=X(26)!
390 T2=X(44)-X(44)-X(44)-X(44)-X(44)-X(44): IF T2=T1 THEN 510:
```

```
T1=(X(37)-X(37))/X(37):
```

```
370 Q1=X(37)/X(44)+X(37): Q2=X(25): IF Q2(X(26) THEN 380:
380 T2=X(31): T3=X(31): Q1=X(26)!
390 T2=X(44)-X(44)-X(44)-X(44)-X(44)-X(44): IF T2=T1 THEN 510:
```

```
T1=(X(37)-X(37))/X(37):
```

```
370 Q1=X(37)/X(44)+X(37): Q2=X(25): IF Q2(X(26) THEN 380:
380 T2=X(31): T3=X(31): Q1=X(26)!
390 T2=X(44)-X(44)-X(44)-X(44)-X(44)-X(44): IF T2=T1 THEN 510:
```

```
T1=(X(37)-X(37))/X(37):
```
Table IX

PROGRAM LISTING (CONTINUED)

```
390 E2=(T1-X(45))/\(T1-X(14)\); N2=X(30)^Q1/X(37)/Q2;
GOSUB '05(E2,N2); U2=X(37)^Q2/Q1;
U3=(1/11)/(1+1/11);N3/(Q2+1/(1+1/11)); U=U1+U2+U3
400 IF U=X(46) THEN 550; IF U\(X(14)\) THEN 510; IF X(14)=X(45)
THEN 550; IF X(14)=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=.5F-4 THEN 410; GOTO 550
430 IF X(14)=X(1) THEN 440; X(40)=X(18); X(41)=U;
X(14)=X(14)-1; GOSUB '02; GOTO 660
440 E1=(ABS(T1-X(45)))/X(45); IF E1=.5E-2 THEN 550;
X(45)=X(14)+\(X(45)*X(14)\)/X(46);
X(37)=X(24)/X(23)/X(36)+X(18)-X(14); \(X(45)=X(14)\)
470 GOSUB '06; GOSUB '07; X(37)=X(24)/X(23)/X(36)+X(18)-X(14); \(X(45)=X(14)\)
480 IF X(37)=X(43)*X(36) THEN 460;
X(37)=X(43)*X(36)
490 GOSUB '10; GOSUB '11; IF X(45)=X(14) THEN 360;
IF X(14)=X(1) THEN 490;
X(37)=X(24)/X(23)/X(36)+X(18)-X(14); \(X(45)=X(14)\)
500 GOSUB '07; GOSUB '07; X(37)=X(24)/X(23)/X(36)+X(18)-X(14); \(X(45)=X(14)\)
510 IF X(45)=X(44) THEN 530; IF E1=.5F-4 THEN 490; GOTO 550
520 IF X(45)=X(44) THEN 530; IF E1=.5F-4 THEN 490; GOTO 550
530 IF X(37)=X(43)*X(36) THEN 460;
X(37)=X(43)*X(36)
540 IF X(14)=X(14)-1; GOSUB '02; GOSUB '10;
GOSUB '11; GOTO 550
550 X(18)=X(18)+1; GOSUB '07; GOSUB '10; GOSUB '11; GOTO 550
560 IF X(45)=X(44) THEN 530; IF E1=.5F-4 THEN 490; GOTO 550
570 SELECT PRINT? 211(156); PRINT HEX(ODDE)
PRINT "SSMS S-1640 STATE COMPUTER PROGRAM"
PRINT FOX('PAAOA')
590 PRINT "PRIM: K=1;AS(Y(1))
PRINT "PRIM: K=1;BS: PRINT HEX('PAAOA')
PRIM: "T-NET DATA -"
500 PRINT TYP 670, E(1), E(2), E(3)
PRINT TYP 660, X(4), X(5), X(6)
PRINT TYP 700, X(7), X(8), X(9)
```

600 PRINT "USING 710,X(10),X(11),X(12):"
710 PRINT "USING 720,X(13),X(16),X(17):"
720 PRINT HEX (0AA)
610 PRINT "GAS LOOP OUTPUT DATA -":
PRINT "USING 730,X(18),X(30),X(10):"
PRINT "USING 740,X(22),X(36),X(20):"
620 PRINT "USING 750,X(29),X(37),X(23):"
PRINT "USING 760,X(40),X(67),X(22):"
PRINT "USING 770,X(44),X(68),X(24):"
630 PRINT "USING 780,X(45),X(51),X(25):"
PRINT "USING 790,X(50),X(66),X(26):"
PRINT HEX (0A)
640 PRINT "COOLANT LOOP OUTPUT DATA -":
PRINT "USING 800,X(31),X(14),X(33):"
PRINT "USING 810,X(34),X(35),X(15):"
650 PRINT "USING 820,X(32),X(30),X(28):"
PRINT "USING 830,X(27),X(29):"
PRINT HEX (0A)
660 IF Y(3)=2 THEN 670: LOAD "RSICS2"
670 V(1)=Y(1)+1: GOTO 250
680 IF RS-20 STT=" CO" CHAMBER=S "=" CHAMBER-L "=" "0"
690 IF 20 CHAM AVIONICS = "=" "RS-11 FLOW"
700 IF RS-11 POWER = "=" "RS-51 FLOW"
710 IF RS-251 POWER = "=" "RS-251 FLOW"
720 IF BYPASS FLOW = "=" "W"
730 IF RS-261 P21 = "=" "V"
740 IF TOTAL AIR FLOW = "=" "Q"
750 IF WGP RS-11 = "=" "0"
760 IF UGP 350-M = "=" "0"
770 IF V BYPASS = "=" "Q"
780 IF W CONDENSATE = "=" "0"
790 IF IGA 350-M = "=" "Q"
800 IF 350-M 1/2 = "=" "T"
810 IF 350-M 1/2 = "=" "T"
820 IF AVION 1/2 = "=" "T"
830 IF V 1/2 = "=" "T"
PROGAM LISTING (CONTINUED)

820 Z7 RS-261 F21 OUT =-99999.99 11 RS-261/150-M =-99999.99 0
1120 RTSTME =-99999.99
830 Z9 RS-251 =-99999.99 0 RS-261 =-99999.99
840 END
850 DEFN'01(C1,D1)
860 DEF A1(6),Y1(6),Y1(6)
870 I1=101: N=3: M=2
880 IF X(I1)=3 THEN 920: IF X(I1)=3 THEN 930:
890 IF X(I1)=0 THEN 950: IF X(I1)=0 THEN 920:
900 IF X(I1)=2 THEN 900: IF X(I1)=2 THEN 920
910 N=1: GOTO 910
920 N=2
930 N=1
940 L=I1: IF X(I1)=0 THEN 960
950 K1=-1: Z1=0: GOTO 1230
960 N9=X(L):
   IF X(I1+1)=0 THEN 950: IF X(I1+1)=0 THEN 950
970 N8=0: GOTO 990
980 N8=X(L+1)
990 K1=0: K8=0: C2=C1: J1=J1+2: J2=J2+2+J1+3:
   IF C2=X(J1) THEN 1030: IF C2=X(J1) THEN 1060
1000 FOR J=J1 TO J2: IF C2=X(J1) THEN 1050: NEXT J
1030 K1=1: C2=X(J1)
1050 J9=J1: GOTO 1060
1060 IF J-J1=1 THEN 1030: IF J-J1=1 THEN 1040:
   IF J=J2 THEN 1020: IF J=J2 THEN 1010:
   J9=J9-1
1080 C3=C2: IF N1=0 THEN 1070: FOR L=1 TO J1: X1(L)=X(19):
   L=L+1: Y1(L)=X(L): J0=J0+1: TEXT L: J=J+1: GOTO 1100
1070 J1=J1+1: J2=J2+1: N2=0: IF N2=X(J1) THEN 1100:
   IF N2=X(J1) THEN 1100: FOR J=J1 TO J2:
   IF N7=J7 THEN 1100: NEXT J
1090 K8=J7: N1=KX(J7)
1090 J9=J9+1: GOTO 1130
1100 J9=J9-1: GOTO 1130
1130 IF J-J1=1 THEN 1100: IF J-J1=1 THEN 1110:
   IF J=J2 THEN 1020: IF J=J2 THEN 1010:
   J9=J9-1
1130 J7=J7+1: J6=J6+1: J5=J5+1: J4=J4+1: J3=J3+1: J2=J2+1: FOR L=1 TO J1:
   X1(L)=X(17): Y1(L)=X(17): J7=J7+1: NEXT L:
1160 GOTO 1150
1180 Y1(J)=Z1: FOR L=1 TO J1: Y1(L)=Y1(L-1): FOR M=1 TO J1:
   Y1(L)=Y1(L-1)+Z1(L): Y1(L)=Y1(L-1): L7=L7+1: NEXT M: NEXT L:
   FOR L=1 TO J1: Y1(L)=Y1(L-1): J9=J9+1: GOTO 1150
1190 C3=N2: J1=1
Table IX

PROGRAM LISTING (CONTINUED)

1150 D=1: X1(1:2)=X1(1); X1(1+1)=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=Y2(J): X1(1)=0: X1(2)=0: X1(3)=0: X1(4)=0
1160 X1(J)=J: GOTO 1220
1170 D=D*C4: ON J: 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(J)=A1(J+1); Z1=0: FOR J=1 TO N1:
X1(J)=N/A1(J)*A1(J+1)*X1(J+1); Z1=Z1+Y1(J)*X1(J);
NEXT J
1220 IF I=0 THEN 1160
1230 IF Z1=0 THEN 1160
1240 IF Z1=0 THEN 1160
1250 DEFF'03
1260 X(101)=20: X(102)=0: RESTORE 51: FOR G=101 TO 142:
READ X(C): NEXT C: GOSUB '01(X(45),0): P2=Z1:
A2=A2*(A2+P2)/(A4,466-P2)+P2/(A3,36)/X(37)
1270 RETURN
1280 DEFF'03
1290 X(101)=20: X(102)=0: RESTORE 51: FOR G=101 TO 142:
READ X(C): NEXT C: GOSUB '01(X(45),0): P2=Z1:
A2=A2*(A2+P2)/(A4,466-P2)+P2/(A3,36)/X(37)
1270 RETURN
1280 DEFF'03
1290 X(101)=20: X(102)=0: RESTORE 51: FOR G=101 TO 142:
READ X(C): NEXT C: GOSUB '01(X(45),0): P2=Z1:
A2=A2*(A2+P2)/(A4,466-P2)+P2/(A3,36)/X(37)
1270 RETURN
1280 DEFF'03
1290 X(101)=20: X(102)=0: RESTORE 51: FOR G=101 TO 142:
READ X(C): NEXT C: GOSUB '01(X(45),0): P2=Z1:
A2=A2*(A2+P2)/(A4,466-P2)+P2/(A3,36)/X(37)
1270 RETURN
1280 DEFF'03
1290 X(101)=20: X(102)=0: RESTORE 51: FOR G=101 TO 142:
READ X(C): NEXT C: GOSUB '01(X(45),0): P2=Z1:
A2=A2*(A2+P2)/(A4,466-P2)+P2/(A3,36)/X(37)
1270 RETURN
1280 DEFF'03
1440  GOSUB '08(P2,53.35): R2=R3:  
R3=(85.75*R1+53.35*R2)/(R1+R2): C3=.24+.2799*R1/P2:  
FOR G=1 TO 6  
1450  X(39)=1.26973.44*X(6)/R3/(X(18)+X(4)/X(36)+459.6):  
X(36)=C3*X(19): NEXT G:  
RETURN  
1460  DEFN109(P4,R4):  
R3=14.4846/R4/(X(18)+459.6):  
RETURN  
1470  DEFN10:  
X(38)=X(18)+X(4)/X(36):  
X(49)=X(18)+X(4)+X(19)/X(36)  
1480  X(46)=X(18)+X(23)/X(36):  
RETURN  
1490  DEFN11:  
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 analyzed 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: M. IN ORBIT R/P = 500  DATE: 10/17/74

CABIN CONDITIONS:
T = 70.00
TDP = 61.27
QS = 452.0
QL = 3064.0
CO₂ = 0.880

T = 67.08
TO CABIN

FROM CABIN:
T = 70.00
Q = 1301.0
T = 73.31

RS-50 LIQH ASSEMBLY

350-M HEAT EXCHANGER
F = 83.89
QS = 4803.5
QL = 3440.2
T = 33.67

T = 32.99
H₂O COOLANT LOOP

T = 51.31
W = 450.0
Q = 8243.7

FIGURE 10 RSECS ARS GAS LOOP SCHEMATIC
**FIGURE 11  RSECS WATER LOOP SCHEMATIC**

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

- **AVIONICS**
  - $T = 88.12$
  - $W = 500$
  - $Q = 13043$
  - $T = 81.85$

- **RS-261 PUMP**
  - $W = 950.0$
  - $Q = 696.4$

- **HEAT EXCHANGER BYPASS**
  - $W = 500$
  - $T = 87.36$

- **350-M HEAT EXCHANGER**
  - $W = 83.99$
  - $Q = 8243.7$

- **NASA HEAT SINK**
  - $Q = 0.00$
  - $T = 32.99$
  - $T = 32.98$
  - $T = 51.31$

- **RS-261 HEAT EXCHANGER**
  - $W = 5200.0$
  - $Q = 21983$

- **GSE COOLANT LOOP**
  - $T = 33.00$
  - $T = 50.29$

**Symbols:**
- $Q = \text{HEAT BTU/HR}$
- $T = \text{TEMP DEG F}$
- $W = \text{FLOW LB/HR}$
PROGRAM LISTING

10 REM RSEC2 PROGRAM LABELS DIAGRAM
20 C0M X(200), A(10), AS(10), 1(64), 2, 3, 4
30 DIM X$(100), 4$(100)
40 SELECT PRINT 005: PRINT HEX(03):
PRINT "RSEC2 FLOW CHART ROUTINE": PRINT
50 FOR I = 1 TO 51
60 IF ABS(X(I)) = 100000 THEN 80:
IF ABS(X(I)) = 1000 THEN 90:
IF ABS(X(I)) = 100 THEN 100:
70 IF ABS(X(I)) = 10 THEN 110:
IF ABS(X(I)) = 1 THEN 120:
80 CONVERT X(I) TO X$(I), (-####): B(I) = 0: GOTO 150
90 CONVERT X(I) TO X$(I), (-#####): B(I) = 1: GOTO 150
100 CONVERT X(I) TO X$(I), (-#####): B(I) = 2: GOTO 150
110 CONVERT X(I) TO X$(I), (-#####): B(I) = 3: GOTO 150
120 CONVERT X(I) TO X$(I), (-#####): B(I) = 4: GOTO 150
130 CONVERT X(I) TO X$(I), (-#####): B(I) = 5: GOTO 150
140 CONVERT X(I) TO X$(I), (-#####): B(I) = 6: GOTO 150
150 NEXT I
160 SELECT PLOT 414
170 STOP "LOAD GAS LOOP SCHEMATIC ON PLOTTER THEN KEY CONTINUE"
180 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
190 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
200 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
210 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
220 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
230 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
240 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
250 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
260 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
270 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
280 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
290 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
300 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
310 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
320 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
330 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
340 IF ABS(T) = 10 THEN 350: IF ABS(T) = 10 THEN 360: IF ABS(T) = 10 THEN 370: IF ABS(T) = 10 THEN 380
350 CONVERT T TO TS, (-#####): B(T) = 0: GOTO 390
360 CONVERT T TO TS, (-#####): B(T) = 1: GOTO 390
370 CONVERT T TO TS, (-#####): B(T) = 2: GOTO 390
380 CONVERT T TO TS, (-#####): B(T) = 3: GOTO 390
390 CONVERT T TO TS, (-#####): B(T) = 4: GOTO 390
400 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
410 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
420 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
430 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
440 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
450 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
460 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
470 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
480 PLOT [13*13, 20*20, U, X(18)], [B(18)*13, 0, U]
Table X

PROGRAM LISTING (CONCLUDED)

<table>
<thead>
<tr>
<th>Line No.</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>490</td>
<td>PLOT [-7*13, -20, U], [.X$,(22)], [B(22)*13, 0, U]</td>
</tr>
<tr>
<td>500</td>
<td>PLOT [-21, -13, -3.5*20, U], [.X$,(30)], [B(30)*13, 0, U]</td>
</tr>
<tr>
<td>510</td>
<td>PLOT [25<em>13, -3.0</em>20, U], [.X$,(51)], [B(51)*13, 0, U]</td>
</tr>
<tr>
<td>520</td>
<td>K=Y(1); PLOT [&quot;, &quot;CASE: &quot;A&quot;], [.A$,K];</td>
</tr>
<tr>
<td>530</td>
<td>PLOT [3*13, 0, U], [&quot;, &quot;DATE: &quot;A&quot;], [.R$], [&quot;, R]</td>
</tr>
<tr>
<td>540</td>
<td>SELECT PRINT 005; PRINT &quot;DATE: &quot;; REMOVE GAS LOOP SCHEMA AND LOAD WATER LOOP SCHEMATIC ON PLOTTER THEN KEY CONTINUE</td>
</tr>
<tr>
<td>550</td>
<td>PLOT [21<em>13, 33</em>20, U], [.X$,(34)], [B(34)*13, 0, U]</td>
</tr>
<tr>
<td>560</td>
<td>PLOT [4<em>13, -50</em>20, U], [.X$,(35)], [B(35)*13, 0, U]</td>
</tr>
<tr>
<td>570</td>
<td>PLOT [-14<em>13, -6.25</em>20, U], [.X$,(10)], [B(10)*13, 0, U]</td>
</tr>
<tr>
<td>580</td>
<td>PLOT [-7*13, -20, U], [.X$,(27)], [B(27)*13, 0, U]</td>
</tr>
<tr>
<td>590</td>
<td>PLOT [-14, -20, 50*20, U], [.X$,(15)], [B(15)*13, 0, U]</td>
</tr>
<tr>
<td>600</td>
<td>PLOT [-7<em>13, -3</em>20, U], [.X$,(33)], [B(33)*13, 0, U]</td>
</tr>
<tr>
<td>610</td>
<td>PLOT [20<em>13, 26.25</em>20, U], [.X$,(13)], [B(13)*13, 0, U]</td>
</tr>
<tr>
<td>620</td>
<td>PLOT [-9<em>13, -2</em>20, U], [&quot;T=&quot;], [.X$,(15)], [B(15)*13, 0, U]</td>
</tr>
<tr>
<td>630</td>
<td>PLOT [-9<em>13, -4</em>20, U], [.X$,(12)], [B(12)*13, 0, U]</td>
</tr>
<tr>
<td>640</td>
<td>PLOT [-6<em>13, -8</em>20, U], [.X$,(47)], [B(47)*13, 0, U]</td>
</tr>
<tr>
<td>650</td>
<td>PLOT [-7*13, -20, U], [.X$,(26)], [B(26)*13, 0, U]</td>
</tr>
<tr>
<td>660</td>
<td>PLOT [-16<em>13, -11.25</em>20, U], [.X$,(14)], [B(14)*13, 0, U]</td>
</tr>
<tr>
<td>670</td>
<td>PLOT [3*13, -20, U], [.X$,(28)], [B(28)*13, 0, U]</td>
</tr>
<tr>
<td>680</td>
<td>PLOT [4*13, 20, U], [.X$(31)], [B(31)*13, 0, U]</td>
</tr>
<tr>
<td>690</td>
<td>PLOT [5<em>13, 26.5</em>20, U], [.X$(32)], [B(32)*13, 0, U]</td>
</tr>
<tr>
<td>700</td>
<td>PLOT [-5<em>13, -8</em>20, U], [.X$,(17)], [B(17)*13, 0, U]</td>
</tr>
<tr>
<td>710</td>
<td>PLOT [-7*13, -20, U], [.X$(29)], [B(29)*13, 0, U]</td>
</tr>
<tr>
<td>720</td>
<td>PLOT [-9<em>13, -11.5</em>20, U], [.X$(16)], [B(16)*13, 0, U]</td>
</tr>
<tr>
<td>730</td>
<td>PLOT [3<em>13, 33.75</em>20, U], [&quot;CASE: &quot;1, [.A$,K]], [3*13, 0, U], [&quot;DATE: &quot;], [.B$,R]</td>
</tr>
<tr>
<td>740</td>
<td>SELECT PRINT 005; PRINT &quot;HEX(03)&quot;</td>
</tr>
<tr>
<td>750</td>
<td>Y(1)=Y(1)+1</td>
</tr>
<tr>
<td>760</td>
<td>LOAD DC R &quot;RSECS&quot;</td>
</tr>
<tr>
<td>770</td>
<td>END</td>
</tr>
</tbody>
</table>
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.
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.
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 CO₂/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 - RF'S GAS LOOP PRESS SURF DROP
20 INPUT "R RS-11 FANS OPERATING" = "FL.
30 INPUT "TOTAL AIR FLOW (CFH) = "OL
40 REM - RS-103
50 P1= (.0765/.3709)*(.02350112/17312+3*01/167)
60 REM - RS-101
70 P2= (.0765/.3709)*(.0036*0112/17312+.61+11*(01/FL!)/7/50012
     +.02055*0112/17312)
80 REM - RS-100
90 P3= (.0765/.3709)*(.0036*0112/17312+.61+0125*0112/17312)
100 REM - ""TLEH INPUT
110 P4= (.0765/.3709)*(.0047*0112/17312+1.0*0112/20012)
120 REM - ""EER E"'
130 C1=+.0129611213E-6 : C2=+.30639538064E-6:
    C3=+.113613027482E-5 : C6=+.1175663200E-7:
    C5=+.70665964391E-5 : C6=+.33632563223E-11:
140 C7=+.105111722E-15 : C7=+.387092076583E-18
150 P5= (.0765/.3709)**5*(C1+C2*(01/.815)+C3*(01/.815)**12+
    C4*(01/.815)**13+C5*(01/.815)**14+C6*(01/.815)**15+
    C7*(01/.815)**16+C8*(01/.815)**17
160 P6=4*(144*0108+R(.0765)/28.26/1096)124P5
170 P7=P1+P2+P3+P4+P6
190 PRINT
190 PRINT
200 PRINT "PS=100 DP (T%=120) = ";P1
210 PRINT "RS-100 DP (T%=120) = ";P2
220 PRINT "RS-100 DP (T%=120) = ";P3
230 PRINT "RS-100 DP (T%=120) = ";P3
240 PRINT "OUTPUT INPUT DP (T%=120) = ";P4
250 PRINT "---------------------------------------------"
260 PRINT "TOTAL DP (T%=120) = ";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>
<thead>
<tr>
<th>Table XII</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLOTTER SETUP AND PROGRAM INPUTS</td>
</tr>
</tbody>
</table>

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 Plot
   - 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)

<table>
<thead>
<tr>
<th>Example:</th>
<th>2.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position 2,2</td>
<td>2.0</td>
</tr>
<tr>
<td>X axis unit/in 2</td>
<td>1.5</td>
</tr>
<tr>
<td>Y axis unit/in .5</td>
<td>1.0</td>
</tr>
<tr>
<td>X axis range 0,8</td>
<td>.5</td>
</tr>
<tr>
<td>Y axis range 0,2.5</td>
<td>1&quot;</td>
</tr>
</tbody>
</table>

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

PLOTTER SETUP AND PROGRAM INPUTS (CONTINUED)

<table>
<thead>
<tr>
<th>QUESTION ON CRT</th>
<th>TYPED IN RESPONSE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>X axis increment units/in?</td>
<td>2</td>
<td>Delta between major divisions on X axis</td>
</tr>
<tr>
<td>Y axis increment units/in?</td>
<td>.5</td>
<td>Delta between major divisions on Y axis</td>
</tr>
<tr>
<td>Location of axis intersection (position on page in inches - X, Y)?</td>
<td>2,2</td>
<td>Location of 0,0 point on plot is 2&quot; over and 2&quot; up from pen reference point</td>
</tr>
<tr>
<td>Limits of X axis (min value, max value)</td>
<td>0,8</td>
<td></td>
</tr>
<tr>
<td>Limits of Y axis (min value, max value)</td>
<td>0,2.5</td>
<td></td>
</tr>
<tr>
<td>X, Y values at intersection</td>
<td>0,0</td>
<td></td>
</tr>
<tr>
<td>X axis label</td>
<td>Delta dew point (F)</td>
<td></td>
</tr>
<tr>
<td>Y axis label</td>
<td>H2O flow Lb/Hr</td>
<td></td>
</tr>
<tr>
<td>Location of X axis labels (1=above, 2=below)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Location of Y axis labels (1=left, 2=right)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Plot points or curve (1=point, 2=curve)</td>
<td>1</td>
<td>Purpose is to plot points generated by previous program</td>
</tr>
<tr>
<td>Desired plot symbol</td>
<td></td>
<td>Entering nothing causes centered dot to be used as plot symbol</td>
</tr>
</tbody>
</table>
Table XII

PLOTTER SETUP AND PROGRAM INPUTS (CONCLUDED)

<table>
<thead>
<tr>
<th>QUESTION ON CRT</th>
<th>TYPED IN RESPONSE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are data points to be loaded from array</td>
<td>1</td>
<td>Array was loaded for previous program</td>
</tr>
<tr>
<td>First and last points to be plotted</td>
<td>1,15</td>
<td>15 points were generated and are to be plotted</td>
</tr>
<tr>
<td>Key continue to plot points</td>
<td>Continue</td>
<td>Starts plotting of points</td>
</tr>
<tr>
<td>Do you wish to connect points with line segments</td>
<td>1</td>
<td>Connects data points to form desired curve</td>
</tr>
<tr>
<td>Reset</td>
<td></td>
<td>End of plot routine</td>
</tr>
<tr>
<td>Do you wish to add labels to plot (0=no, 1=yes)</td>
<td>1</td>
<td>Activates portion of program that makes plotter act like a typewriter</td>
</tr>
<tr>
<td>Desired character size</td>
<td>1</td>
<td>Selects size of characters for labels (smallest=1, largest=10)</td>
</tr>
<tr>
<td>Do you wish to continue plotting</td>
<td>0</td>
<td>Ends program</td>
</tr>
</tbody>
</table>
FIGURE 14 SAMPLE PLOT 1
FLOW (LB/HR)

0.000 2.00 4.00 6.00

FIGURE 15 SAMPLE PLOT
FLOW (LB/HR)
5. YOUR PROGRAM FOR A GENERAL-PURPOSE PLOT ROUTINE

```
10 REM SUBROUTINE "PLOT"
20 COM X(100),Y(100),C(10),X$25,Y$25,PS1
30 DEFN'00"PLOT"
40 DEFN'01"CONVERT"
50 SELECT PRINT 00:PRINT HEX(03)
60 PRINT :PRINT "PLOT 2200 GENERAL PLOT ROUTINE";PRINT "DEVELOPED BY HILL AYOTTE (9/74)";PRINT :PRINT
70 INPUT "X AXIS INCREMENT (UNITS/IN)";XO
80 INPUT "Y AXIS INCREMENT (UNITS/IN)";YO
90 PRINT "LOCATION OF AXIS INTERSECTION";INPUT "(POSITION ON PAGE IN INCHES- X, Y)";X1,Y1
100 PRINT "LIMITS OF X AXIS (MIN VALUE, "AX VALUE)";S1,S2
110 PRINT "LIMITS OF Y AXIS (MIN VALUE, "AX VALUE)";T1,T2
120 PRINT "X,Y VALUES OF AXIS INTERSECTION";C1,C2
130 INPUT "X AXIS LABEL";X$
140 INPUT "Y AXIS LABEL";Y$
150 P1=100./X0:F2=100./YO
160 GOSUB 500
170 PRINT "PLOT POINTS OR CURVE (1=POINT, 2=CURVE)";U1
190 IF U1=1 THEN 310
200 PLOT };[100*X1,100*Y1],U1
210 IF U1=2 THEN 320
220 PRINT "DESIRED PLOT RANGE (MIN AND MAX VALUES)";W1,Z1:PRINT "DESIRED PLOT INCREMENT";D
230 STOP "INPUT EQUATION TO BE PLOTTED ON LINE 250 THEN KEY RUN"
240 FOR X=X1 TO X2 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 IF X[X1 THEN 250:U1=1:GOSUB '02(X,Y,X4,Y4):U1=2:GOTO 290
280 GOSUB '02(X,Y,X4,Y4)
290 NEXT X
300 PLOT [];U]:PLOT [];Z]:GOTO 1350
310 PRINT "INPUT DATA POINTS OR CURVE (1=POINT, 2=CURVE)";U1
320 PLOT {};[100*X1,100*Y1],U1
330 IF U1=2 THEN 340
340 STOP "INPUT FIRST AND LAST DATA POINTS TO BE PLotted";X,K5
350 IF K1 THEN 380:GOSUB 390
370 IF K1 THEN 380:GOSUB 390
380 PLOT [];K1,1:GOSUB 390
390 PRINT "INPUT EQUATION TO BE PLOTTED (YES=1, NO=0)";U1
400 IF U1=0 THEN 330:IF K1=K5+1 THEN 410:GOTO 360
410 PRINT "DO YOU WANT TO CONNECT PLOTTED POINTS WITH LINE SEGMENTS (YES=1, NO=0)";U1
420 IF U1=0 THEN 330:IF K1=K5+1 THEN 410:GOTO 360
430 PLOT [];K1,1:GOSUB 390
440 PLOT [];U]:PLOT [];Z]:GOTO 1350
300 SELECT PRINT 414
190 REM SUBROUTINE DRAWS AND LABELS ON AXIS
220 INPUT "LOCATION OF X AXIS LABELS (1=ABOVE, 2=BElOW)";L1
230 INPUT "LOCATION OF Y AXIS LABELS (1=LEFT, 2=RIGHT)";L2
```

The provided code appears to be a BASIC program for a general-purpose plot routine. It includes various input prompts for defining the plot, such as axis increments, limits, and labels. The routine also allows for plotting points or curves and can be used to plot data points or curves with or without connecting the points with line segments.
Table XIII

PROGRAM LISTING (CONTINUED)

550 A1=F1*ABS(S1-C1):A2=F1*ABS(S2-C1):A3=F2*ABS(T1-C2):A4=F2*ABS(T2-C2)
560 PLOT [100*X1,100*Y1,U],[-A1,0,0],[A1+A2,0,0],[-A2,-31,0],[0,31+2,0]
570 N5=(ABS(S1-C1)+ABS(S2-C1))/XO:N5=(ABS(T1-C2)+ABS(T2-C2))/Y0
580 K=N
590 S3=S1-X0
600 PLOT [-3,-(B1+B2),U]
610 FOR I3=1 TO N5+1
620 PLOT [6,0,0],[],U]
630 IF I3=N5+1 THEN 600:PLOT [-6,F2*Y0,0]
640 NEXT I3
650 PLOT [-(A1+3),-(B2+6),U]
660 FOR I4=1 TO N5+1
670 PLOT [0,12,2],[],U]
680 IF I4=5+1 THEN 600:PLOT [F1*X0,-12,0]
690 NEXT I4
700 IF L1=2 THEN 710:PLOT [-(A1+A2+24),20,0]:GOTO 720
710 PLOT [-(A1+A2+24),-36,0]
720 FOR I=1 TO N5+1
730 IF I1=N5+1 THEN 640
740 S3=S3-X0
750 IF A3(S1)=100 THEN 770:IF A3(S1)=10 THEN 790:IF A3(S1)=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$,(-#####):GOTO 810
810 IF K[0] THEN 320: PLOT [,,S3$]:GOTO 840
820 IF S3[1]=1 THEN 330:PLOT [F1*X0,0,0]:GOTO 840
830 PLOT [(F1*X0)-60,0,0],[],U]
840 K=K+1:NEXT I1
350 IF L2=1 THEN 360:PLOT [-(A2+20),0,0]:GOTO 370
850 PLOT [-(A2+100),0,0]
370 IF L1=1 THEN 380:PLOT [0,-(B1-31),0]:GOTO 390
880 PLOT [0,-(B1+24),0]
890 K=0
900 T3=TI+Y0
910 FOR I2=1 TO N5+1
920 IF I2=N5+1 THEN 1030
930 T1=T3+Y0
940 IF A3(T1)=1000 THEN 960:IF A3(T1)=1 THEN 990
950 CONVERT T1 TO T1$:(-##):GOTO 1000
960 CONVERT T1 TO T1$,(-###):GOTO 1000
970 CONVERT T1 TO T1$,(-####):GOTO 1900
980 CONVERT T1 TO T1$,(-#####):GOTO 1000
1000 IF K[0] THEN 1010:PLOT [,,T3$]:GOTO 1030
1010 IF T3[1]=2 THEN 1020:PLOT [0,F2*Y0,0]:GOTO 1030
1020 PLOT [-(60,F2*Y0,0),[],T3$]
1030 K=K+1:NEXT I2
1040 PLOT [0,0,0]
1050 IF X$=A THEN 1110: PLOT [100*X1,100*Y1,0],[-A1,0,0]
1060 IF L1=2 THEN 1070:PLOT [0,50,0]:GOTO 1050
1070 PLOT [0,100,0]
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 [A1+X3]
1110 IF Y$=-'n' THEN 1180
1120 PLOT [,.R],[100*X1,100*Y1,U],[0,-B1,U]
1130 IF L2=1 THEN 1140: PLOT [90,0,U]: GOTO 1150
1140 PLOT [-90,0,U]
1150 IF B2[]0 THEN 1160: PLOT [0,2*B2/3,U]: GOTO 1170
1160 PLOT [0,B1+B2*2/3,U]
1170 PLOT [0,-20,S],[,,Y$],[12,,S],[,,R]
1180 RETURN
1190 DEFN '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$],[,,U]
1230 E1=F2*Y3-INT(F2*Y3)
1240 E=E+1+4
1250 P8=F2*D2+P9=INT(P9)
1260 E5=F1*X3-INT(F1*X3)
1270 E6=E5+P8+E8
1280 S8=F1*D1+E6+S9=INT(S3)
1290 PLOT [S9,P9,D]
1300 E3=E3+P9
1310 E4=F2*Y3-E3
1320 E7=S9+E7
1330 E3=F1*X3-E3
1340 RETURN
1350 INPUT "DO YOU WISH TO ADD LABELS OR COMMENTS TO PLOT (O=NO, 1=YES)",
1360 IF C=0 THEN 1480
1370 INPUT "DESIRED CHARACTER SIZE (NUMBER FROM 1 TO 5)"",K
1380 PLOT [K,,C],[,,S]
1390 :RETURN
1400 GOTO 1390
1410 IF P$=HEX(00) THEN 1430: IF P$=HEX(02) THEN 1440: IF P$=HEX(08)
1420 IF P$=HEX(00) THEN 1460: IF P$=HEX(01) THEN 1470:
1430 PLOT [0,-20*K,U],[-999,0,U]: GOTO 1390
1440 PLOT [-13*K,0,U]: GOTO 1390
1450 PLOT [0,20*K,U]: GOTO 1390
1460 PLOT [0,-20*K,U]: GOTO 1390
1470 PLOT [0,13*K,U]: GOTO 1390
1480 INPUT "DO YOU WISH TO CONTINUE PLOTTING (O=NO, 1=YES)",
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, ε, α) 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**

<table>
<thead>
<tr>
<th>CRT SYMBOL</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaporator H$_2$O Flow</td>
<td>Maximum radiator system heat rejection is affected by evaporator water flow and it must be input</td>
</tr>
<tr>
<td># of Panels</td>
<td>Usually equal to 6 or 8 (baseline and space lab missions)</td>
</tr>
<tr>
<td>Inlet temperature</td>
<td>System inlet temp. °F</td>
</tr>
</tbody>
</table>

Data below is repeated for each panel in system

- Panel Type
- Flux
- Shape factor to space
- Flow source
- Last panels in system
  - #'s of last two panels in system (flow from these panels is mixed and becomes inlet to evaporator)
ASSUMPTIONS: RADIATION FIN $\eta = .9$
FLUID TO TUBE $\Delta T = 3.0^\circ F$

ANALYSIS: GUESS VALUE FOR $T_{out}$

$T_{sink} = \left(\frac{Q_{env}/T}{L_{<S}}\right)^4$
($\sigma = 1.714 \times 10^{-8}$)

$Y = (\sigma) (\eta) (T_{sink})^3 (A) \left(\frac{R^2}{D}\right) \sqrt{\frac{W_{Fz1}}{T_{in}}}$

$I = (T_{in} - \Delta T + 460) / T_{sink}$

$O = (T_{out} - \Delta T + 460) / T_{sink}$

$UZ = (2.5) \left[ \log_e \left( \frac{T_{sink} + 1}{T_{sink} - 1} \right) + 0.5 \left( \text{ARCTAN} \left( \frac{I}{O} \right) \right) \right]$

$UZ = (2.5) \left[ \log_e \left( \frac{T_{sink} + 1}{T_{sink} - 1} \right) + 0.5 \left( \text{ARCTAN} (O) \right) \right]$
Find F21 enthalpy in (H1) and
enthalpy out (H2)

\[ \text{AVG Cp} = \frac{H2 - H1}{0 - 1} \]

\[ U3 = U1 + \frac{Y}{Cp} \]

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(1)
20 REM: PROGRAM "RADIATOR"
30 C2=.166E-4
40 L1=.2
50 C1=-.1624E-4
60 C0=.242
70 C=.25
80 S=0.177.3E-8.
90 M=.0001
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 "FLOW (BTU/HR-SQ FT)",E7(I)
200 IF I>1 THEN 201:INPUT "FLOW (LB/HR)", F(I)
210 F(I)=F(I)
220 INPUT "FLOW SOURCES (XY,X=SOURCE#1,Y=SOURCE#2) ", S(I)
230 F(I)=.9:INPUT "SHAPE FACTOR TO SPACE (DEFAULT=1.0) ",F(I):
240 IF F(I)<>1 THEN 220:F(I)=1.0
250 IF T9=2 THEN 230:E8(I)=.32:E9(I)=.9:A9(I)=166.00:GOTO 240
260 E8(I)=.044:E9(I)=.841:A9(I)=312.00
270 NEXT I
280 INPUT "LAST PANELS IN SYSTEM",L1,L2
290 Q6=0:SELECT PRINT 005:PRINT HEX(73):PRINT " TIN = ";I;I6;" FLOW = ":F(I)*12
300 FOR I=1 TO P1
320 IF S(I)>0 THEN 350:X=F1(S(I))*T1(S(I))*C1(S(I)):Y=F1(S(I))*C1(S(I))
330 IF S(I)=0 THEN 350:Y=F1(S(I))*T1(S(I))*C1(S(I))
340 IF S2=0 THEN 350:Y=F1(S2)*T1(S2)*C1(S2):Y1=F1(S2)*C1(S2)
350 IF I=1 THEN 360:X2=X*T*25:X3=X*25:GOTO 370
360 IF I>1 THEN 360:X2=X*T*25:X3=X*25:GOTO 370
370 L=(X1+X2)/(X1+Y1+X3)
380 K=20
390 T5=(E/S/FO)!;25:0= .2*(T5-460)+.8*I;SELECT PRINT 005:
400 PRINT "RESULTS FOR PANEL NUMBER ";I;I6;" ";
410 IF E(I)>0 THEN 410:E=.001
Table XIV

RADIATOR PROGRAM LISTING (CONCLUDED)

410 T5= (E/S/F0)^1.25
420 F1= 90: D= 3.0
430 Y=S*E1*T5: 3)+R1: F0/R2
440 I1=(I-D+459.69)/T5
450 O1=(O-D+459.69)/T5
460 U1=.25*LOG(ABS((I1+I)/(I1-L)))+5*ARCTAN(I1)
470 U2=.25*LOG(ABS((O1+I)/(O1-L)))+5*ARCTAN(O1)
480 IF ABS(O-I)>.001 THEN 490: O=I+.001
490 H=C0*T1+Cl*T1/2+C2*T1/3; H1=C0*E+C1*O/2+C2*O/3
500 C=ABS((H1-H)/(O-I))
510 U3=U1+Y/C
520 IF ABS(U2-U1)=M THEN 660
530 Y=Z
540 Z=0
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 PRINT USING 780,05
690 PRINT USING 790,06
700 PRINT: PRINT USING 780,04
710 PRINT USING 790,06
720 PRINT USING 800,05
730 PRINT USING 810,07
740 PRINT " RADIATOR OUTLET MIX TEMP = "; O
750 PRINT " RADIATOR TOTAL HEAT REJECTION = "; O
760 PRINT " EVAPORATOR OUTLET TEMP = "; O
770 PRINT " RADIATOR/EVAPORATOR SYSTEM TOTAL HEAT REJECTION = "; O
780 SELECT PRINT 005
790 STOP : GOTO 260
800 END
FIGURE 17  SAMPLE INPUT TO RADIATOR HAND BOOK

67
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 input/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. Console Input/Edit

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 ($^\circ$F), Thermal Capacitance (Btu/$^\circ$F)
- **Arithmetic Nodes**: Initial Temp ($^\circ$F)
- **Boundary Nodes**: Constant Temp

2) Conductor Data

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

Two node numbers specifying the hookup and a conductor value (Btu or area) are supplied by the user for each conductor input. Time-$^\circ$F

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 $M C_p$ of the fluids.

If the conductor is to simulate a radiation hook up, the conductor value is input as a negative $\mathcal{D}A$ (area). If the conductor is linear, it is input as positive ($hA/\lambda\delta A = A\mathcal{H}_\lambda$ 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 108, 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

\[ CSG_\text{(node I)} = \frac{C(I)}{N} \]

\[ C(I) = \sum_{J=1}^{N} G_{iJ}^T \]

- \( N \) = total number of nodes
- \( G_{iJ}^T \) = 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:

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

\[ + \left( \Sigma \text{SIGMA} \right) \sum_{J=1}^{N} R_{iJ}^T \left( T_J^2(t) + T_I^2(t) \right)(T_J(t) + T_I(t))(T_J(t) - T_I(t)) \]

- \( T \) = temperature
- \( t \) = time
- \( \Delta t \) = time step
- \( C_I \) = Thermal mass of node I
- \( G_{iJ}^T \) = 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'\text{th} node
- \( R_{iJ}^T \) = radiation conductor between node I and J \(( \Sigma \cdot A \cdot )\).
- 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:

\[
X_{L}(L+1) = \frac{Q_L + \left[ \sum_{L=N}^{L} G_{LJ} T_J(L) \right] + \left[ (\Sigma G_{LJ}^{(A)}) \sum_{L=1}^{L} R_{LJ} (T_L(L) + T_J(L)) (T_J(L) + T_L(L)) \right]}{\left[ \sum_{N=1}^{N} G_{LJ} \right] + \left[ (\Sigma G_{LJ}^{(A)}) \sum_{J=1}^{J} R_{LJ} (T_L(L) + T_J(L)) (T_J(L) + T_L(L)) \right]}
\]

where

\[
T(L+1) = D(\frac{X(L+1) + (1-D)T(L)}{L = 6, 1, 2, \ldots, \text{Iteration count}})
\]

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:


TABLE XV
THERMAL NETWORK INPUT/OUTPUT SEQUENCE

<table>
<thead>
<tr>
<th>CRT SYMBOL</th>
<th>DESCRIPTION/COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. a)</td>
<td>Is network stored on</td>
</tr>
<tr>
<td></td>
<td>tape drive 10B</td>
</tr>
<tr>
<td>b)</td>
<td>If the answer to part a) is yes, then input model file number</td>
</tr>
<tr>
<td></td>
<td>File # 1 → M</td>
</tr>
<tr>
<td></td>
<td>where model is stored</td>
</tr>
<tr>
<td>NOTE:</td>
<td>If the network is stored on tape the sequence continues at step 6.</td>
</tr>
<tr>
<td>2.</td>
<td>Input number of diffusion arithmetic and boundary node</td>
</tr>
<tr>
<td></td>
<td>I1, I2, I3</td>
</tr>
<tr>
<td>3.</td>
<td>Input for diffusion nodes 1 to I1, initial temp. and thermal mass.</td>
</tr>
<tr>
<td></td>
<td>Input for each node at a time.</td>
</tr>
<tr>
<td>4.</td>
<td>Input for arithmetic nodes 1 to I2, initial temp.</td>
</tr>
<tr>
<td></td>
<td>Input for each node at a time.</td>
</tr>
<tr>
<td>5.</td>
<td>Input for boundary node 1 to I3, constant temp.</td>
</tr>
<tr>
<td></td>
<td>Input for each node at a time.</td>
</tr>
<tr>
<td>6.</td>
<td>Node Data Printout desired</td>
</tr>
<tr>
<td></td>
<td>1 = Yes Prints user node data</td>
</tr>
<tr>
<td></td>
<td>2 = No</td>
</tr>
<tr>
<td>7.</td>
<td>Input conductor data NA, NB, value</td>
</tr>
<tr>
<td></td>
<td>At this point, the user inputs each conductor one at a time.</td>
</tr>
</tbody>
</table>

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)

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

THERMAL NETWORK SOLUTION ROUTINE INPUTS

<table>
<thead>
<tr>
<th>CRT SYMBOL</th>
<th>DESCRIPTION/COMMENT</th>
</tr>
</thead>
</table>
| 1. Type of solution desired | 1 = Forward differencing  
2 = Steady state                                                                  |
| 2. Initial time           | Problem start time                                                                   |
| 3. Output interval        | Used only with forward difference 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 Btu minute °C 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 iterations | 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.

\[ h_f = 1000 \text{ Btu/hr} \cdot \text{ft}^2 \cdot \text{°F} \]

\[ h_r = 30 \text{ Btu/hr} \cdot \text{ft}^2 \cdot \text{°F} \]

\[ L = 1 \text{ ft} \]

\[ K = 0.25 \text{ Btu/hr} \cdot \text{ft} \cdot \text{°F} \]

\[ A = 0.1 \text{ ft}^2 \]

\[ Q = \text{Heat Flux} \]
### Thermal Network Inputs

**Node Data Block**

<table>
<thead>
<tr>
<th>Node</th>
<th>Diff</th>
<th>Initial Temp</th>
<th>Value</th>
<th>Cap Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>40.00</td>
<td>CAP</td>
<td>1.81500E+02</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>70.00</td>
<td>CAP</td>
<td>1.81500E+02</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>40.00</td>
<td>CAP</td>
<td>1.81500E+02</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>50.00</td>
<td>CAP</td>
<td>1.81500E+02</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>65.00</td>
<td>CAP</td>
<td>1.81500E+02</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>60.00</td>
<td>CAP</td>
<td>1.81500E+02</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>45.00</td>
<td>CAP</td>
<td>1.81500E+02</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>50.00</td>
<td>CAP</td>
<td>1.81500E+02</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>60.00</td>
<td>CAP</td>
<td>1.81500E+02</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>70.00</td>
<td>CAP</td>
<td>1.81500E+02</td>
</tr>
<tr>
<td>11</td>
<td>11</td>
<td>60.00</td>
<td>CAP</td>
<td>1.81500E+02</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>100.00</td>
<td>CAP</td>
<td>1.81500E+02</td>
</tr>
</tbody>
</table>

**Conductor Data Block**

<table>
<thead>
<tr>
<th>Type</th>
<th>XA</th>
<th>WE</th>
<th>Condu Cor Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>NEW</em> LIN</td>
<td>12</td>
<td>1</td>
<td>1.25000E+01</td>
</tr>
<tr>
<td><em>NEW</em> LIN</td>
<td>1</td>
<td>2</td>
<td>6.25000E+00</td>
</tr>
<tr>
<td><em>NEW</em> LIN</td>
<td>11</td>
<td>4</td>
<td>1.25000E+01</td>
</tr>
<tr>
<td><em>NEW</em> LIN</td>
<td>4</td>
<td>5</td>
<td>6.25000E+00</td>
</tr>
<tr>
<td><em>NEW</em> LIN</td>
<td>5</td>
<td>6</td>
<td>6.25000E+00</td>
</tr>
<tr>
<td><em>NEW</em> LIN</td>
<td>10</td>
<td>11</td>
<td>1.00000E+03</td>
</tr>
<tr>
<td><em>NEW</em> LIN</td>
<td>-7</td>
<td>6</td>
<td>1.00000E+02</td>
</tr>
<tr>
<td><em>NEW</em> LIN</td>
<td>-2</td>
<td>6</td>
<td>1.00000E+02</td>
</tr>
<tr>
<td><em>NEW</em> LIN</td>
<td>-10</td>
<td>7</td>
<td>1.00000E+02</td>
</tr>
<tr>
<td><em>NEW</em> LIN</td>
<td>1</td>
<td>14</td>
<td>1.00000E+02</td>
</tr>
<tr>
<td><em>NEW</em> LIN</td>
<td>2</td>
<td>14</td>
<td>1.00000E+02</td>
</tr>
<tr>
<td><em>NEW</em> LIN</td>
<td>3</td>
<td>14</td>
<td>1.00000E+02</td>
</tr>
<tr>
<td><em>NEW</em> LIN</td>
<td>4</td>
<td>13</td>
<td>2.00000E+00</td>
</tr>
<tr>
<td><em>NEW</em> LIN</td>
<td>5</td>
<td>13</td>
<td>2.00000E+00</td>
</tr>
<tr>
<td><em>NEW</em> LIN</td>
<td>6</td>
<td>13</td>
<td>2.00000E+00</td>
</tr>
</tbody>
</table>

**ORIGINAL PAGE IS OF POOR QUALITY**

**Figure 18 Winda Sample Problem (Continued)**
## NETWORK HEAT TRANSFER PATHS

<table>
<thead>
<tr>
<th>EDIT NO.</th>
<th>TYPE</th>
<th>NA(G1/R1)</th>
<th>NB(G2/R2)</th>
<th>VALUE(G/R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G 1</td>
<td>LIN</td>
<td>12</td>
<td>1</td>
<td>1.25E+01</td>
</tr>
<tr>
<td>G 2</td>
<td>LIN</td>
<td>1</td>
<td>1</td>
<td>1.25E+01</td>
</tr>
<tr>
<td>G 3</td>
<td>LIN</td>
<td>1</td>
<td>2</td>
<td>6.25E+00</td>
</tr>
<tr>
<td>G 4</td>
<td>LIN</td>
<td>2</td>
<td>2</td>
<td>6.25E+00</td>
</tr>
<tr>
<td>G 5</td>
<td>LIN</td>
<td>1</td>
<td>3</td>
<td>6.25E+00</td>
</tr>
<tr>
<td>G 6</td>
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### NUMBER OF HEAT TRANSFER PATHS IN NETWORK 32 (26 LINEAR, 6 RADIATION)

### SOURCE DATA BLOCK

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*NEW* SOURCE 7 VALUE 1.00E+03
*NEW* SOURCE 9 VALUE -2.00E+02
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### NETWORK NET HEATING RATES ARRAY (Q)

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**NETWORK SAVED TO FILE 1 SUCCESSFULLY**

*NOTE THAT NETWORK WAS SAVED*

---

**ORIGINAL PAGE IS OF POOR QUALITY.**
### CONTROL CONSTANTS INPUTS

**FORWARD DIFFERENCE SOLUTION ROUTINE SELECTED (CFRWD)**

- **INITIAL TIME:** 0
- **OUTPUT INTERVAL-OUTPUT END:** 1.00000000E-03
- **FINAL TIME:** 5.00000000E-03
- **RADIAN SIGMA:** 1.71300000E-09

**TIME STEP STABILITY CRITERIA:**
- **CSGFA**: 1.00000000E-04
- **ARITHMETIC NODE RELAXATION CRITERIA:** 1.00000000E-02
- **DIFFUSION NODE RELAXATION CRITERIA:** 1.00000000E-02

**ARITHMETIC NODE DAMPING FACTOR:** -9

**DIFFUSION NODE DAMPING FACTOR:** 1

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

**TRANSIENT SOLUTION FOR .005 HRS.**

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*** CONTROL CONSTANTS INPUTS ***

STEADY STATE SOLUTION ROUTINE SELECTED (CINDSS)
INITIAL TIME-TIME  0
OUTPUT INTERVAL-OUTPUT  0
FINAL TIME-TIME  100
RADIATION SIGMA 1.71300000E-09
TIME STEP STABILITY CRITERIA-CSGFA  1
MAXIMUM NUMBER OF ITERATIONS-LOOP  1000
ARITHMETIC NODE RELAXATION CRITERIA-ARLCA 1.00000000E-03
ARITHMETIC NODE DAMPING FACTOR- DAMFA -7
DIFFUSION NODE RELAXATION CRITERIA-DRLCA 1.00000000E-03
DIFFUSION NODE DAMPING FACTOR-DAMPD -7

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

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STEADY STATE IERATIONS PERFORMED 1000 LOOP 1000

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PART B - SAME NETWORK AS IN PART A

\[ \dot{q}_7 = 500 \text{ Btu/hr} \]
\[ \dot{q}_9 = -400 \text{ Btu/hr} \]

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 19 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
*NAME SOURCE 9 VALUE -2.000000E+02
*NAME SOURCE 7 VALUE -5.000000E+02

NETWORK NET HEATING RATES ARRAY (Q)

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\text{NODE NO.} & \text{NET HEAT RATE} \\
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1 - 10 & 0.0000E+00 & 0.0000E+00 & 0.0000E+00 & 0.0000E+00 \\
11 - 15 & 0.0000E+00 & 0.0000E+00 & 0.0000E+00 & 0.0000E+00 \\
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\]

*** CONTROL CONSTANTS INPUTS ***

FORWARD DIFFERENCE SOLUTION ROUTINE SELECTED (CNFRMND)
INITIAL TIME-TIMED 0
OUTPUT INTERVAL-OUTPUT 1.00000000E-03
FINAL TIME-TIMED -5.00000000E-03
RADIATION SIGMA 1.71100000E+00
TIME STEP STABILITY CRITERIA-CGCPAC 1
"ARITH" NUMBER OF ITERATIONS-LOOP 3
ARITHMETIC NODE RELAXATION CRITERIA-ARLNG 1.00000000E-02
ARITHMETIC NODE DAMPING FACTOR-DAMPA 0
DIFFUSION NODE RELAXATION CRITERIA-DRLNG 1.00000000
DIFFUSION NODE DAMPING FACTOR-DAMPD 1

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

TRANSIENT SOLUTION FOR .005 HRS.
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*** CONTROL CONSTANTS INPUTS ***
STEADY STATE SOLUTION ROUTINE SELECTED (CINDSS)
INITIAL TIME-TIEIIEO 1
FINAL TIME-TIEIIEO 100
OUTPUT INTERVAL-OUTPUT 0
RADlATION SIGN 1.71390099E-09
TIME STEP STABILITY CRITERIA-CSGFAC 1
MAXIMUM NUMBER OF ITERATIONS-MLOOP 1000
ARITHMETIC NODE RELAXATION CRITERIA-ARLXCA 1.0000000E-03
ARITHMETIC NODE DAMPING FACTOR-DA"PA -7
DIFFUSION NODE RELAXATION CRITERIA-DRLXCA 1.0000000E-03
DIFFUSION NODE DAMPING FACTOR-DAMPD -7

*** END OF INPUT SEQUENCE — BEGIN EXECUTION PHASE ***

TIME   1.0000  DTINE  0.000000E+00  CSQHIN  0.000000E+00  AT NODE n
NODE NO.  TEMPERATURE (DEG F)
  1     -  5     51.69     44.94     41.52     70.00     77.70
   6    - 10     81.69     77.04     61.33     46.81     52.79
  11   - 15     39.31     61.73    130.00    -459.00    -460.00

STEADY STATE IERATIONS PERFORMED 1000  MLOOP 1000

TIME  100.0000  DTINE  0.000000E+00  CSQHIN  0.000000E+00  AT NODE n
NODE NO.  TEMPERATURE (DEG F)
  1     -  5     99.06     98.43     98.23     86.03     97.94
   6    - 10     93.42    100.72    160.23     86.19     95.81
  11   - 15     95.32    100.21    190.00    -459.00    -460.00
UNITED TECHNOLOGIES

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), R2(250), X(40), Y(40); I8=40; G8, R8=250
30 SELECT PRINT 211(95):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) P
60 DATA LOAD "MODEL": DATA LOAD I1, I2, I3, I9, G9, R9, T(), C(), Q(), G1(), G2(), G(), R1(), R2(), R(): IF (I9 END THEN 70
70 SELECT TAPE 10A: PRINT " NETWORK FROM FILE ": S6; WAS SUCCESSFULLY LOADED": PRINT
80 PRINT "NODE DATA BLOCK": IF S5=1 THEN 140: INPUT "NUMBER OF DIFFUSION, ARITHMETIC, AND BOUNDARY NODES", I1, I2, I3
90 I9=I1+I2+I3: IF I9=I1 THEN 100: PRINT "MAXIMUM NODE CAPABILITY " + I9: EXCEEDED, WILL TERMINATE": GOTO 130
100 SELECT PRINT 005: IF I1=0 THEN 110: PRINT "WARNING, THIS NETWORK 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: PRINT " 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: PRINT " BOUNDARY NODE "; I: INPUT "CONSTANT TEMP", T(I): NEXT I
140 SELECT PRINT 211(95): GO=0: INPUT "DETAILED NODE DATA PRINTOUT DESIRED (1=YES,0=NO)", GO: IF GO=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 #: BOUNDARY 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
210 PRINT " TOTAL "; I9
220 PRINT " CONDUCTOR BLOCK": PRINTUSING 220
230 IF (R9+G) R8 THEN 360: IF (G9+R) G8 THEN 360: I=0; J=0; GO=0: INPUT "CONDUCTOR DATA -NA, NB, G, BV TO TERMINATE INPUT ENTER A ZERO NO DE PARE": I, J, GO
250 IF (I=0 THEN 360: G=I+1: G1(G9)=I: G2(G9)=ABS(J): G(G9)=GO
260 IF J=0 THEN 390: G=I+1: G1(G9)=I: G2(G9)=ABS(J): G(G9)=GO: GOTO 290

85
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(R)
9=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* LIM -## -## -## -## -## 
320 %NEW* RAD -## -## -## -## 
330 SELECT PRINT 005:PRINT "NODE NUMBER NOT INPUT, CONDUCTOR IGNORED":SELECT PR
INT 211(95);GOTO 230
340 SELECT PRINT 005:PRINT "NA=1, CONDUCTOR IGNORED":SELECT PRINT 211(95);GOTO 2
30
350 SELECT PRINT 005:PRINT "NUMBER OF LINEAR OR RADIATION HEAT TRANSFER PATHS EXCEED
PROGRAM LIMITS (";G0;"), WILL TERMINATE":GOTO 1320
370 G0=0:INPUT "DETAILED NETWORK PRINTOUT DESERED (1=YES, 0=NO)",G0:IF G0=0 TH
EN 440
380 PRINT :PRINT "NETWORK HEAT TRANSFER PATHS":PRINTUSING 300
390 Z#TJ 30* TYPE NA(G1/R1) NS(G2/R2) VALUE(G/R)
400 ### LIM -## -## -## -## -## 
410 ### RAD -## -## -## -## 
420 IF G0=0 THEN 430:FOR I=1 TO G9:PRINTUSING 400,I,G1(I),G2(I),G(I);NEXT I
430 IF G9=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;" LINTER, ";R9;" RADIATION)"
450 PRINT :PRINT "SOURCE DATA BLOCK"
460 I=0:INPUT "HEATING/COOLING RATES-NODE, RATE-TO TERMINATE IN PUT A ZERO MOD
E ";I,70
470 IF I=0 THEN 510:IF I1(I1+I2) THEN 480:Q(I)=Q(I)+Q0;GOTO 490
480 SELECT PRINT 005:PRINT "NODE NUMBER NOT RECOGNIZED, SOURCE IGNORED":SELECT PR
INT 211(95);GOTO 440
490 PRINTUSING 500,I,G0;GOTO 460
500 %NEW* SOURCE # VALUE -## -## -## -## -## 
510 G0=0:INPUT "DETAILED NET HEATING RATE PRINTOUT DESERED (1=YES
S, 0=NO)",G0:IF G0=0 THEN 560:RE" END OF O INPUTS
520 PRINT :PRINT "NETWORK NET HEATING RATES ARRAY (Q)":PRINTUSING
530 %NEW* 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;NEXT I
560 STOP "ALL CHANGES TO THIS NETWORK FROM DEMAND MODE, TO TERMINATE PRO
CESS, CONTINUE".
570 "=0:G0=1:INPUT "DO YOU WISH TO SAVE THIS NETWORK ON TAPE 10
B ";=YES,=.NO)"
Table XVII
"WINDA" LISTING (continued)

Table XVII

"WINDA" LISTING (continued)

920 IF R9=0 THEN 930:FOR J=1 TO R9:P1=T1(R1(J)):P2=T1(R2(J)):GO=R5*R(J)*(P1+P2):(P1*P1+P2*P2):X(R1(J))=Y(R1(J)):GO:NEXT J
930 X(I)=C(I)/X(I):IF I=1 THEN 940:F2=X(1):F9=1
940 IF X(I)=P2 THEN 950:F2=T1(I):F9=I
950 NEXT I
960 IF F2=0 THEN 970:PRINT:PRINT "TIME STEP LESS THAN ZERO, RETURN TO PREVIOUS STATE";GOSUB 1250:GOTO 1320
970 IF 09=0 THEN 990:GOSUB 1250:GO TO 1320
990 P=F2:IF (09+F2) THEN 1000:GOSUB 1250:GOTO 1320
1000 GOSUB 1250:GOTO 1320

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:PI=T1(R1(J)):P2=T1(R2(J)):GO=R5*R(J)*(P1+P2)*(P1*P1+P2*P2):X(R1(J))=Y(R1(J)):GO:NEXT J:
1050 X(I)=X(I)+Q(I):T(I)=T1(I)+(r*(I)/C(I)):NEXT I
1060 L=L+1:IF (L+1)>L1 THEN 1150:REX:1250:STEADY STATE ITERATIONS
1070 L2=L+1:IF (L+1)>L1 THEN 1150:REX:1250:DIFFUSION NODES
1080 IF S=1 THEN 1150:REX:1250
1090 IF I=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(P1)*G(J)):Y(P1)=Y(P1)+G(J):GO:NEXT J
1110 IF R9=0 THEN 1120:FOR J=1 TO R9:P1=T1(R1(J)):P2=T1(R2(J)):GO=R5*R(J)*(P1+P2)*(P1*P1+P2*P2):X(R1(J))=Y(R1(J)):GO:NEXT J:
1120 X(I)=X(I)+Q(I):T(I)=T1(I)+(S*(I)/C(I)):NEXT I
1130 IF ABS(T(I)-T1(I))>1140:GO TO 1150:GO TO 1150
1140 NEXT I
1150 IF I2=0 THEN 1120:RETURN 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(P1)*G(J)):Y(P1)=Y(P1)+G(J):GO:NEXT J
1180 IF R9=0 THEN 1190:FOR J=1 TO R9:P1=T1(R1(J)):P2=T1(R2(J)):GO=R5*R(J)*(P1+P2)*(P1*P1+P2*P2):X(R1(J))=Y(R1(J)):GO:NEXT J:
1190 X(I)=X(I)+Q(I):T(I)=A*(I)+A*(T1(I)):GO:NEXT I
1200 IF ABS(T(I)-T1(I))>1120:GO TO 1210:GO TO 1210
1210 NEXT I
1220 IF L2=0 THEN 1230:GOTO 1270:END OF ITERATION/STEP
1230 IF S=1 THEN 990:PRINT:PRINT "STEADY STATE ITERATIONS PERFORMED";L1:"M1000:GOSUB 1250
1240 :0=0:INPUT "DO YOU WISH TO CONTINUE THE PROBLEM WITH THIS NETWORK AT THE FINAL TEMPERATURES (1=NO, 0=YES)";NO:IF NO=1 THEN 6
Table XVII

"WINDA" LISTING (CONCLUDED)

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<th>SELECT PP.IAT</th>
<th>005:EN1</th>
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<tr>
<td>1300 STEP 5</td>
<td>M1=I-I</td>
<td>1310 T=(F36-460)</td>
<td>T=(F42-460)</td>
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<td>1320 PRINT T loneliness</td>
<td>T1,T3,I4,F1,F2,F3,F4,F5</td>
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<td>1330 END</td>
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- Table continues here with code and data output for the "WINDA" listing.
APPENDIX A

ADJUSTED TEST DATA
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 an 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.
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<th>FLOW (CFM)</th>
<th>T (°F) IN</th>
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<th>VAP (°C) IN</th>
<th>VAP (°C) OUT</th>
<th>FLOW (14/HR) IN</th>
<th>T (°F)</th>
<th>VAP (°C) IN</th>
<th>VAP (°C) OUT</th>
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<th>T (°F)</th>
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## TABLE A-1

### REDUCED TEST RESULTS

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<th>TEST POINT</th>
<th>AIR FLOW (CFM)</th>
<th>TI (^°F)</th>
<th>TO (^°F)</th>
<th>FLOW</th>
<th>PHI X (^°F)</th>
<th>SEC FLOW</th>
<th>Q (^°F)</th>
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<td>IN</td>
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<td>OUT</td>
<td>(13/HR)</td>
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<td>OUT</td>
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A-4
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 IX 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 IX 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 curves 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)
CONDENSER FIX CALCULATION PROCEDURE:

1. Obtain $I_A$ ($I_B$) from chart (see note 5.1)
2. Assume value for $X_A$ ($X_B$)

FIELD AIR & COOLANT TEMPS AT FIX POINT:

$$T_x = \frac{I_A}{L_A} \left[ \frac{L_A}{L_B} (T_{in} - (T_{co} - T_{out})) \right]$$

$$T_y = T_{out} - \frac{L_A}{L_B} (T_x - T_{in})$$

FIND $E_{dry}$, $M_{dry}$, $K_{dry}$ AND $T_A$ $T_B$:

$$E_{dry} = \frac{T_{in} - T_x}{T_{in} - T_y} \quad \text{EFFECTIVENESS}$$

$$M_{dry} = \frac{(w_c)_c}{(w_c)_h} \quad \text{HEAT FLOW RATIO}$$

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APPENDIX B.1

NOTE: To find the coordinates for a given test point, follow the procedure given above:

From steam tables find inlet and outlet air steam saturation pressures.

\[ P_{in} = f(T_{in}) \]
\[ P_{out} = f(T_{out}) = f(T_0) \]

Then find \( u_{in}, u_{out} \):

\[ u_{in} = \frac{(600) P_{in}}{14.69 - P_{in}} \quad u_{out} = \frac{(600) P_{out}}{14.69 - P_{out}} \]

Find air mass flow:

\[ m_{air} = \frac{P_{in} \Delta h}{2T} = \frac{(4.69) (0.84) 344 \text{ (lb)}}{(53.3) (T_0 + 460) \text{ (hr)}} \]

Then:

\[ h_{out} = h_{in} (u_{in} - u_{out}) \]

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APPENDIX B.1

NOTE: 

To determine \( \Delta A_0 \), follow procedure described here.

SINGLE COOLANT LOOP

1. Find \( W/\alpha \) (we total coolant side flow)
2. With \( W/\alpha \), read \( L_0 \) from curve B8

Then:

\[ \Delta A_0 = L_0 \times \frac{37}{3} \times (5408) \]

DOUBLE COOLANT LOOP

1. Find \( W/\alpha \)
2. With \( W/\alpha \), read \( L_0 \) from curve B8

Then:

\[ \Delta A_0 = L_0 \times 2.7 \times (5408) \]

To determine \( \Delta A_H \) do the following:

SINGLE COOLANT LOOP:

1. Find velocity = \( \frac{CFM}{8815} \) (CFM ft/min in CFM)
2. With velocity, read \( \% A \) from curve B3

Then:

\[ \Delta A_H = \% A \times 0.513 \times 5408 \times \Delta \]

DOUBLE COOLANT LOOP:

Same as above except:

\[ \Delta A_H = \% A \times 0.513 \times 5408 \times \Delta \]
UA_DRY = OVERALL HEAT TRANSFER
        COEFFICIENT, DRY POSITION
UA_NET = OVERALL HEAT TRANSFER
        COEFFICIENT, NET POSITION
Q_s = SENSIBLE HEAT, NET POSITION
Q_l = LATENT " " " "
Q_t = TOTAL " " " "
UA_NET = OVERALL HEAT TRANSFER COEFFICIENT
        FOR NET SECTION FOR SENSIBLE HEAT
        TRANSFER ONLY
UA_TOTAL = OVERALL HEAT TRANSFER COEFFICIENT
        FOR COMBINED NET & DRY POSITIONS

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DEFINITION OF SYMBOLS

INPUTS

$T_{gi} \quad$ INLET GAS TEMPERATURE ($^\circ$F)

$T_{go} \quad$ OUTLET $^\circ$F

$T_{ow} \quad$ INLET OIL TEMPERATURE ($^\circ$F)

$T_{oo} \quad$ OUTLET $^\circ$F

$(U_{cp})_c \quad$ COOLANT SIDE (FLOW RATE)(SPEIFIC HEAT)

$(U_{cp})_a \quad$ AIR $^\circ$F

CALCULATED VALUES

$T_x \quad$ AIR TEMP AT NOSE POINT ($^\circ$F)

$T_y \quad$ COOLANT $^\circ$F

$K_{an} \quad$ AIR SIDE FLOW COEFFICIENT AREA (ft$^2$)

$K_{ac} \quad$ COOLANT $^\circ$F

$E_{dry} \quad$ EFFECTIVENESS DRY PORTION

$E_{wet} \quad$ EFFECTIVENESS WET PORTION

$M_{dry} \quad$ HEAT FLOW RATIO DRY PORTION

$M_{wet} \quad$ HEAT FLOW RATIO WET PORTION

$K_{dry} \quad$ NTU FOR DRY PORTION

$K_{wet} \quad$ NTU FOR WET PORTION

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B-9
\[ \frac{1}{V_{\text{final}}} = \frac{1}{L_1} + \frac{1}{L_2} \]

\[ L_1 = \frac{1}{V_{\text{final}} - L_2} \]

Check this calculated value of \( L_1 \) against initial value; if they do not agree then use new value of \( L_1 \) and repeat entire process. Continue until agreement is within acceptable range.

A similar approach is used to calculate a value for \( L_2 \) when \( L_1 \) is assumed to be known.
FIND \( C_{\text{WET}} \), \( M_{\text{WET}} \), \( K_{\text{WET}} \), AND \( (U_A)_{\text{WET}} \):

\[
C_{\text{WET}} = \frac{T_r - T_{\text{en}}}{T_{\text{ex}} - T_{\text{ci}}}
\]

\[
M_{\text{WET}} = \frac{\dot{m}_{\text{in}}}{\dot{m}_{\text{in}}}
\]

\[
\text{USE COUNTERFLOWS AND EFFECTIVENESS CHARTS TO FIND VALUE OF } K_{\text{WET}}
\]

\[
(U_A)_{\text{WET}} = (U_A)_1 \left( \frac{Q_r}{Q_s} \right) (K_{\text{WET}})
\]

FIND VALUE OF \( (U_A)_{\text{WET}} \) AND \( U_A_{\text{SENS}} \):

\[
(U_A)_{\text{WET}} = \frac{1}{1 + \frac{U_A}{U_A}} + \frac{1}{1 + \frac{U_A}{U_A}} \cdot \frac{U_A}{U_A}
\]

\[
(U_A)_{\text{SENS}} = (U_A)_{\text{WET}} \left( \frac{(U_A)_{\text{SENS}}}{(U_A)_{\text{WET}}} \right)
\]

\[
(U_A)_{\text{TOTAL}} = (U_A)_{\text{DRY}} + (U_A)_{\text{SENS}}
\]
USE COUNTER FLOW HX EFFECTIVENESS CHART (PG 89)
To find values of K dry & NTU for HX

Then find UA dry:

\[ UA_{dry} = (K_{dry})(NTU) \]

This completes dry section analysis

---

**Wet Section**

Find Q sensible, Q latent, Q total for wet section

\[ Q_s = (W_{dry})(C_{p,d})(T_x - T_{60}) \]

\[ Q_l = (W_{wet})(C_{p,l}) \] (See note 60 for calculation)

where \( W_{wet} \) 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-W CONDENSING HEAT EXCHANGER AIR SIDE FILM COEFFICIENT VS AIR FLOW
FIGURE B-4 EFFECTIVENESS CHART FOR COUNTER FLOW HEAT EXCHANGER

B-15
APPENDIX B.2

LISTING OF COMPUTER PROGRAM USED IN DATA REDUCTION
10 REM - 350-M HX PERFORMANCE:
20 REM - WATER VAPOR PROPERTIES - TEMPERATURE (1):
30 REM - WATER VAPOR PROPERTIES - PRESSURE (21):
40 REM - WATER VAPOR PROPERTIES - ENTHALPY (41):
50 REM - WATER SIDE FILM COEFFICIENT (31):
60 REM - AIR SIDE FILM COEFFICIENT (31):
70 DATA 9,0,100,150,200,250,300,350,400,450,500,134,183,
282,370,463,560,655,765,860,
80 INPUT "# OF CASES (1-50) = "Y(2):
90 FOR Z=1 TO Y(2): SELECT PRINT 005:
100 PRINT "CASE ":Z
110 INPUT "T "S-11 IN (DEC F) = "A(Z,1):
120 INPUT "T "S-11 DEWPT (DEC F) = "A(Z,2):
130 INPUT "T 350-M IN (DEC F) = "A(Z,3):
140 INPUT "T 350-M DEWPT (DEC F) = "A(Z,4):
150 INPUT "T 350-M OUT (DEC F) = "A(Z,5):
160 INPUT "ARS OUTLET FLOW (CFH) = "A(Z,6):
170 INPUT "RS-51 FLOW (CFH) = "A(Z,7):
180 INPUT "P CHAMBER (IN HG) = "A(Z,8):
190 INPUT "T PRI H2O IN (DEC F) = "A(Z,9):
200 INPUT "T PRI H2O OUT (DEC F) = "A(Z,10):
210 INPUT "T SEC H2O IN (DEC F) = "A(Z,11):
220 INPUT "T SEC H2O OUT (DEC F) = "A(Z,12):
230 INPUT "PRI H2O FLOW (LB/HR) = "A(Z,13):
240 INPUT "SEC H2O FLOW (LB/HR) = "A(Z,14):
250 NEXT Z

150 IF Y(1)=Y(2) THEN 160 :
160 FOR Z=1 TO 14: X(Z)=A(Y(1),Z): NEXT Z: X(17)=X(13)+X(14):
170 X(15)=(X(9)*X(13)+X(10)*X(14))/(X(13)+X(14)):  
X(16)=(X(11)*X(13)+X(12)*X(14))*X(13)+X(14))
180 X(18)=X(17)*X(16): 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
HAMILTON STANDARD

**FOR Z=101 TO 120**
READ X(Z): NEXT Z:
GOSUB '02(X(30),0): X(31)=Z1: IF X(13)=0 THEN 200:
IF X(14)=0 THEN 200: X(19)=27*.5408*X(31): GOTO 210
200 X(13)=27*.5408*X(31):/2
210 X(20)=X(6)+X(7): IF X(2)>10 THEN 220: X(21)=X(4): GOTO 240
220 IF X(4)=0 THEN 230: X(2)=X(2)*2: GOTO 240
230 X(21)=X(X(2)+X(4)):1/2
240 X(19)=0: X(10)=0: RESTORE: FOR Z=101 TO 120: READ X(Z): NEXT Z:
GOSUB '02(X(27),0): P1=Z1: GOSUB '02(X(21),0): P2=Z1:
X(22)=144.65*X(1)+.4912*X(20)/53.34/(X(1)+459.6)
250 X(23)=2.2*(X(3)-(X(5))): A1=.622*P1/(X(2)+.4912-P1):
260 X(19)=Z1: FOR Z=101 TO 128: READ X(Z): NEXT Z:
GOSUB '02(X(27),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)=.5*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)=11: GOTO 330
320 X(19)=11
330 N=X(27)/X(19)
T1=(.24*X(22)+X(3)+X(17)+X(21)+X(16))/
(.24*X(17)+X(2)+X(22))
340 Q1=.24*X(3)+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 T3=X(11)+H*(T1-X(21))): E1=(X(3)-T1)/(X(3)-T2)
M1=X(17)/(.24*X(22)): GOSUB '01(01,H1):
U1=.24*X(22)*X
360 E2=(T1-X(5))/T1-X(15)): M2=X(17)*Q1/(.24*X(22))/Q2:
GOSUB '01(E2,T2): U2=.24*X(22)*K*XQ2/Q1:
U3=((1/H)/(1+1/H))*Q1/Q2+(1/(1+1/H)): X(25)=U1+U2+U3
370 ON Y(3) GOTO 330,400
330 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 300: T(29)=X(27)/313/.5408: IF X(13)=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(ODDE):
ON Y(3) JOTO 430,440

...
430 PRINT "RSECS 350-M IX PERFORMANCE / HOT SIDE BALANCE":
PRINT HEX(0A):
GOTO 450

440 PRINT "RSECS 350-M IX PERFORMANCE / COLD SIDE BALANCE":
PRINT HEX(0A):

050 PRINT "CASE #: "; Y(1):
PRINT "DATE: "; A$: PRINT HEX(01):
PRINT "INPUT DATA -":

460 PRINT USING 510, X(1), X(2), X(3):
PRINT USING 520, X(4), X(5), X(6):
PRINT USING 530, X(7), X(8), X(9):

470 PRINT USING 540, X(10), X(11), X(12):
PRINT USING 550, X(13), X(14):
PRINT HEX(0A):

080 PRINT "OUTPUT DATA -":
PRINT USING 560, X(17), X(30), X(20):
PRINT USING 570, X(22), X(26), X(28):

490 PRINT USING 580, X(19), X(31), X(27):
PRINT USING 590, X(29), X(23), X(24):
PRINT USING 600, X(18), X(25):
PRINT HEX(0A):

510 ZT RS-11 INLET =--##*## T RS-11 DEWPT =--##*## T
350-M INLET =--##*## T 350-° OUTLET =--##*## A
520 ZT 350-° DEWPT =--##*## T 350-° OUTLET =--##*## T
RS OUTLET FLOW =--##*## T

530 ZRS-51 FLOW =--##*## T CHAMBER PRESSURE =--##*## T
PRI H2O INLET =--##*## T

540 ZT SEC H2O INLET =--##*## T PRI H2O OUTLET =--##*## T
SEC H2O OUTLET =--##*## T

550 ZTRI H2O FLOW =--##*## SEC H2O FLOW =--##*##
560 ZTOTAL H2O FLOW =--##*## H2S FLOW/START =--##*## T
TOTAL AIR FLOW =--##*## T

570 ZAIR WEIGHT FLOW =--##*## AIR VELOCITY =--##*## T
STALUX =--##*##
580 ZCOLD SIDE HA =--##*## COLD FILM COEFF =--##*## H
ST SIDE HA =--##*##
590 ZHOT +ILM COEFF =--##*## Q SENSIBLE =--##*## Q
HATENT =--##*##

600 ZC TOTAL =--##*## HEAT BALANCE =--##*##

610 END

620 DEFN '01(E3,H3)
630 IF H3=1 THEN 640: IF M3=1 THEN 650: P
K=M3/(1-M3)*LOG((1-E3)/(1-E3/H3)): GOTO 660

640 K=E3/(1-E3): GOTO 660
650 K=M3/(H3-1)*LOG((1-E3/M3)/(1-E3))
660 RETURN

670 DEFN '02(C1,D1)
680 DIM A1(6),X1(6),Yh(6)
690 T1=101: N=3: N2=2
500 IF X(11)=3 THEN 740: IF X(11)]=3 THEN 750: IF X(11)=0 THEN 770: IF X(11)=0 THEN 740: IF X(11)=2 THEN 720: IF X(11)=2 THEN 740
510 N=1: GOTO 730
520 N=2
530 N=1
540 N=1
550 I=1: IF X(L)]=0 THEN 780
560 K=1: K=0: GOTO 1050
570 :=X(L)
580 IF X(L+1)=0 THEN 770: IF X(L+1)=0 THEN 300
590 N8=0: GOTO 810
600 N8=X(J+1)
610 K=0: K=0: C2=C1: J1=I1+2: J2=N9+I1+1:
620 OR J=J1 TO J2P IF C2=X(J) THEN 850P IF C2=X(J) THEN 860
630 K=1-1: C2=T(J)
640 J9=J2-x: GOTO 850
650 K=1: C2=X(J1)
660 J9=J1: GOTO 930
670 IF J=J1=1 THEN 850: IF J=J1=1 THEN 860P IF J=J2 THEN 840P IF J=J2 THEN 830:
680 J9=J2
690 L6=6P D2=X(J2)
700 J8=J2=1: GOTO 950
710 J8=J2=2: GOTO 950
720 J9=J1-1: GOTO 950
730 J9=J1-1: GOTO 950P IF J=J1=1 THEN 930: IF J=J2 THEN 910: IF J=J2 THEN 900P J8=J=N2
740 J7=J9: L6=L8+J8(J7-I1-L7): L7=L7+H8: FOR L=1 TO N1:
750 X1(L)=X(j7): Y1(L)=X(L7): L7=L7+N8: J7=J7+1: NEXT L:
760 I=OP GOTO 970
770 Y1(I)=Z1: FOR I=1 TO N; L7=L8+I: Y1(I+1)=0P FOR N=1 TO N1:
780 Y1(I+1)=Y1(I+1)+X(L7)*X1(N): L7=L7+H8: NEXT M: NEXT I:
790 FOR L=1 TO N1: X1(L)=X(J8): J8=J8+1: NEXT L: C3=C2+1: I=1
800 D=1: X1(N+2)=X1(N): X1(N+3)=X1(2): FOR J=1 TO N1:
810 A1(J+1)=A1(J+1)-X1(J): C4=C3-X1(J): IF C4[10 THEN 990:
820 Zn=Y1(J): X1(J)=0: X1(2)=0: X1(3)=0P X1(4)=0
830 X1(J)=1: GOTO 1040
840 D=B[CX; ON N GOTO 1000,1010,1020
850 X1(J]=C4/A1(J+1): GOTO 1030
860 X1(J]=C4: GOTO 1030
870 X1(J]=X1(J+2)-X1(J): A1(J)=C4
880 NEXT J: A1(J)=A1(J+1): Z1=0: FOR J=1 TO N1:
890 X1(J)=Z(J+1)*X1(J): Z1=Z1+Y1(J)*X1(J):
900 NEXT J
910 IF I=0 THEN 960
920 K1=K1+K8:
930 RETURN
APPENDIX B.3

RESULTS OF DATA REDUCTION PROGRAM
## 350-M HEAT EXCHANGE / HOT SIDE BALANCE

### Input Data

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<th>Cold Side HA</th>
<th>Cold Film Coeff</th>
<th>Hot Side HA</th>
<th>Hot Film Coeff</th>
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## 350-M HEAT EXCHANGE / HOT SIDE BALANCE

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### Output Data

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<th>H2O Flow/Start</th>
<th>Total Air Flow</th>
<th>Cold Side HA</th>
<th>Cold Film Coeff</th>
<th>Hot Side HA</th>
<th>Hot Film Coeff</th>
<th>Sensible</th>
<th>Latent</th>
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<tr>
<td>750.00</td>
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<td>606.68</td>
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## Output Data

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## Output Data

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<tr>
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<td>444.49</td>
<td>45.50</td>
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<td>52.17</td>
<td>47.30</td>
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## Output Data

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<td>47.30</td>
<td>0.00</td>
<td>750.07</td>
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### RSECS 350-1 HX PERFORMANCE / HOT SIDE BALANCE

**CASE #1: 3**

**DATE:** 7/3/75

#### INPUT DATA

- **T RS-11 INLET:** 72.30°F
- **T 350-1 DEHN:** 46.50°F
- **RS-51 FLOW:** 8.25 SCFH
- **T SEC H2O INLET:** 0.00°F
- **PRI H2O FLOW:** 750.00 SCFH

#### OUTPUT DATA

- **TOTAL H2O FLOW:** 750.00 SCFH
- **H2O FLOW/START:** 375.00 SCFH
- **T 350-1 INLET:** 46.50°F
- **T 350-1 DEHN:** 46.20°F

#### INPUT DATA

- **T RS-11 INLET:** 72.50°F
- **T 350-1 DEHN:** 47.50°F
- **RS-51 FLOW:** 7.50 SCFH
- **PRI H2O FLOW:** 750.00 SCFH

#### OUTPUT DATA

- **TOTAL H2O FLOW:** 750.00 SCFH
- **H2O FLOW/START:** 375.00 SCFH
- **T 350-1 INLET:** 47.50°F
- **T 350-1 DEHN:** 46.40°F

#### BALANCE DATA

- **COLD SIDE VA:** 4425.30 SCFH
- **COLD FILM COEFF:** 606.63
- **HOT FILM COEFF:** 33.73

---

**OUTPUT DATA**

- **TOTAL AIR FLOW:** 1237.25 SCFH
- **AIR VELOCITY:** 338.65
- **COLD SIDE HA:** 1633.32
- **HOT SIDE HA:** 333.57

---

**OUTPUT DATA**

- **TOTAL H2O FLOW:** 750.00 SCFH
- **H2O FLOW/START:** 375.00 SCFH
- **TOTAL AIR FLOW:** 1372.50 SCFH
- **AIR VELOCITY:** 338.65
- **HOT SIDE HA:** 1633.32
- **HOT SIDE HA:** 333.57

---

**OUTPUT DATA**

- **TOTAL H2O FLOW:** 10950.00 SCFH
- **H2O FLOW/START:** 375.00 SCFH
- **TOTAL AIR FLOW:** 1237.25 SCFH
- **AIR VELOCITY:** 338.65
- **HOT SIDE HA:** 1633.32
- **HOT SIDE HA:** 333.57
## Case 5: 7/8/75

### Input Data
- **T RS-11 Inlet**: 79.10°F
- **T 350-4 Deft**: 82.60°F
- **RS-11 FLO**: 1.50 gpm
- **T SEC H2O Inlet**: 0.00°F
- **PRI H2O Flow**: 750.00 gpm

### Output Data
- **Total H2O Flow**: 750.00 gpm
- **Air Weight Flow**: 3356.06 lbm/h
- **Cold Side HA**: 4429.30°F
- **Hot Film Coeff**: 13.55
- **Q Total**: 8350.00 Btu/h

### Heat Balance
- **Heat Balance**: 1.043

---

## Case 6: 7/8/75

### Input Data
- **T RS-11 Inlet**: 79.50°F
- **T 350-4 Deft**: 77.49°F
- **RS-11 FLO**: 1.50 gpm
- **T SEC H2O Inlet**: 0.00°F
- **PRI H2O Flow**: 750.00 gpm

### Output Data
- **Total H2O Flow**: 750.00 gpm
- **Air Weight Flow**: 3354.06 lbm/h
- **Cold Side HA**: 4429.30°F
- **Hot Film Coeff**: 13.55
- **Q Total**: 8250.00 Btu/h

### Heat Balance
- **Heat Balance**: 1.023
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**Case 8**

**Date** : 7/8/75

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**Heat Balance**

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**Heat Balance**

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### RSECS 350-M HA PERFORMANCE / HOT SIDE BALANCE

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<td>T 350-M Deep</td>
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<td>T 350-M Outlet</td>
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<td>T PRI H2O Inlet</td>
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<tr>
<td>T Sec H2O Inlet</td>
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### RSECS 350-M 4X PERFORMANCE / HOT SIDE BALANCE

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<td>Chiller Pressure</td>
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<td>T PRI H2O Inlet</td>
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<td>T Sec H2O Inlet</td>
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**Output Data**

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### RSECS 350-X HX Performance / Hot Side Balance

**Case #**: 11  
**Date**: 7/8/75

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<td>FRI H2O Flow</td>
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#### Heat Balance

- **Total Heat Balance**: 1.01
- **Cold Side Heat**: 9450.00
- **Total Air Flow**: 297.89
- **Total HX LA**: 1353.23
- **Hot Side HA**: 1913.87
- **Hot Film Coeff**: 16.16
- **Sec H2O Flow**: 162.32
- **Air Weight Flow**: 338.85
- **Cold Side HA**: 11002.79
- **Total Flow**: 12075.00
- **Heat Balance**: 1.01
### CASE F: 13
**DATE:** 7/8/75

**INPUT DATA**
- \( T_{RS-11} \) INLET: 62.60
- \( T_{350-N} \) DEWPT: 54.00
- \( T_{RS-51} \) FLOW: 7.50
- \( T_{SEC H2O} \) INLET: 0.00
- PRI H2O FLOW: 400.00

**OUTPUT DATA**
- TOTAL H2O FLOW: 400.00
- H2O FLO/START: 200.00
- TOTAL AIR FLOW: 297.30
- AIR VELOCITY: 337.49
- COLD SIDE HA: 2053.82
- HOT FILM COEFF: 16.22
- Q TOTAL: 1091.00

### CASE F: 14
**DATE:** 7/8/75

**INPUT DATA**
- \( T_{RS-11} \) INLET: 62.20
- \( T_{350-N} \) DEWPT: 54.00
- \( T_{RS-51} \) FLOW: 7.60
- \( T_{SEC H2O} \) INLET: 0.00
- PRI H2O FLOW: 600.00

**OUTPUT DATA**
- TOTAL H2O FLOW: 600.00
- H2O FLO/START: 300.00
- TOTAL AIR FLOW: 297.69
- AIR VELOCITY: 337.59
- COLD SIDE HA: 3390.27
- HOT FILM COEFF: 16.24
- Q TOTAL: 1206.00

### RSEC-350-N HX PERFORMANCE / HOT SIDE BALANCE

**INPUT DATA**
- \( T_{RS-11} \) INLET: 62.60
- \( T_{350-N} \) INLET: 54.00
- \( T_{RS-51} \) OUTLET: 32.50
- \( T_{SEC H2O} \) INLET: 0.00
- PRI H2O OUTLET: 0.00

**OUTPUT DATA**
- TOTAL H2O FLOW: 400.00
- H2O FLO/START: 200.00
- TOTAL AIR FLOW: 297.30
- AIR VELOCITY: 337.49
- COLD SIDE HA: 2053.82
- HOT FILM COEFF: 16.22
- Q TOTAL: 1091.00

### RSEC-350-N HX PERFORMANCE / HOT SIDE BALANCE

**INPUT DATA**
- \( T_{RS-11} \) INLET: 62.20
- \( T_{350-N} \) INLET: 54.00
- \( T_{RS-51} \) OUTLET: 32.50
- \( T_{SEC H2O} \) INLET: 0.00
- PRI H2O OUTLET: 0.00

**OUTPUT DATA**
- TOTAL H2O FLOW: 600.00
- H2O FLO/START: 300.00
- TOTAL AIR FLOW: 297.69
- AIR VELOCITY: 337.59
- COLD SIDE HA: 3390.27
- HOT FILM COEFF: 16.24
- Q TOTAL: 1206.00
### RSECS 350-HX PERFORMANCE / HOT SIDE BALANCE

#### Case #: 15
**DATE:** 7/8/75

**Input Data:**
- **T RS-11 INLET:** 79.90°F
- **T 330-9 DEWPT:** 45.50°F
- **RS-51 FLOW:** 7.40 ft³/s
- **T SEC H2O INLET:** 46.00°F
- **PRI H2O FLOW:** 0.00 ft³/s

**Output Data:**
- **TOTAL H2O FLOW:** 750.00 ft³/s
- **AIR WEIGHT FLOW:** 441.90 lb/s
- **COLD SIDE HA:** 4429.30 Btu/s
- **HOT FILM COEFF:** 10.38
- **Q TOTAL:** 4425.00 Btu/s

**Heat Balance:** 0.995

### RSECS 350-HX PERFORMANCE / HOT SIDE BALANCE

#### Case #: 16
**DATE:** 7/8/75

**Input Data:**
- **T RS-11 INLET:** 73.90°F
- **T 350-M DEWPT:** 45.23°F
- **RS-51 FLOW:** 7.40 ft³/s
- **T SEC H2O INLET:** 46.00°F
- **PRI H2O FLOW:** 0.00 ft³/s

**Output Data:**
- **TOTAL H2O FLOW:** 750.00 ft³/s
- **AIR WEIGHT FLOW:** 837.44 lb/s
- **COLD SIDE HA:** 4429.30 Btu/s
- **HOT FILM COEFF:** 3.8
- **Q TOTAL:** 6900.00 Btu/s

**Heat Balance:** 0.995
### RSECS 350-M HX Performance / Hot Side Balance

#### Case # 19
**Date:** 7/3/75

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<tbody>
<tr>
<td>RS-11 Inlet</td>
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<td>RS-11 DEPHT</td>
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<td>350-M DEPHT</td>
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<td>Sec H2O Inlet</td>
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<td>Pri H2O Flow</td>
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<tbody>
<tr>
<td>Total H2O Flow</td>
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<td>Air Veloc.</td>
<td>225.52</td>
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<td>Hot Side HA</td>
<td>1690.77</td>
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<td>Total Air Flow</td>
<td>1381.62</td>
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### RSECS 350-M HX Performance / Hot Side Balance

#### Case # 20
**Date:** 7/3/75

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<td>RS-11 DEPHT</td>
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<td>350-M DEPHT</td>
<td>51.50</td>
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<tr>
<td>RS-51 Flow</td>
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<td>Sec H2O Inlet</td>
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<td>Pri H2O Flow</td>
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<td>Hot Side HA</td>
<td>1512.53</td>
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<td>Total Air Flow</td>
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<th>OUTPUT DATA</th>
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<tbody>
<tr>
<td>J</td>
<td>7/8/75</td>
<td>T RS-11 INLET</td>
<td>T RS-11 DEWPT</td>
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<tr>
<td></td>
<td></td>
<td>T 350-H INLET</td>
<td>T 350-H DEWPT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T 350-H FLOW</td>
<td>T 350-H PRESSURE</td>
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<td></td>
<td>T SEC H2O INLET</td>
<td>T SEC H2O FLOW</td>
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<td></td>
<td></td>
<td>P31 H2O FLOW</td>
<td>TOTAL H2O FLOW</td>
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<td>TOTAL AIR FLOW</td>
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<td></td>
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<td>TOTAL AIR FLOW</td>
<td>COLD SIDE HA</td>
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<td>HOT FILM COEFF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SECURITY</td>
<td>Q SENSIBLE</td>
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<td>Q TOTAL</td>
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**RSECS 350-HX PERFORMANCE / HOT SIDE BALANCE**

**CASE J: 22**

**DATE: 7/8/75**

**INPUT DATA**

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<td>61.00</td>
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<td>3.00</td>
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<th>TOTAL AIR FLOW</th>
<th>COLD SIDE HA</th>
<th>HOT FILM COEFF</th>
<th>Q SENSIBLE</th>
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<td>750.00</td>
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## RSECS 350-M EX PERFORMANCE / HOT SIDE BALANCE

### CASE #: 23

**DATE**: 7/6/75

### INPUT DATA

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<th>Description</th>
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<tbody>
<tr>
<td>RS-11 INLET</td>
<td>33.50</td>
<td>52.00</td>
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<tr>
<td>T 350-M DEPT</td>
<td>62.00</td>
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<tr>
<td>RS-11 FLOW</td>
<td>3.60</td>
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<tr>
<td>AIR WEIGHT FLOW</td>
<td>1307.71</td>
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<tr>
<td>COLD SIDE HA</td>
<td>4429.30</td>
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<td>HOT FILM COEFF</td>
<td>15.96</td>
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<td>12562.50</td>
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## RSECS 350-M EX PERFORMANCE / HOT SIDE BALANCE

### CASE #: 24

**DATE**: 7/6/75

### INPUT DATA

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<td>RS-11 FLOW</td>
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<tbody>
<tr>
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<td>16.71</td>
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<td>Q TOTAL</td>
<td>9360.00</td>
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### CASE 1: 25
**DATE:** 7/3/75

**INPUT DATA**
- **T RS-11 INLET:** 60.90
- **T RS-11 DEPHT:** 51.90
- **T 350-4 INLET:** 82.80
- **T 350-4 DEPHT:** 49.10
- **RS-51 FLOW:** 7.50
- **CHAMER PRESSURE:** 30.00
- **T PRI H2O INLET:** 45.00
- **T SEC H2O INLET:** 0.00
- **PRI H2O FLOW:** 600.00
- **SEC H2O FLOW:** 2.00

**OUTPUT DATA**
- **TOTAL H2O FLOW:** 600.00
- **AIR FLOW:** 1282.65
- **AIR VELOCITY:** 329.33
- **TOTAL INLET:** 350.4
- **TOTAL DEPHT:** 47.00
- **RS-51 FLOW:** 7.50
- **CHAMER PRESSURE:** 30.00
- **T PRI H2O OUTLET:** 45.00
- **T SEC H2O OUTLET:** 63.60
- **SEC H2O FLOW:** 0.00

**RSCEC 350-4 HX PERFORMANCE / HOT SIDE BALANCE**

**CASE 2: 26**
**DATE:** 7/3/75

**INPUT DATA**
- **T RS-11 INLET:** 79.10
- **T RS-11 DEPHT:** 47.00
- **T 350-4 INLET:** 32.50
- **T 350-4 DEPHT:** 32.50
- **RS-51 FLOW:** 7.50
- **CHAMER PRESSURE:** 30.00
- **T PRI H2O INLET:** 45.00
- **T SEC H2O INLET:** 45.00
- **PRI H2O FLOW:** 375.00
- **SEC H2O FLOW:** 2.00

**OUTPUT DATA**
- **TOTAL H2O FLOW:** 600.00
- **AIR FLOW:** 1282.65
- **AIR VELOCITY:** 329.33
- **TOTAL INLET:** 350.4
- **TOTAL DEPHT:** 47.00
- **RS-51 FLOW:** 7.50
- **CHAMER PRESSURE:** 30.00
- **T PRI H2O OUTLET:** 45.00
- **T SEC H2O OUTLET:** 52.71
- **SEC H2O FLOW:** 45.00

**RSCEC 350-4 HX PERFORMANCE / HOT SIDE BALANCE**
### CASE 6: 7/8/75

**INPUT DATA**
- T RS-11 INLET = 75.00
- T 350-1 DEPHT = 65.50
- T 350-1 OUTLET = 45.40
- RS-51 FLOW = 7.50
- CHAMBER PRESSURE = 30.30
- T SEC H2O INLET = 45.00
- T PRI H2O OUTLET = 57.00
- PRI H2O FLOW = 375.00

**OUTPUT DATA**
- TOTAL H2O FLOW = 750.00
- AIR VELOCITY = 226.83
- COLD SIDE EA = 3796.81
- HOT SIDE HA = 1804.73
- Q. TOTAL = 7312.50

### CASE 1: 7/8/75

**INPUT DATA**
- T RS-11 INLET = 75.00
- T 350-1 DEPHT = 68.90
- T 350-1 OUTLET = 48.90
- RS-51 FLOW = 7.50
- CHAMBER PRESSURE = 30.00
- T SEC H2O INLET = 47.00
- T PRI H2O OUTLET = 64.50
- PRI H2O FLOW = 75.00

**OUTPUT DATA**
- TOTAL H2O FLOW = 750.00
- AIR VELOCITY = 48.90
- COLD SIDE EA = 3796.81
- HOT SIDE HA = 1804.73
- Q. TOTAL = 7312.50
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<td>T 350-H OUTLET</td>
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<td>HS-51 FLOW</td>
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<td>PRI H2O FLOW</td>
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**Output Data**

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<td>HOT FILM COEFF</td>
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**Input Data**

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<tr>
<td>T 350-H OUTLET</td>
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<td>HS-51 FLOW</td>
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**Output Data**

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</table>
**HAMILTON STANDARD**

---

### CASE # 31
**DATE**: 7/2/75

#### INPUT DATA
- **T RS-11 INLET** = 79.80
- **T 350-N DEHP** = 52.00
- **T ES-11 INLET** = 7.60
- **T SEC H20 INLET** = 66.90
- **PRI H2O FLOW** = 375.00

**Chamber Pressure** = 83.00
**ARS OUTLET FLOW** = 49.33
**PRI H2O INLET** = 46.00
**T SEC H2O OUTLET** = 32.50
**SEC H2O FLOW** = 375.00

#### OUTPUT DATA
- **TOTAL H20 FLOW** = 750.00
- **AIR WEIGHT FLOW** = 1375.53
- **COLD SIDE HA** = 3796.41
- **HOT FILM COEFF** = 16.33
- **Q TOTAL** = 11479.00

**H2O FLOW/START** = 187.50
**H2O FLOW** = 294.69
**AIR VELOCITY** = 339.87
**HOT SIDE HA** = 2214.51
**Q SENSIBLE** = 10561.32
**H2O FLOW** = 375.03

---

### CASE # 32
**DATE**: 7/3/75

#### INPUT DATA
- **T RS-11 INLET** = 80.50
- **T 350-N DEHP** = 61.00
- **T ES-11 INLET** = 61.00
- **T 350-N OUTLET** = 45.04
- **CHAMBER PRESSURE** = 39.00
- **H20 FLOW** = 1375.00
- **H20 INLET** = 45.00
- **SEC H20 OUTLET** = 56.04
- **PRI H2O FLOW** = 375.00

**ARS OUTLET FLOW** = 99.93

#### OUTPUT DATA
- **TOTAL H20 FLOW** = 750.00
- **AIR VELOCITY** = 331.25
- **HOT FILM COEFF** = 10.65
- **Q TOTAL** = 6731.25

**H20 FLOW/START** = 187.50
**H20 FLOW** = 294.69
**AIR VELOCITY** = 110.72
**HOT SIDE HA** = 1442.24
**Q SENSIBLE** = 4446.41

---

**RSEC 350-N HX PERFORMANCE / HOT SIDE BALANCE**

---

**RSEC 350-N HX PERFORMANCE / HOT SIDE BALANCE**
### Rsecs 350-M HX Performance / Hot Side Balance

#### Case #: 33

| Date         | 7/8/75 |

**Input Data**
- T RS-11 Inlet = .77.20
- T 350-1 DENT = 62.00
- T 350-2 OUTLET = 66.00
- RS-31 Flow = 63.20
- 1 SEC H2O INLET = 64.00
- PRI H2O FLOW = 375.00

**Output Data**
- TOTAL H2O Flow = 750.00
- H2O Flow/START = 157.50
- AIR Flow/START = 246.03
- AIR VELOCITY = 315.33
- COLD FILL COEFF = .1314
- HOT FILL COEFF = .304
- Q Sensible = 77.78
- Q Latent = 32.33
- Heat Balance = 1.012

### Rsecs 350-M HX Performance / Hot Side Balance

#### Case #: 34

| Date         | 7/8/75 |

**Input Data**
- T RS-11 Inlet = 61.20
- T 350-1 DENT = 62.00
- T 350-2 OUTLET = 35.00
- RS-31 Flow = 63.20
- 1 SEC H2O INLET = 31.00
- PRI H2O FLOW = 375.00

**Output Data**
- TOTAL H2O Flow = 750.00
- H2O Flow/START = 157.50
- AIR Flow/START = 246.03
- AIR VELOCITY = 315.33
- COLD FILL COEFF = .1314
- HOT FILL COEFF = .304
- Q Sensible = 77.78
- Q Latent = 32.33
- Heat Balance = 1.012
## HX PERFORMANCE / HOT SIDE BALANCE

### Case 35
- Date: 7/8/75

**Input Data**
- RS-11 Inlet = 81.20
- RS-11 Dewpt = 53.00
- RS-21 Flow = 7.50
- SEC H2O Inlet = 65.00
- PRI H2O Flow = 250.00

**Output Data**
- Total H2O Flow = 500.00
- AIR Weight Flow = 1300.00
- Cold Side HA = 2372.76
- Hot Film Coeff = 4.53
- Q Total = 10350.00

**Heat Balance**
- HEAT BALANCE = 1099

---

## HX PERFORMANCE / HOT SIDE BALANCE

### Case 36
- Date: 7/8/75

**Input Data**
- RS-11 Inlet = 81.30
- RS-11 Dewpt = 53.00
- RS-21 Flow = 7.50
- SEC H2O Inlet = 65.00
- PRI H2O Flow = 300.00

**Output Data**
- Total H2O Flow = 600.00
- AIR Weight Flow = 1302.56
- Cold Side HA = 2391.11
- Hot Film Coeff = 4.44
- Q Total = 11000.00

**Heat Balance**
- HEAT BALANCE = 997
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<td>52.50</td>
</tr>
<tr>
<td>CHAMBER PRESSURE</td>
<td>7.50</td>
</tr>
<tr>
<td>T SEC H2O INLET</td>
<td>40.00</td>
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<tr>
<td>PRI H2O FLOW</td>
<td>400.00</td>
</tr>
</tbody>
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### OUTPUT DATA

<table>
<thead>
<tr>
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<th>Value</th>
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</thead>
<tbody>
<tr>
<td>TOTAL H2O FLOW</td>
<td>800.00</td>
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<tr>
<td>AIR WEIGHT FLOW</td>
<td>1334.00</td>
</tr>
<tr>
<td>COLD SIDE HA</td>
<td>417.65</td>
</tr>
<tr>
<td>HOT FILM COEFF</td>
<td>16.49</td>
</tr>
<tr>
<td>Q TOTAL</td>
<td>10950.00</td>
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### RSECS 350-1 HX PERFORMANCE / HOT SIDE BALANCE

<table>
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<tr>
<td>AIR VELOCITY</td>
<td>335.22</td>
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<tr>
<td>Q SENSIBLE</td>
<td>10171.25</td>
</tr>
<tr>
<td>HEAT BALANCE</td>
<td>0.093</td>
</tr>
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</table>

### RSECS 350-1 HX PERFORMANCE / COLD SIDE BALANCE

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<tbody>
<tr>
<td>AIR VELOCITY</td>
<td>212.33</td>
</tr>
<tr>
<td>Q SENSIBLE</td>
<td>6713.72</td>
</tr>
<tr>
<td>HEAT BALANCE</td>
<td>1.099</td>
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### RSECS .350-\(\text{H}\)-HX PERFORMANCE / HOT SIDE BALANCE

#### CASE # 1: 39

**DATE:** 7/8/75

<table>
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<tbody>
<tr>
<td>T RS-11 INLET = 76.60</td>
<td>T RS-11 DEWPT = 53.03</td>
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<tr>
<td>T 350-INLET = 53.00</td>
<td>T 35O-OUTLET = 45.55</td>
</tr>
<tr>
<td>RS-51 FLOW = 5.25</td>
<td>CHAMBER PRESSURE = 30.00</td>
</tr>
<tr>
<td>T SEC H2O INLET = 45.00</td>
<td>T SEC H2O OUTLET = 57.23</td>
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<tr>
<td>PHI H2O FLOW = 375.00</td>
<td>SEC H2O FLOW = 375.00</td>
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</table>

<table>
<thead>
<tr>
<th>OUTPUT DATA</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL H2O FLOW = 750.00</td>
<td>H2O FLOW/START = 187.50</td>
</tr>
<tr>
<td>AIR WEIGHT FLOW = 842.30</td>
<td>AIR VELOCITY = 214.63</td>
</tr>
<tr>
<td>COLD SIDE HA = 375.04</td>
<td>COLD FILM COEFF = 260.03</td>
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<tr>
<td>HOT FILM COEFF = 13.43</td>
<td>Q SENSIBLE = 6721.57</td>
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<tr>
<td>Q TOTAL = 8512.50</td>
<td>HEAT BALANCE = 1.009</td>
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### RSECS .350-\(\text{H}\)-HX PERFORMANCE / HOT SIDE BALANCE

#### CASE # 2: 40

**DATE:** 7/8/75

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<td>T RS-11 INLET = 79.70</td>
<td>T RS-11 DEWPT = 46.25</td>
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<td>T 350-INLET = 46.25</td>
<td>T 35O-OUTLET = 44.54</td>
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<tr>
<td>RS-51 FLOW = 7.50</td>
<td>CHAMBER PRESSURE = 30.00</td>
</tr>
<tr>
<td>T SEC H2O INLET = 0.00</td>
<td>T PHI H2O OUTLET = 50.25</td>
</tr>
<tr>
<td>PHI H2O FLOW = 750.00</td>
<td>SEC H2O FLOW = 0.00</td>
</tr>
</tbody>
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<table>
<thead>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL H2O FLOW = 750.00</td>
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</tr>
<tr>
<td>AIR WEIGHT FLOW = 453.57</td>
<td>AIR VELOCITY = 116.27</td>
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<td>COLD SIDE HA = 44.30</td>
<td>COLD FILM COEFF = 596.68</td>
</tr>
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<td>HOT FILM COEFF = 10.13</td>
<td>Q SENSIBLE = 4132.28</td>
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<tr>
<td>Q TOTAL = 4312.50</td>
<td>HEAT BALANCE = 1.005</td>
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### RSECS 350-M HX PERFORMANCE / HOT SIDE BALANCE

**CASE #: 61**  
**DATE: 7/6/75**

#### INPUT DATA

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<tr>
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<td>76.50</td>
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<tr>
<td>T DS-11 DEPDT</td>
<td>53.50</td>
</tr>
<tr>
<td>T 350-M INLET</td>
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<tr>
<td>T 350-M OUTLET</td>
<td>45.50</td>
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<tr>
<td>RS-31 FLOW</td>
<td>10.00</td>
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<tr>
<td>CHARGE PRESSURE</td>
<td>30.00</td>
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<tr>
<td>T SEC H2O INLET</td>
<td>44.00</td>
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<tr>
<td>PRI H2O FLOW</td>
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#### OUTPUT DATA

<table>
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<tr>
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</thead>
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<tr>
<td>TOTAL H2O FLOW</td>
<td>750.00</td>
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<tr>
<td>H2O FLOW/START</td>
<td>187.50</td>
</tr>
<tr>
<td>TOTAL AIR FLOW</td>
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<tr>
<td>AIR WEIGHT FLOW</td>
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<tr>
<td>AIR VELOCITY</td>
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<td>TOTAL HX &amp;A</td>
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<tr>
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<tr>
<td>Q SECS13L</td>
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<tr>
<td>Q LATEAL</td>
<td>2323.73</td>
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</table>
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 an 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 Ax Performance Prediction

Procedure

\[ T_{Gi} \rightarrow \text{Dry} \rightarrow T_x \rightarrow \text{Wet} \rightarrow T_{Gi} (\text{sat}) \]

\[ T_{Gi} \rightarrow T_{Ci} (\text{final}) \]

With Air Flow, Find \( L_A \), from Fig A-3 (See Note 1)

With coolant Flow, Find \( L_A \), from Fig A-8 (Note 1.2)

\[
\frac{L_A}{L_{tot}} = \frac{1}{L_a + \frac{L_i}{L_A}}
\]

Assume initial value for \( T_{Gi} = (T_{Ci} + 1) \)

Find \( q_s, q_d, q_l, T_{Gi} \)

\[
q_s = (\omega_{Gi})_a (T_{Gi} - T_{Gi})
\]

\[
q_d = \left[ \frac{U_A}{T_{Gi} - T_{Gi}} \right] w_d (\text{See Note 1.2})
\]

\[ q_l = q_s + q_d \]

\[ T_{Gi} = \frac{q_l}{U_A_{tot}} + T_{Gi} \]

Find \( T_{Gi}, T_x, T_y \)

\[
T_{Gi} = \frac{U_A_{tot} T_{Gi} + (U_A)_{tot} [\frac{U_A}{T_{Gi}} T_{Gi} - (T_{Gi} - T_{Gi})]}{U_A_{tot} + (U_A)_{tot}}
\]

\[ L_A \frac{(U_A)_{tot} + (U_A)_{tot}}{L_A (U_A)} \]

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C-3
APPENDIX C-1

NOTE A-1

CALCULATIONS OF M\(\alpha\) AND M\(\alpha\) AT ASH SHOWN IN APPENDIX B-1 NOTE A-2.

IN ADDITION THE VALUE OF M\(\alpha\) USED IS CONSIDERED TO BE THE AVERAGE VALUE FOR THE M\(\alpha\).

\[\lambda_{\alpha, \text{ave}} = 1015.0 - 0.56(T_{\text{in}} - 32)\]

\[\lambda_{\alpha, \text{ave}} = 1015.0 - 0.56(T_{\text{in}} - 32)\]

\[\lambda_{\alpha} = \frac{\lambda_{\alpha, \text{ave}}}{2}\]
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 coolant 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 performance prediction program and is activated automatically if both coolout loops are flowing.
<table>
<thead>
<tr>
<th>TP</th>
<th>AIR W</th>
<th>DP IN</th>
<th>P x %</th>
<th>SEC %</th>
<th>PRI W</th>
<th>SEC W</th>
<th>TDP-TG</th>
<th>PRI DT</th>
<th>SEC DT</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
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<td>47.00</td>
<td>67.54</td>
<td>32.45</td>
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<td>375</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
</tr>
<tr>
<td>27</td>
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<td>61.53</td>
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<tr>
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<td>7.50</td>
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<td>11.00</td>
<td>11.00</td>
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<td>400</td>
<td>3.80</td>
<td>4.10</td>
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</tbody>
</table>

**TABLE C.2-1**

**ORIGINAL PAGE IS OF POOR QUALITY**
FIGURE C.2-1 HEAT LOAD SPLIT BETWEEN COOLANT LOOPS FOR 350-M HX
(FUNCTION OF DEWPOINT AND AIR FLOW RATE)
C-10
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 DEFN1(X)=3.10715762E-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 DEFN2(X)=106.7019036671-.79*5628830407*X+1.42137844E-02*X^2
  -4.03702990E-05*X^3+6.35142232E-08*X^4-4.0497326E-11*X^5
50 DEFN3(X)=7.304894511*2-3.19172743E-02*X-1.83198194E-05*X^2
  +6.78977362E-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) =",X(1):
90 INPUT "INTERNAL BYPASS (%) =",X(2):
100 PRINT "AIR TEMPERATURE (F) =",X(3):
110 PRINT "AIR DEW POINT (F) =",X(4):
120 PRINT "INPUT PRI COOLANT LOOP CONDITIONS"
130 INPUT "PRI LOOP FLOW (LB/HR) =",X(5):
140 INPUT "PRI LOOP TEMP IN (F) =",X(6):
150 PRINT "INPUT SEC COOLANT LOOP CONDITIONS"
160 INPUT "SEC LOOP FLOW (LB/HR) =",X(7):
170 INPUT "SEC LOOP TEMP IN (F) =",X(8):
180 PRINT "COLD HX PROGRAM IS RUNNING ****"
190 PRINT "**** COND HX PROGRAM IS RUNNING ****"
200 PRINT ":PRINT " CALC T GUESS "
210 X(17)=X(13)+X(14)
220 X(19)=X(17)+X(18)
230 IF X(13)=0 THEN 240
240 X(19)=27*X(19)/29985084X(31):GOTO 250
250 X(19)=27*X(19)/29985084X(31)/2
260 X(21)=X(2)+X(26):X(27)=313*X(27)
270 IF X(13)=0 THEN 280: IF X(14)=0 THEN 280:
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)):
320 IF X(22)=144860*X(8)*.4912*X(20)/53.35/(X(1)+459.6)

FIGURE G.3-1  350-M HX PERFORMANCE PREDICTION PROGRAM
320 L=1
330 IF T(2) > X(15) THEN 340: X(24) = 0: L = 0: GOTO 630
340 X(23) = 2.4 * X(22) * (X(3) - X(5))
350 T3 = 6.22 * P1/(X(8) * 4912 - P1):
   A2 = 6.22 * P2/(X(8) * 4912 - P2): X(24) = 1065 * X(22) * (A2 - A3)
360 X(18) = X(23) + X(24)
370 T(16) = (X(23) + X(24))/X(17) + X(15)
380 H = X(27)/X(19)
400 M1 = X(17)/(X(3) - T2)
410 IF X(2) > X(3) THEN 420: T1 = X(3); T2 = X(16); U1 = 0: GOTO 490
420 T1 = (* 2.4 * X(22) * X(3) + X(17) * (2.4 * X(21) + X(21) - X(16))/
   (X(3) - T2))
430 T2 = X(21) - H * (T1 - X(21))
440 IF T2 > X(24) THEN 450: GOTO 630
450 E1 = (X(3) - T1)/(X(3) - T2)
460 IF E1 > 10 THEN 470: E1 = 1.0
470 GOSUB 'Q1(1, 1, 1); U1 = 0.24 * X(22) * K
480 IF U1 > U THEN 490: GOTO 440
490 U2 = U - M1
500 Q7 = X(18) - X(17) * (X(16) - T2)
510 Q8 = Q7 - X(24)
520 N2 = M1 * Q8/Q7
530 K1 = I/(1 + I/II) + I/II * Q8/Q7/(1 + I/II)
540 U3 = U2/K1
550 K2 = U3 * Q8/Q7/(X(22))/24
560 GOSUB 'Q2(N2, 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) > 2.0 THEN 700: PRINT , T0, X(5)
600 IF Q1 + Q2 THEN 620
630 T(16) = X(17)/(X(22) * 24)
640 K2 = U/(X(22) * 24)
650 GOSUB 'Q3(N2, K2)
660 IF L = 1 THEN 670: P(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
700 IF L = 0 THEN 710: X(18) = X(22) + 24 * (X(3) - X(5)): X(23) = X(18): X(24) = 0
710 X(16) = X(18)/X(17) + X(15)
720 PRINT PPRI1: 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)
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 = ";X(6)
780 IF X(14)=0 THEN 300
590 PRINT " SEC COOLANT FLOW (LB/HR) ";X(14)
PRINT " SEC TIN = ";T(10); " SEC TOUT = ";T(7)
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 = ";X(5)
840 PRINT
850 PRINT " Q LATENT = ";X(24):
PRINT " Q SENS = ";X(23):
PRINT " Q TOTAL = ";X(18)
860 PRINTUSING 370, X(19), X(27), U:
870% HAH = -####-## HAH = -####-## UA = @####-##
880 SELECT PRINT 005
890 GOTO 1030
900 DEFFN'01(E1, M1)
910 IF E1=.00 THEN 920:E1=M1-.01
920 IF E1=.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 DEFF'02(M2, K2)
980 IF M2=.00 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*(M2-1)/M2):E1=(1-C1)/(1/C1/M2):GOTO 1020
1010 E1=K2/(1+K2)
1020 RETURN
1030 STOP "FOR NEXT CASE KEY CONTINUE":GOTO 60
1040 DEFFNA(T)=1.2896377E-02+2.00639183E--03*T-2.02793661E--05*T!2
+1.19983928E-06*T!3-9.17383683E-09*T!4+8.06114440E-11*T!5
-1.49070697E-13*T!6
1050 DEFFNB(P)=1.2896377E-02+2.00639183E--03*T-2.02793661E--05*T!2
+3.63241174E-02*(LOG(P))!3+5.6179189424*(LOG(P))!4
+3.63241174E-02*(LOG(P))!3+4.87666468E-03*(LOG(P))!4
1060 DEFFNC(P1)=-.622cP1/(h4,69-P1)
1070 DEFFND(T)=1061.5425925934*4348148148148*T
1080 H=.001:N=.001:K=1.
1090 A1=X(20)
1100 T1=X(5):D1=X(5)
1110 A2=X(20)/(100-B4)*B4
1120 T2=X(3):D2=X(3)
1130 W1=14.7*144*A1*60/53.3/(T1+460)
1140 W2=14.7*144*A2c60/53.3/(T2+460)
1150 S1=FNA(D1):S2=FNA(D2)

FIGURE C.3-1 (continued)
1160 V1=FNC(S1); V2=FNC(S2)
1170 V1=V1+U1; V2=*2*N2
1180 W=U1+U2; V=V1+V2
1190 H=FN0(T1); I=FN0(T2)
1200 H=((W1-V1)*T2+V1*H1)/((W2-V2)*T2+V2*H2)
1210 T=(U1*2*T1+U2*2*T2)/(U1*2+U2*2)
1220 HO=(W-·)*T+V*F(N)(T)
1230 PRINT H, HO, T
1240 IF ABS(H-HO) [.9] THEN 1330
1250 Y=Z
1260 Z=T
1270 IF HO=H+N THEN 1330
1280 T=T+K
1290 IF Y[N] THEN 1220
1300 K=X/2
1310 T=T-K
1320 JOTO 1220
1330 T=T-K
1340 IF Y[N] THEN 1220
1350 K=K/2
1360 T=T+K
1370 GOTO 1220
1380 P=W*14.69/(W+M*622)
1390 DEEFN (P)
1400 REM
1410 RETURN
1420 DEEFN6 (X)=15.965242137769+19.580231306397*X-4.01064665E-04*X!
1430 DEEFN7 (X)=3.3035818936-2.6817973E-02*X+6.01984427E-05*X!
1440 DEEFN8 (X)=-.161759673865+1.49855566E-03*X-3.39129732E-06*X!
1450 DEEFN9 (X)=A+B*X+C*X!2
1460 DEEFN5 (X)=A+B*X+C*X!2
1470 IF X(13)=0 THEN 1480: IF X(14)=0 THEN 1480: POTO 1490
1480 X=FN6(X(5)); X7=X5: C=FN8(X5): F2=FN9(X(2)-T(h0));
1490 IF X(13)=0 THEN 1480: IF X(14)=0 THEN 1480: POTO 1490
1500 X=(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)