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MODEL BASIN
WASHINGTON, D.C.

DEPARTMENT OF THE NAVY

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HYDROMECHANICS

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ACOUSTICS AND VIBRATION

COMPUTER PROGRAM DOCUMENTATION

STEAM CONDENSER DESIGN

[redacted]

by

M. Botting

D. Kelly

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APPLIED MATHEMATICS LABORATORY

RESEARCH AND DEVELOPMENT REPORT

July 1966

Report 2255

PRNC-TMB-648 (Rev 1-64)

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Report 2255
SR003-0801
Task 10894

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ADMINISTRATIVE INFORMATION

This work was accomplished under project SR003-0801, Task 10894.

The Computer program and documentation herein has been approved by the Naval Ship Engineering Center for use in naval ship design.

I. IDENTIFICATION DATA

A. Title - Steam Condenser Design

1. FORTRAN IV   Deckname - COND

2. Revision - A - Original Issue

B. Abstract - This program calculates all the necessary information required for the selection of main or auxiliary steam condensers to either preliminary or contract design requirements.

For preliminary design a graph is also provided which relates condenser overall length with tube sheet diameter for a specified set of design conditions. For contract design a graph relating condenser absolute pressure and increments of heat rejection at integer circulating water velocities is also provided for analysis of part load performance.

C. Input/Calculated   Items/Output

1. Input

Term	Standard Symbol
Tube Material	XMA1TU
Tube Gage	GA1TU
Tube Outside Diameter (inches)	D5TU
Number of Passes	XN2PS
Cleanliness Factor	F2TCLN
Number of Tube Sheets per end	XN2TSE
Ineffective Tube Length per end (inches)	XL1TUI

Term	Standard Symbol
Tube Hole Space Factor	F2TUHO
Steam Flow to Condenser (lb/hr)	R9SF5
Heat Rejected per pound of Steam (BTU/lb)	HT1SR
Design Back Pressure (inches-hg)	P2BDES
Injection Water Temperature (^{o}F.)	TE1INJ
Overall Condenser Length Desired (ft)	XL1TT
Desired Diameter of Tube Sheet (ft)	D5COND
Circulating Water Velocity in Tubes (ft/sec)	V1WTU
Ordered Tube Length Shortest	XL1TUO
Ordered Tube Length Longest	QL1TUO

2. Internal Values

Term	Standard Symbol
Tube Wall Thickness	TH1TU
Basic Heat Transfer Coefficient	C1HEAT
Tube Constant	C9TU
Material and Gage Factor	F2MG
Temperature Correction Factor	F2TEC
GPM/1 FPS/Tube	F1V6TU

3. Output

Term	Standard Symbol
Temperature Saturated Liquid	TE1SAT
Ordered Tube Length	XL1TUO
Tube Surface Area	S2TU

Term	Standard Symbol
Effective Tube Length	XL1TUE
Number of Tubes	XN2TUT
Tube Sheet Diameter	D5TUSH
Tube Sheet Area	A1TUSH
Overall Condenser Length	XL1CON
Circulating Water Required (GPM)	R9SW2
Circulating Water Outlet Temp.	TE1O
Terminal Temperature Diff.	TE1TD
Circulating Water Temperature Rise	TE1R

D. Author/Date

Maxine Botting Denis Kelly December 1965

E. Organization

Computer-Aided Ship Design Division, Code 850, David Taylor Model Basin.

F. Computer/Source Language

IBM 7090 FORTRAN IV CARD INPUT

G. Reference to Documentation

DTMB Report 2255 of July 1966

H. Security Classification

Unclassified

I. Estimated Running Time

1 1/2 minutes.

II. PURPOSE AND METHOD

A. Description of Method

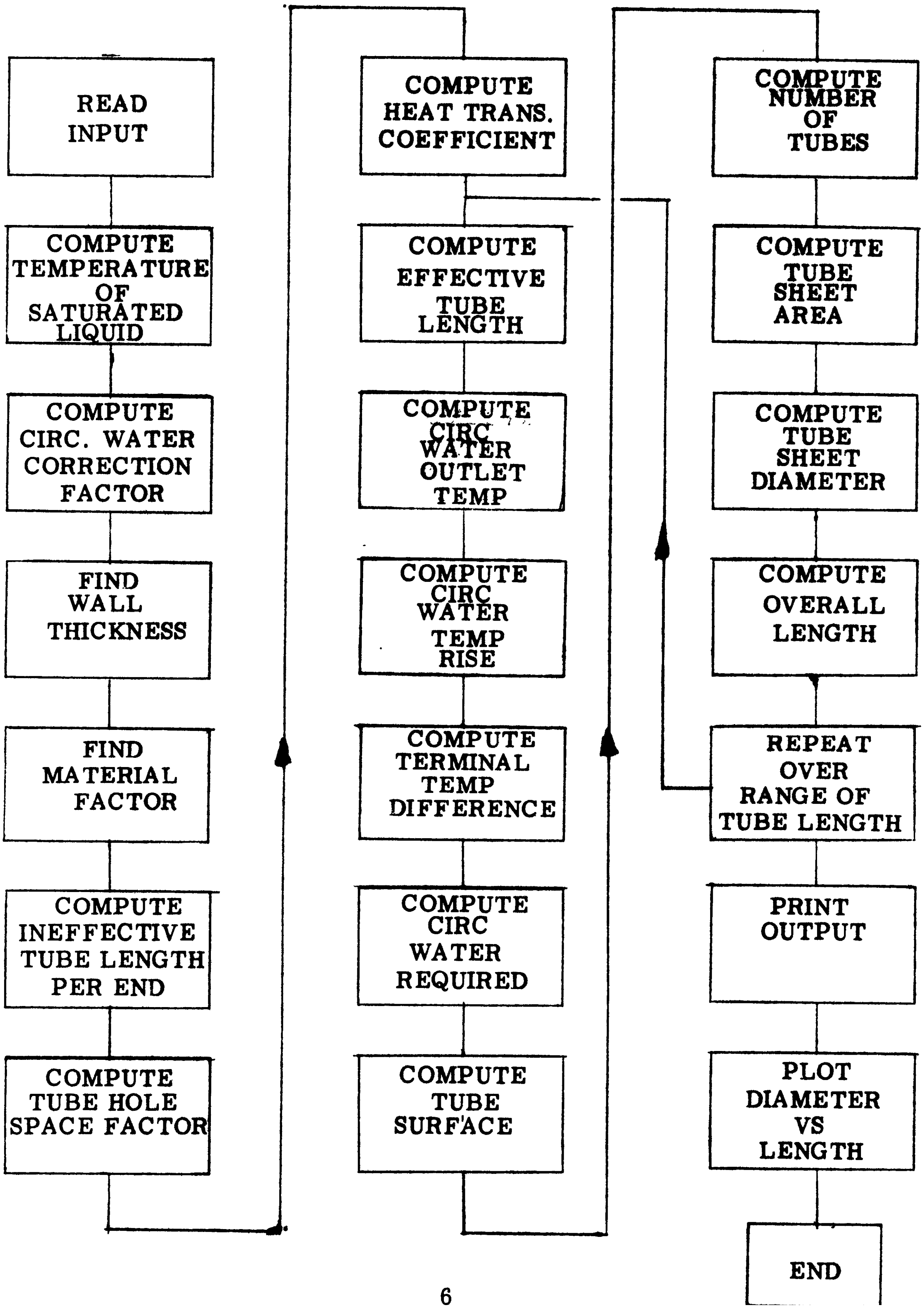
The purpose of this program is to develop the required design data necessary for the selection of a steam condenser in accordance with the ordering data specified in military specification MIL-C-15430G. Since any condenser design is a balance of tube surface, tube length and cooling water quantity, it is the space allowed for the condenser that actually is the deciding factor in the design. If the limiting dimensions are known the contract design mode is employed and the design is calculated based on these specific dimensions. If exact limiting dimensions are not known, a range of tube lengths can be specified, the preliminary design mode employed, and a number of satisfactory designs reviewed.

The theory and formulations of the design process are shown in design data sheet DDS4601-1 of 15 October 1953.

The temperature of a saturated liquid as a function of pressure and pressure as a function of temperature are obtained by formulations develop by Westinghouse Corporation based on Keenan and Keyes values.

A simple descriptive flow chart is as follows:

PRELIMINARY DESIGN MODE



Contract Design Mode

In the contract design mode an estimated ordered tube length is computed based on the overall condenser length used as input. The above calculations are then performed and a calculated overall length developed. This value is compared with the desired overall length. If larger the ordered tube length is incremented six inches smaller and the calculations repeated. When the calculated length is equal or smaller the program then checks the tube sheet diameter. If the calculated value is too large the program stops. If it is satisfactory a plot of heat load versus absolute pressure is developed for various circulating water velocities from input value down to 3 feet/sec.

B. Assumptions

Tube materials and gage factors for 12 and 13 BWG are extrapolated from HEI standards for steam surface condensers which include only 14-18 BWG.

C. References

1. Design Data Sheet DDS4601-1 of 15 October 1953 - Steam Condensers.

2. Military Specification MIL-C-15430G Condensers, Steam Surface, Naval Shipboard.

3. Share Programs C3-WH58-PA-3137 (Westinghouse Corporation Properties of Steam).

III. RESTRICTIONS

A. Non-standard subroutines not included in the program are the North American S-C 4020 subroutine package.

B. A tape is required on B-9 to go to the S-C 4020.

C. Non-standard hardware is the S-C 4020.

D. Maximum Array Size

In the preliminary design mode there is a limit of 10 tube lengths starting with the shortest and increasing at six inch intervals.

IV. NON-STANDARD OPERATING INSTRUCTIONS

A. There are no special operating instructions.

B. There are no restart instructions.

C. There are no on line error corrections.

D. Validation Checks

The program has been checked and found to be accurate against the sample problems contained in design data sheet DDS4601-1 of 15 October 1953.

V. DATA PREPARATION

A. Card Input Description

All input except the first card is a 12 column fields. The specified columns are where a typical value would be. Decimal points are necessary and all values should be right adjusted.

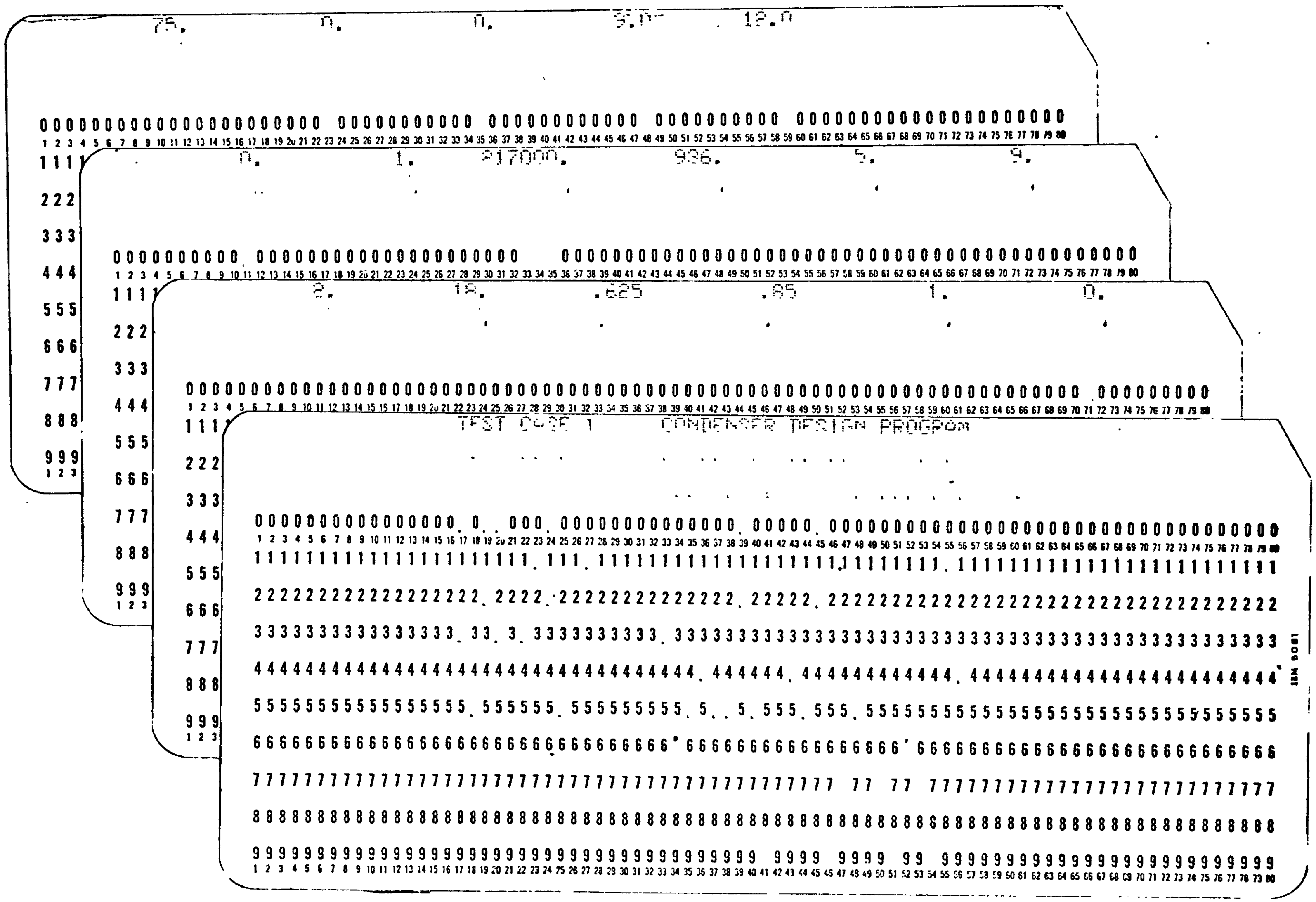
For limitations on input see VI-C- SPECIAL DIAGNOSTICS.

CARD	DATA	TYPICAL FIELD	INPUT PARAMETERS	COLUMNS
First	Title for output (Must be centered in field to be centered on output)			1 - 72
Second	(Tube Material)	X.	1. (70 - 30 CU-NI) 2. (90 - 10 CU-NI)	11 - 12
Second	(Tube Gage)	XX.	12 to 18	22 - 24
Second	(Tube Diameter)	.XXX	.625 .750 .875	33 - 36
Second	(Cleanliness Factor)	.XX	.85 (Typical Value)	46 - 48
Second	(No. of Tube Sheets/ end)	X.	1. or 2.	59 - 60
Second	(Ineffective Tube Length per end)	X.	If 0 program will calculate this value	71 - 72
Third	(Tube Hole Space Factor)	X.XX	If 0 program will calculate this value	9 - 12
Third	(No. of passes)	X.		23 - 24
Third	(Steam to Condenser)	XXXXXX.		30 - 36
Third	(Heat Rejected	XXX.		45 - 48
Third	(Design Back Pressure)	XX.X		57 - 60

CARD	DATA	TYPICAL FIELD	INPUT PARAMETERS	COLUMN
Third	(Circ. Water Velocity)	XX.		70 - 72
Fourth	(Injection water temperature)	XX.		10 - 12
Fourth	(Desired overall condenser length)	XX.X	If 0 will execute preliminary design If a value will execute contract design	21 - 24
Fourth	(Desired diameter of tube sheet)	XX.X		33 - 36
Fourth	(Shortest ordered tube length)	XX.X	Must be 10 values or less at 6 inch intervals between shortest and longest ordered tube length	
Fourth	(Longest ordered tube length)	XX.X		57 - 60

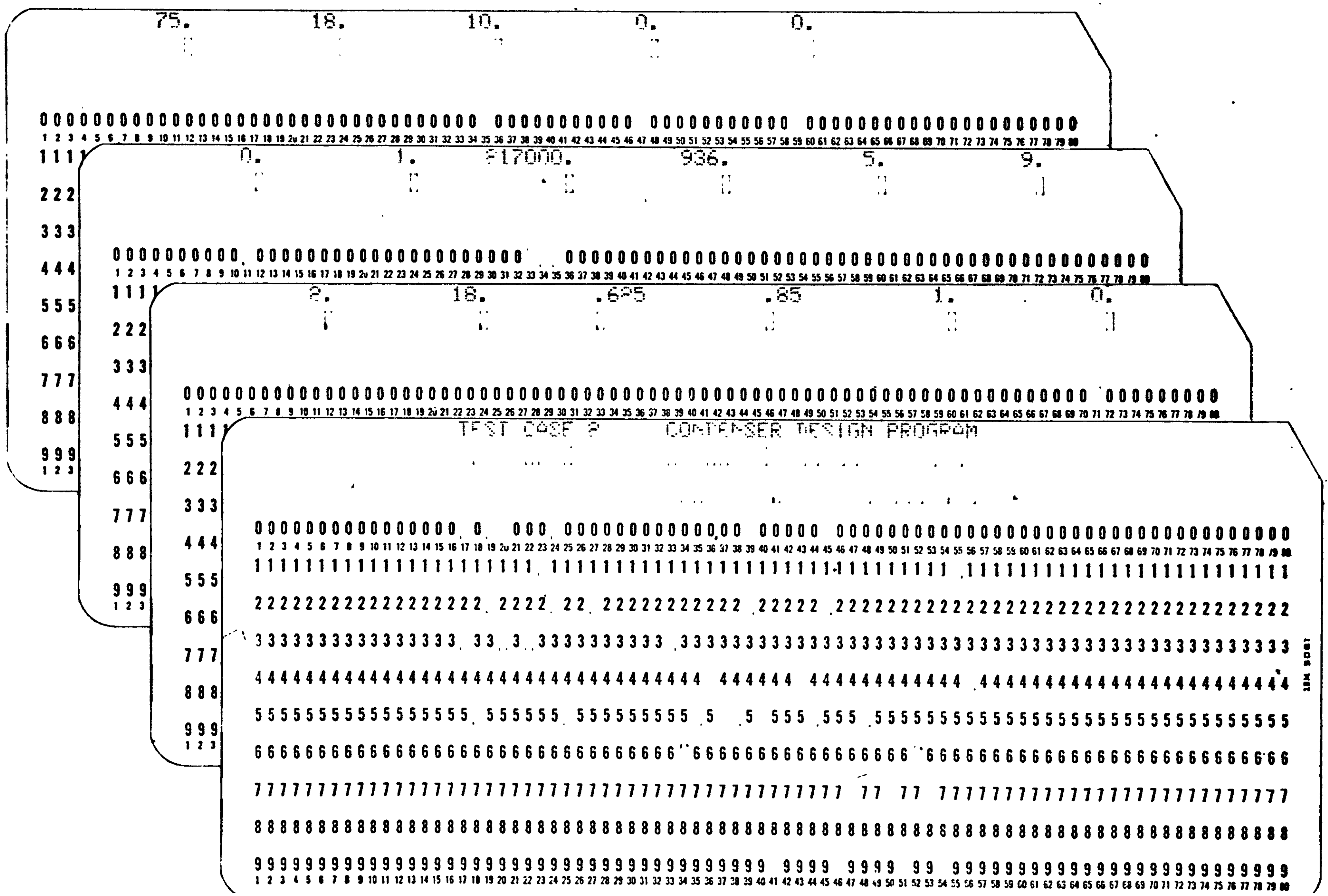
V-B. SAMPLE INPUT

PRELIMINARY DESIGN MODE



V - B. SAMPLE INPUT

CONTRACT DESIGN MODE



C. Output Form Description

The input data is printed as the first output in each mode. In the preliminary design mode the desired overall condenser length and tube sheet diameter values are zero. The calculated output is self-explanatory for each mode. Graphic output for the preliminary mode shows the relationship between circular tube sheet diameter and overall condenser length for a given set of design conditions. Graphic output for the contract design mode shows condenser part load performance with the condenser absolute pressure and heat rejection load (up to 110% of full power) shown at various circulating water velocities.

TEST CASE 1 CONDENSER DESIGN PROGRAM

INPUT VALUES

TUBE MATERIAL	90-10
TUBE GAGE	18.
TUBE DIAMETER (IN)	0.6250
CLEANLINESS FACTOR	0.8500
NUMBER OF TUBE SHEETS PER END	1.
INEFFECTIVE TUBE LENGTH PER END (IN)	0.
TUBE HOLE SPACE FACTOR	0.
NUMBER OF PASSES	1.
STEAM TO CONDENSER (LB/HR)	217000.
HEAT REJECTED PER POUND OF STEAM (BTU/LB)	936.00
DESIGN BACK PRESSURE (IN HG)	5.00
CIRC WATER VELOCITY IN TUBES (FT/SEC)	9.00
INJECTION WATER TEMPERATURE (DEG F)	75.00
DESIRED OVERALL CONDENSER LENGTH (FT)	0.
DESIRED DIAMETER OF TUBE SHEET (FT)	0.
ORDERED TUBE LENGTH SHORTEST (FT)	9.00
ORDERED TUBE LENGTH LONGEST (FT)	12.00

V.D-1 SAMPLE OUTPUT

PRELIMINARY DESIGN MODE

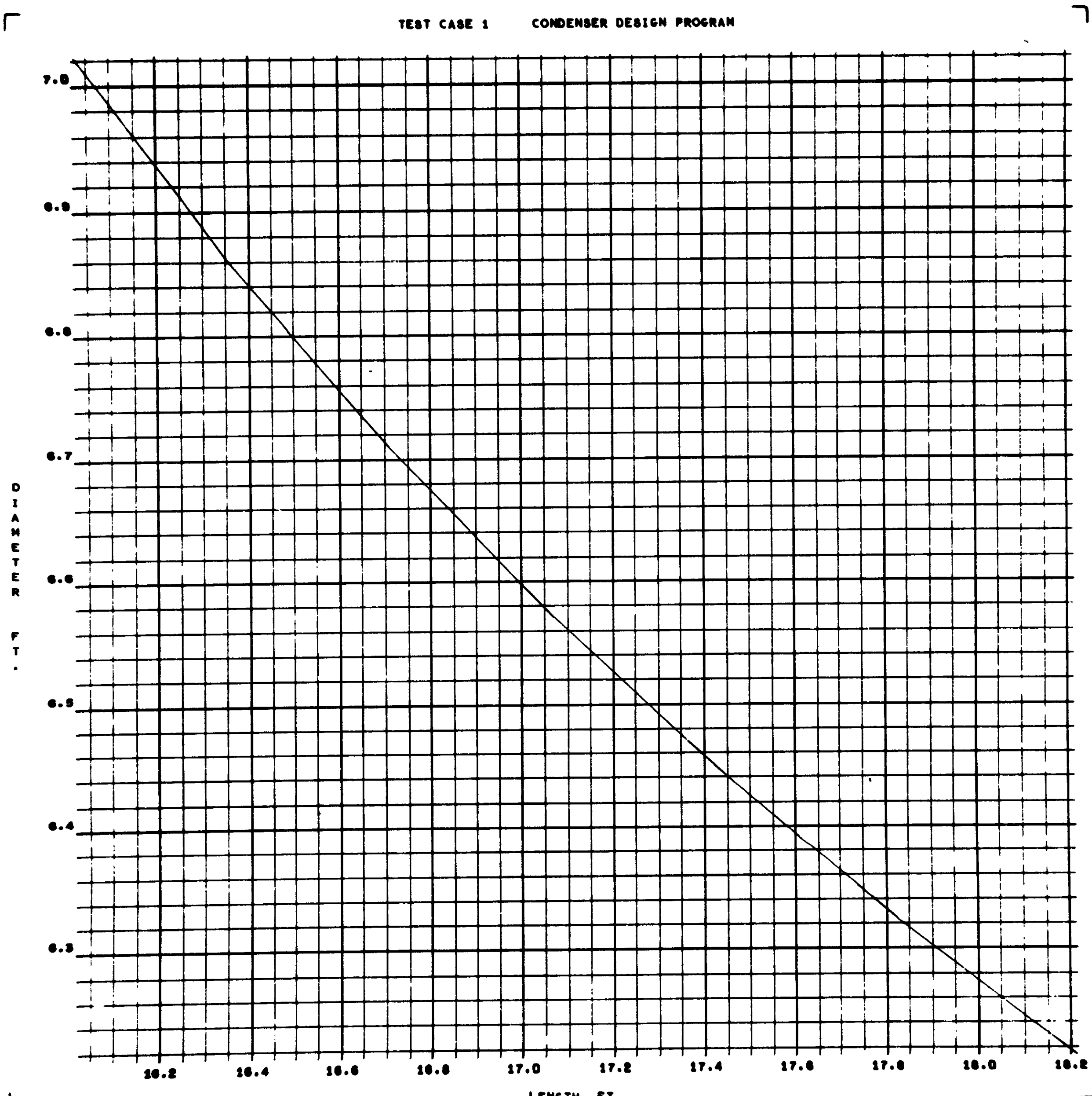
OUTPUT VALUES

TEMPERATURE SATURATED LIQUID (DEG F)			133.7590				
ORDERED TUBE LENGTH (FT)	9.00	9.50	10.00	10.50	11.00	11.50	12.00
TUBE SURFACE AREA (SQ FT)	6299.	6350.	6401.	6452.	6504.	6556.	6608.
EFFECTIVE TUBE LENGTH (FT)	8.82	9.32	9.82	10.32	10.82	11.32	11.82
NUMBER OF TUBES	4364.	4163.	3983.	3820.	3673.	3539.	3416.
TUBE SHEET DIAMETER (FT)	7.02	6.86	6.71	6.57	6.44	6.32	6.21
TUBE SHEET AREA (SQ FT)	38.74	36.96	35.36	33.91	32.61	31.42	30.32
OVERALL CONDENSER LENGTH (FT)	16.02	16.36	16.71	17.07	17.44	17.82	18.21
CIRCULATING WATER REQD (GPM)	26697.	25469.	24368.	23374.	22473.	21652.	20902.
CIRC WATER OUTLET TEMP (DEG F)	90.22	90.95	91.67	92.38	93.08	93.76	94.43
TERMINAL TEMP DIFF (DEG F)	43.54	42.81	42.09	41.38	40.68	40.00	39.32
CIRC WATER TEMP RISE (DEG F)	15.22	15.95	16.67	17.38	18.08	18.76	19.43

V.D-1 SAMPLE OUTPUT

PRELIMINARY DESIGN MODE

V. D-1 SAMPLE OUTPUT
PRELIMINARY DESIGN MODE



TEST CASE 2 CONDENSER DESIGN PROGRAM

INPUT VALUES

TUBE MATERIAL	90-10
TUBE GAGE	18.
TUBE DIAMETER (IN)	0.6250
CLEANLINESS FACTOR	0.8500
NUMBER OF TUBE SHEETS PER END	1.
INEFFECTIVE TUBE LENGTH PER END (IN)	0.
TUBE HOLE SPACE FACTOR	0.
NUMBER OF PASSES	1.
STEAM TO CONDENSER (LB/HR)	217000.
HEAT REJECTED PER POUND OF STEAM (BTU/LB)	936.00
DESIGN BACK PRESSURE (IN HG)	5.00
CIRC WATER VELOCITY IN TUBES (FT/SEC)	9.00
INJECTION WATER TEMPERATURE (DEG F)	75.00
DESIRED OVERALL CONDENSER LENGTH (FT)	18.00
DESIRED DIAMETER OF TUBE SHEET (FT)	10.00
ORDERED TUBE LENGTH SHORTEST (FT)	0.
ORDERED TUBE LENGTH LONGEST (FT)	0.

V.D-2 SAMPLE OUTPUT

CONTRACT DESIGN MODE

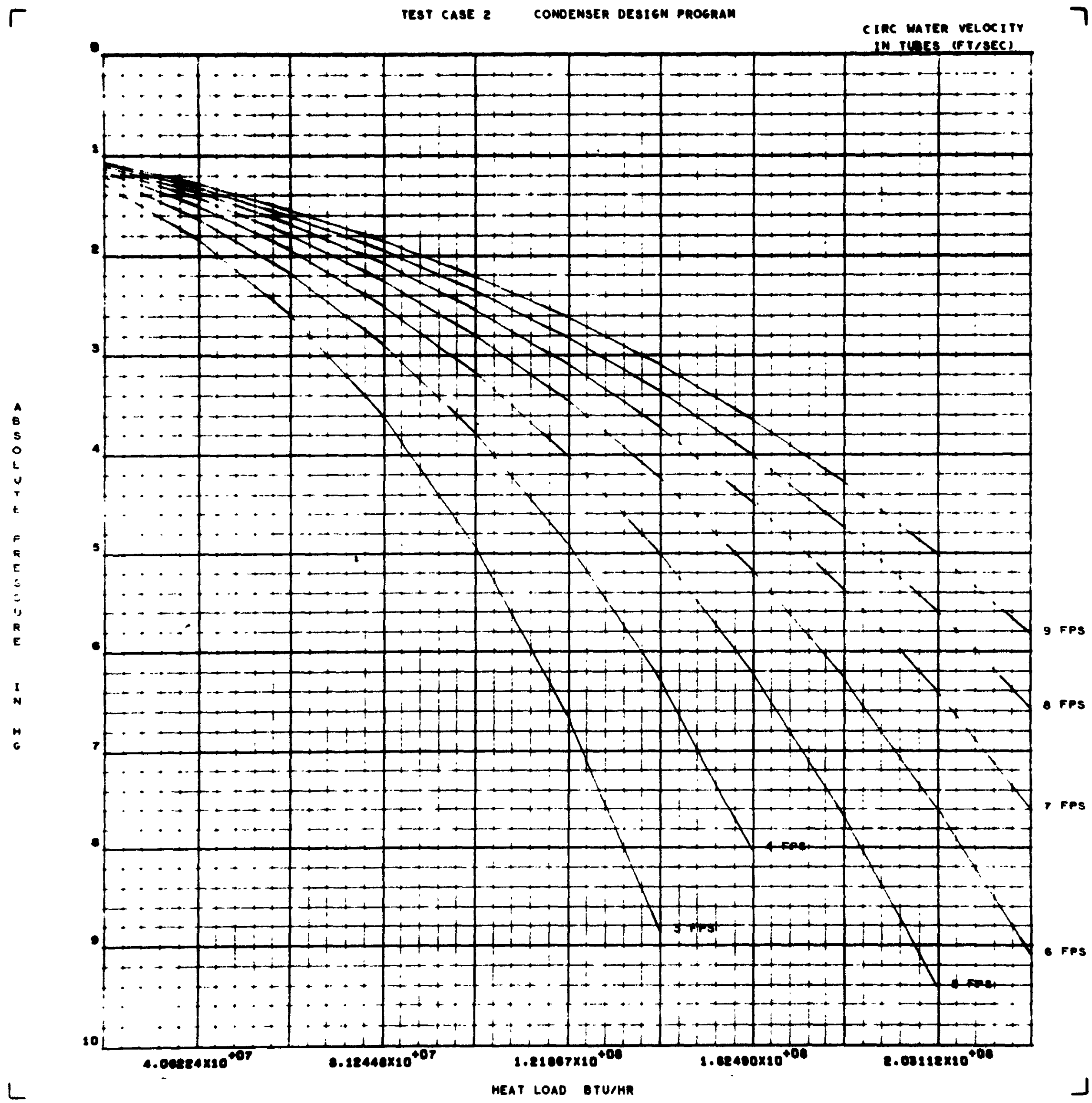
OUTPUT VALUES

TEMPERATURE SATURATED LIQUID (DEG F)	133.7590
ORDERED TUBE LENGTH (FT)	11.50
TUBE SURFACE AREA (SQ FT)	6556.
EFFECTIVE TUBE LENGTH (FT)	11.32
NUMBER OF TUBES	3539.
TUBE SHEET DIAMETER (FT)	6.32
TUBE SHEET AREA (SQ FT)	31.42
OVERALL CONDENSER LENGTH (FT)	17.82
CIRCULATING WATER REQD (GPM)	21652.
CIRC WATER OUTLET TEMP (DEG F)	93.76
TERMINAL TEMP DIFF (DEG F)	40.00
CIRC WATER TEMP RISE (DEG F)	18.76

V. D-2 SAMPLE OUTPUT

CONTRACT DESIGN MODE

V. D-2 SAMPLE OUTPUT
CONTRACT DESIGN MODE



E. Symbol List

See list in I. C.

F. Data Tables Used by Program

1. Factors used in determining saturated liquid temperature:

Reference (3)

(QAA) A_0 = 35.15789

A_1 = 24.592588

A_2 = 2.1182069

A_3 = -.3414474

A_4 = .15741642

A_5 = -.031329585

A_6 = .0038658282

A_7 = -.00024901784

A_8 = .0000068401559

2. Circulating Water Temperature Correction Factors:

Reference (1)

(QCF) 30^oF = .65

35^oF = .70

40^oF = .75

45^oF = .798

50^oF = .843

55^oF = .886

60^oF = .926

(QCF)	$65^{o}F$	= .963
	$70^{o}F$	= 1.0
	$75^{o}F$	= 1.025
	$80^{o}F$	= 1.045
	$85^{o}F$	= 1.061
	$90^{o}F$	= 1.076
	$95^{o}F$	= 1.09
	$100^{o}F$	= 1.1

3. Wall Thickness Factors: Reference (1) and page 6, II B

(QTH)	BWG 12	- .109
	13	- .095
	14	- .083
	15	- .072
	16	- .065
	17	- .058
	18	- .049

4. Material and Gage Factors: Reference (1) and page 6, II B

(QCU)	CU-NI 70-30	CU-NI 90-10	BWG
	.46	.55	12
	.55	.64	13
	.64	.72	14
	.71	.79	15

CU-NI 70-30	CU-NI 90-10	BWG
.76	.84	16
.80	.87	17
.83	.90	18

5. Factors Used in Determining Saturation Pressure of a Saturate

Liquid: Reference (3)

(QPFT)

A = 3.2437814

B = .00586826

C = 1.1702379E-8

D = .0021878462

E = 0.0

A = 3.346313

B = .0414113

C = 7.515484E-9

D = .013794481

E = 6.56444E-11

VI CODING INFORMATION

A. Flow Charts

I

```
      COMMON XMA1TU,GA1TU,D5TU,F2TCLN,XN2TSE,XL1TUI
      COMMON F2TUHO,XN2PS,R9SF5,HT1SR,P2BDES,V1WTU
      COMMON TE1INJ,XL1TT,D5COND,XL1TUO,QL1TUO
      COMMON S2TU,XL1TUE,XN2TUT,D5TUSH,A1TUSH,XL1CON
      COMMON R9SW2,TE1O,TE1TD,TE1R,W2COND,VL1HW
      DIMENSION QTITLE(12)
      DIMENSION QAA(9),QCU(7,2),QCF(15),QTH(7)
      DIMENSION QPFT(5,2),QMA(2)
      DIMENSION QP1(11),QP2(11),QP3(10),QP4(10),QP5(10),QP6(10),QP7(10)
      QP8(10),QP9(10),QP10(10),QP11(10)
  SEE DATA STATEMENT                                      QAA
  SEE DATA STATEMENT                                      QCU
  SEE DATA STATEMENT                                      QCF
  SEE DATA STATEMENT                                      QTH
  SEE DATA STATEMENT                                      QPFT
      DATA QAA/35.15789,24.592588,2.1182069,-.3414474,.15741642,
       .3132958E-1,.38658282E-2,-.24901784E-3,.68401559E-5/
      DATA QCU/.46,.55,.64,.71,.76,.80,.83,.55,.64,.72,.79,.84,
      .87,.90/
      DATA QCF/.65,.7,.75,.798,.843,.886,.926,.963,1.,1.025,
      1.045,1.061,1.076,1.09,1.1/
      DATA QTH/.109,.095,.083,.072,.065,.058,.049/
      DATA QPFT/3.2437814,.00586826,1.1702379E-8,.0021878462,0.,
      3.346313,.0414113,7.515484E-9,.013794481,6.56444E-11/
      DATA QMA/6H 70-30,6H 90-10/
1     FORMAT (12A6)
2     FORMAT (1H1,//,24X,12A6,// ,13H0INPUT VALUES,//)
3     FORMAT (6E12.6)
```

```
5     FORMAT(14H0TUBE MATERIAL,40X,A6/10H TUBE GAGE,30X,F20.0/
      20H TUBE DIAMETER  (IN),20X,F20.4)

6     FORMAT (19H CLEANLINESS FACTOR,21X,F20.4/30H NUMBER OF TUBE
      SHEETS PER END,10X,F20.0/38H INEFFECTIVE TUBE LENGTH PER
      END  (IN),F22.4)

7     FORMAT(23H TUBE HOLE SPACE FACTOR,17X,F20.4,/17H NUMBER OF
      PASSES,23X,F20.0,/28H STEAM TO CONDENSER  (LB/HR),F32.0)

8     FORMAT(43H HEAT REJECTED PER POUND OF STEAM  (BTU/LB),F17.2,/
      30H DESIGN BACK PRESSURE  (IN HG),F30.2,/39H CIRC WATER
      VELOCITY IN TUBES  (FT/SEC,F21.2)

9     FORMAT (37H INJECTION WATER TEMPERATURE  (DEG F),F23.2,/39H
      DESIRED OVERALL CONDENSER LENGTH  (FT),F21.2,/37H DESIRED
      DIAMETER OF TUBE SHEET  (FT),F23.2)

10    FORMAT (36H ORDERED TUBE LENGTH  SHORTEST  (FT),F24.2,/
      35H ORDERED TUBE LENGTH  LONGEST  (FT),F25.2)

15    FORMAT (6E20.8)

20    FORMAT (22H0INPUT VALUE P2BDES IS,E15.8,5X,28HSHOULD BE BETWE
       AND 450)

21    FORMAT (22H0INPUT VALUE TE1INJ IS,E15.8,5X,28HSHOULD BE BETWE
       AND 100)

22    FORMAT (21H0INPUT VALUE GA1TU IS,E15.8,5X,27HSHOULD BE BETWEE
      AND 18)

23    FORMAT (22H0INPUT VALUE XMA1TU IS,E15.8,5X,16HSHOULD BE 1 OR

24    FORMAT (19H0XL1TUI IS NEGATIVE,E15.8)

25    FORMAT (22H0INPUT VALUE XN2TSE IS,E15.8,5X,16HSHOULD BE 1 OR

26    FORMAT (19H0F2TUHO IS NEGATIVE,E15.8)

27    FORMAT (1H0,30X,36HTERMINAL TEMP DIFF LESS THAN 5 DEG F)

28    FORMAT (36H0DIAMETER OF TUBE SHEET IS TOO LARGE)

39    FORMAT (14H1OUTPUT VALUES,//,38H0TEMPERATURE SATURATED
      LIQUID  (DEG F),F22.4)

40    FORMAT (26H0ORDERED TUBE LENGTH  (FT),4X,10F9.2)

41    FORMAT (27H0TUBE SURFACE AREA  (SQ FT),3X,10F9.0)

42    FORMAT (28H0EFFECTIVE TUBE LENGTH  (FT),2X,10F9.2)

43    FORMAT (16H0NUMBER OF TUBES,14X,10F9.0)

44    FORMAT (26H0TUBE SHEET DIAMETER  (FT),4X,10F9.2)

45    FORMAT (25H0TUBE SHEET AREA  (SQ FT),5X,10F9.2)

46    FORMAT (31H0OVERALL CONDENSER LENGTH  (FT),F8.2,9F9.2)
```

```
47        FORMAT (20HOCIRCULATING WATER REQD  (GPM),10F9.0)
48        FORMAT (22HOCIRC WATER OUTLET TEMP  (DEG F),F7.2,9F9.2)
49        FORMAT (28HOTERMINAL TEMP DIFF  (DEG F),2X,10F9.2)
50        FORMAT (30HOCIRC WATER TEMP RISE  (DEG F),10F9.2)
          CALL CAMRAV (35)

      READ INPUT

      SEE NEXT STATEMENT                                        QTITLE

       ***READ(5,1)QTITLE
       ***READ(5,3)XMA1TU,GA1TU,D5TU,F2TCLN,XN2TSE,XL1TUI
       ***READ(5,3)F2TUHO,XN2PS,R9SF5,HT1SR,P2BDES,V1WTU
      SEE NEXT STATEMENT                                        QL1TUO

       ***READ(5,3)TE1INJ,XL1TT,D5COND,XL1TUO,QL1TUO

      PRINT INPUT

       ***WRITE(6,2)QTITLE
          I=XMA1TU
       ***WRITE(6,5)QMA(I),GA1TU,D5TU
       ***WRITE(6,6)F2TCLN,XN2TSE,XL1TUI
       ***WRITE(6,7)F2TUHO,XN2PS,R9SF5
       ***WRITE(6,8)HT1SR,P2BDES,V1WTU
       ***WRITE(6,9)TE1INJ,XL1TT,D5COND
       ***WRITE(6,10)XL1TUO,QL1TUO
      SEE NEXT STATEMENT                                        MPTS
                 I
          I MPTS =0                               I
          I P2BDES =P2BDES*.49115                 I
```

```
                    I


        COMPUTE TEMPERATURE OF SATURATED LIQUID



                    I
                    I
                  . *   * .
              . *    IF      * .
            *    (P2BDES-.2)     *
          I * .                 . * I
          I     * .         . *     I
          I         * . *           I
        - I         0 I           + I
       ----
       I 105 I     I 106 I     I 106 I
       -- -

105       ***WRITE(6,20)P2BDES

             STOP
                    I
                    I
106               . *   * .
              . *    IF      * .
            *   (P2BDES-450.)    *
          I * .                 . * I
          I     * .         . *     I
          I         * . *           I
        - I         0 I           + I
       ----
       I 109 I     I 105 I     I 105 I
       -- -

                    I

109          I TE1SAT =QAA(1)                       I

                    I

        SEE NEXT STATEMENT                                      QT1

                    I

             I QT1   =1.                            I

                    I

        SEE NEXT STATEMENT                                      QT2

                    I

             I QT2   =ALOG(10.*P2BDES)              I
```

```
                        I
                        I
                  +            +
                 + DO           +
     ++++++++++    110           +
     +          +   K=2,9       +
     +            +            +
     +                  I
     +                  I
     +
     +        I QT1   =QT1*QT2                          I
     +
     +                  I
     +
110  ++++++++I TE1SAT =TE1SAT+QAA(K)*QT1                I

                        I

          ***WRITE (6,39)TE1SAT



          COMPUTE CIRC WATER CORRECTION FACTOR



                        I
                        I
                     , *   * .
                  . *   IF    * .
                *  (TE1INJ-30.)    *
              I * .              . * I
              I    * .        . *    I
              I       *  .  *        I
            - I       0  I         + I
           --*+
           I 115 I    I 116 I    I 116 I
           -- +

115       ***WRITE(6,21)TE1INJ

              STOP
                        I
                        I
116                  . *   * .
                  . *   IF    * .
                *  (TE1INJ-100.)   *
              I * .              . * I
              I    * .        . *    I
              I       *  .  *        I
            - I       0  I         + I
           --+-
           I 120 I    I 120 I    I 115 I
           -- -

                        I
```

```
120          I K     =TE1INJ/5.-5.                                    I
             I QT1   =(K+5)*5                                         I
             I F2TEC=QCF(K)+(QCF(K+1)-QCF(K))                         I
             I          *(TE1INJ-QT1)*.2                              I

                        I


       FIND WALL THICKNESS


                        I
                        I
                    . *   * .
                . *    IF     * .
              *    (GA1TU-12.)    *
            I * .               . * I
            I     * .       . *     I
            I         * . *         I
          - I         0 I         + I
         ----
         I 121 I    I 122 I    I 122 I
         --*-

121      ***WR!TE(6,22)GA1TU

             STOP
                        I
                        I
122                 . *   * .
                . *    IF     * .
              *    (GA1TU-18.)    *
            I * .               . * I
            I     * .       . *     I
            I         * . *         I
          - I         0 I         + I
         ----
         I 125 I    I 125 I    I 121 I
         -- -

                        I

125          I K     =GA1TU-11.                                       I
             I TH1TU=QTH(K)                                           I

                        I


       FIND MATFRIAL FACTOR
```

```
                       I
                       I
                   . *   * .
               . *    IF     * .
             *   (XMA1TU-1.)     *
           I * .               . * I
           I     * .       . *     I
           I         * . *         I
         - I         0 I         + I
        ----
        I 126 I     I 128 I     I 127 I
        --+-

126        ***WRITE(6,23)XMA1TU

               STOP
                       I
                       I
127                . *   * .
               . *    IF     * .
             *   (XMA1TU-2.)     *
           I * .               . * I
           I     * .       . *     I
           I         * . *         I
         - I         0 I         + I
        --*-
        I 126 I     I 128 I     I 126 I
        --*-

                       I

128            I L    =XMA1TU                    I
               I F2MG =QCU(K,L)                  I

                       I
```

COMPUTE INEFFECTIVE TUBE LENGTH PER END

```
                       I
                       I
                   . *   * .
               . *    IF     * .
             *    (XL1TUI)       *
           I * .               . * I
           I     * .       . *     I
           I         * . *         I
         - I         0 I         + I
        ----
        I 140 I     I 145 I     I 150 I
        ----

140        ***WRITE(6,24)XL1TUI
```

```
            STOP
                       I
                       I
145                 . *   * .
               . *    IF      * .
             *    (XN2TSE-1.)     *
           I * .                . * I
           I     * .        . *     I
           I         * . *          I
         - I           0 I        + I
        ----
        I 146 I     I 147 I     I 148 I
        --*-

146        ***WRITE(6,25)XN2TSE

            STOP
                       I

147         I XL1TUI =1.0625                                  I

                       I
                       I
                     --
                   I 150 I
                     --


                       I
                       I
148                 . *   * .
               . *    IF      * .
             *    (XN2TSE-2.)     *
           I * .                . * I
           I     * .        . *     I
           I         * . *          I
         - I           0 I        + I
        ----
        I 146 I     I 149 I     I 146 I
        -- -

                       I

149         I XL1TUI =6.25                                    I

                       I


          COMPUTE TUBE HOLE SPACE FACTOR


                       I
                       I
```

```
150                    . *     * .
                   . *     IF      * .
                 *     (F2TUHO)        *
               I * .                 . * I
               I     * .         . *     I
               I         * . *           I
             - I         0 I           + I
            ----
            I 151 I     I 152 I     I 160 I
            --*+


151        ***WRITE(6,26)F2TUHO

              STOP
                         I
                         I
152                    . *     * .
                   . *     IF      * .
                 *   (P2BDES-1.25)     *
               I * .                 . * I
               I     * .         . *     I
               I         * . *           I
             - I         0 I           + I
            --+-
            I 153 I     I 153 I     I 154 I
            -- -

                         I

153           I F2TUHO =.22                             I

                         I
                         I
                       --
                       I 160 I
                       --



                         I

154           I F2TUHO =.24                             I

                         I



         COMPUTE HEAT TRANSFER COEFFICIENT



                         I
                         I
160                    . *     * .
                   . *     IF      * .
                 *    (D5TU-.875)      *
               I * .                 . * I
```

```
     I      * .         . *      I
     I         * . *             I
   - I         0 I             + I
  --*-
  I 162 I      I 161 I      I 161 I
  -- -

                 I

161        I C1HEAT =263.                              I

                 I
                 I
              --
              I 180 I
              --


                 I

162        I C1HEAT =270.                              I

                 I


     COMPUTE GPM / TUBE / 1 FPS VELOCITY


                 I

180        I QT2   =D5TU-2.*TH1TU                      I
           I QT1   =QT2*QT2                            I
           I R1V6TU =2.4479922*QT1                     I

                 I


     COMPUTE TUBE CONSTANT


                 I

           I C9TU =.10694444*D5TU/QT1                  I

                 I

     SEE NEXT STATEMENT

                 I

           I QT3   =C1HEAT*C9TU*F2MG*F2TEC*F2TCLN      I
```

```
         I         /500.                              I
                    I

      IF CONTRACT DESIGN   FIND ORDERED TUBE LENGTH

                    I
                    I
                . *   * .
            . *    IF     * .
          *      (XL1TT)     *
        I * .               . * I
        I     * .       . *     I
        I         * . *         I
      - I         0 I         + I
     ----
     I 200 I     I 200 I     I 190 I
     ---+

                    I
190          I XL1TUO =XL1TT-7.5                      I
                    I

      COMPUTE EFFECTIVE TUBE LENGTH

                    I
200          I XL1TUE =(XL1TUO-XL1TUI/6.)*XN2PS       I
                    I

      COMPUTE CIRC. WATER OUTLET TEMP.

                    I
             I TE1O =TE1SAT-(TE1SAT-TE1INJ)/EXP(XL1TUE
             I          *QT3/SQRT(V1WTU))             I
                    I
```

```
COMPUTE CIRC. WATER TEMP. RISE


               I
     I TE1R =TE1O-TE1INJ                      I
               I


COMPUTE TERMINAL TEMP. DIFF.


               I
     I TE1TD=TE1SAT-TE1O                      I
               I


STOP PROGRAM IF TERMINAL TEMP. DIFF. LESS THAN 5 DEGREE


               I
               I
            . *   * .
         . *    IF     * .
       *   (TE1TD.GE.5.)     *

ON I                          I OFF
   I                          I
-----**
I GOTOI02                 I       I
-----**


  ***WRITE(6,27)
               I
     I XL1TT=-1.                              I
     I R9SW2=0.                               I
     I S2TU =0.                               I
     I XN2TUT =0.                             I
     I A1TUSH =0.                             I
     I D5TUSH =0.                             I
```

```
I XL1CON =0.                                     I
I W2COND =0.                                     I
I VL1HW=0.                                       I

          I
          I
        --
        I 300 I
        --
```

COMPUTE CIRC. WATER REQT

```
          I
202    I R9SW2=R9SF5*HT1SR/(500.*TE1R)           I
          I
```

COMPUTE TUBE SURFACE

```
          I
I S2TU =XL1TUE*R9SW2*C9TU/V1WTU                  I
          I
```

COMPUTE NUMBER OF TUBES

```
          I
I L      =(R9SW2*XN2PS/(R1V6TU*V1WTU))           I
I         +1.                                    I
I XN2TUT =L                                      I
          I
```

COMPUTE TUBE SHEET AREA

```
            I

I QT1   =D5TU*D5TU*XN2TUT/(F2TUHO          I
I          *144.)                          I
I A1TUSH =.7854*QT1                        I

            I
```

COMPUTE TUBE SHEET DIAMETER

```
            I

I D5T'JSH =SQRT(QT1)                       I

            I
```

COMPUTE OVERALL LENGTH

```
              I
              I
           . *   * .
       . *    IF      * .
     *   (D5TUSH-7.5)     *
   I * .              . * I
   I     * .      . *     I
   I         * . *        I
 - I          0 I       + I
---*
I 215 I     I 215 I     I 210 I
--+-

              I

210        I XL1CON =XL1TUO+7.5                I

              I
              I
           --
           I 220 I
           --
```

```
                    I
215        I XL1CON =XL1TUO+D5TUSH                  I
                    I
                    I
                    I
220              . *    * .
              . *    IF     * .
            *     (XL1TT)       *
          I * .               . * I
          I     * .       . *     I
          I         * . *         I
        - I         0 I         + I
        --*-
        I 350 I    I 300 I     I 221 I
        -- -

                    I
                    I
221              . *    * .
              . *    IF     * .
            * (XL1CON-XL1TT)    *
          I * .               . * I
          I     * .       . *     I
          I         * . *         I
        - I         0 I         + I
        ----
        I 222 I    I 222 I     I 350 I
        ----

                    I
222        I MPTS =0                                I
                    I


      STORE OUTPUT VALUES


                    I
300        I MPTS =MPTS+1                           I
                    I
      SEE NEXT STATEMENT                                        QP1
                    I
           I QP1(MPTS) =XL1TUO                      I
                    I
      SEE NEXT STATEMENT                                        QP2
```

```
              I
    I QP2(MPTS) =S2TU                          I
              I
SEE NEXT STATEMENT                                             QP3
              I
    I QP3(MPTS) =XL1TUE                        I
              I
SEE NEXT STATEMENT                                             QP4
              I
    I QP4(MPTS) =XN2TUT                        I
              I
SEE NEXT STATEMENT                                             QP5
              I
    I QP5(MPTS) =D5TUSH                        I
              I
SEE NEXT STATEMENT                                             QP6
              I
    I QP6(MPTS) =A1TUSH                        I
              I
SEE NEXT STATEMENT                                             QP7
              I
    I QP7(MPTS) =XL1CON                        I
              I
SEE NEXT STATEMENT                                             QP8
              I
    I QP8(MPTS) =R9SW2                         I
              I
SEE NEXT STATEMENT                                             QP9
              I
    I QP9(MPTS) =TE10                          I
```

```
                      I
       SEE NEXT STATEMENT                                          QP10
                      I
           I QP10(MPTS) =TE1TD                   I
                      I
       SEE NEXT STATEMENT                                          QP11
                      I
           I QP11(MPTS) =TE1R                    I
                      I
                      I
                      I
                  . *   * .
              . *    IF     * .
            *     (MPTS-10)     *
          I * .                . * I
          I     * .        . *     I
          I         * . *          I
        - I         0 I          + I
        ----
        I 309 I     I 350 I     I 350 I
        --**

                      I
                      I
309               . *   * .
              . *    IF     * .
            *      (XL1TT)      *
          I * .                . * I
          I     * .        . *     I
          I         * . *          I
        - I         0 I          + I
        --*-
        I 350 I     I 310 I     I 320 I
        -- -

                      I
310        I XL1TUO =XL1TUO+.5                   I

                      I
                      I
                      I
                  . *   * .
              . *    IF     * .
            * (XL1TUO-QL1TUO)   *
          I * .                . * I
          I     * .        . *     I
          I         * . *          I
        - I         0 I          + I
        --*-
        I 200 I     I 200 I     I 350 I
        ----
```

```
                          I
320                   . *   * .
                  . *    IF      * .
                *  (XL1CON-XL1TT)    *
              I * .                . * I
              I     * .        . *     I
              I         * . *          I
            - I         0 I          + I
            ----
            I 321 I     I 350 I     I 350 I
            ----

                          I
321               I XL1TUO =XL1TUO+.5                          I
                          I
                          I
                        --
                        I 200 I
                        --
```

PRINT OUTPUT

```
350         ***WRITE(6,40)(QP1(K),K=1,MPTS)
            ***WRITE(6,41)(QP2(K),K=1,MPTS)
            ***WRITE(6,42)(QP3(K),K=1,MPTS)
            ***WRITE(6,43)(QP4(K),K=1,MPTS)
            ***WRITE(6,44)(QP5(K),K=1,MPTS)
            ***WRITE(6,45)(QP6(K),K=1,MPTS)
            ***WRITE(6,46)(QP7(K),K=1,MPTS)
            ***WRITE(6,47)(QP8(K),K=1,MPTS)
            ***WRITE(6,48)(QP9(K),K=1,MPTS)
            ***WRITE(6,49)(QP10(K),K=1,MPTS)
            ***WRITE(6,50)(QP11(K),K=1,MPTS)
                          I
                          I
                      . *   * .
                  . *    IF      * .
                *      (XL1TT)       *
```

```
 I  *  .              .  *  I
 I      *  .      .  *      I
 I          *  .  *         I
- I            0 I        +  I
-- -
I 1000I     I 400 I     I 500 I
----



      PLOT DIAMETER VERSUS LENGTH


                              I

400           I QT1   =QP5(1)                      I
              I QT2   =QP5(1)                      I

                              I

      SEE NEXT STATEMENT                                         QLL

                              I

              I QLL   =QP7(1)                      I

                              I

      SEE NEXT STATEMENT                                         QLR

                              I

              I QLR   =QP7(1)                      I

                              I
                              I
                   +              +
                  + DO              +
     ++++++++++     410               +
     +            +  K=2,MPTS       +
     +             +              +
     +                        I
     +                        I
     +
     +        I QT1   =AMIN1(QT1,QP5(K))           I
     +        I QT2   =AMAX1(QT2,QP5(K))           I
     +        I QLL   =AMIN1(QLL,QP7(K))           I
     +
     +                        I
     +
410  ++++++++I QLR   =AMAX1(QLR,QP7(K))           I

                              I

      SEE NEXT STATEMENT                                         QDX
```

```
          SEE NEXT STATEMENT                                              MERR

              CALL DXDYV (1,QLL,QLR,QDX,N,I,NX,20.,MERR)

          SEE NEXT STATEMENT                                              QDY

              CALL DXDYV (2,QT1,QT2,QDY,M,J,NY,20.,MERR)

              CALL GRID1V (3,QLL,QLR,QT1,QT2,QDX,QDY,N,M,-I,-J,NX,NY)

              CALL PRINTV (-11,11HLENGTH  FT.,492,4)

              CALL PRINTV (72,QTITLE,244,1012)

              CALL APRNTV (0,-14,-13,13HDIAMETER  FT.,4,584)

          SEE NEXT STATEMENT                                              MX1

                        I

              I MX1  =NXV(QP7(1))                     I

                        I

          SEE NEXT STATEMENT                                              MY1

                        I

              I MY1  =NYV(QP5(1))                     I

                        I
                        I
             +             +
            + DO            +
++++++++++   420             +
+           +  K=2,MPTS     +
+            +             +
+                       I
+
+         SEE NEXT STATEMENT                                              MX2
+
+                       I
+
+             I MX2  =NXV(QP7(K))                     I
+
+                       I
+
+         SEE NEXT STATEMENT                                              MY2
+
+                       I
+
+             I MY2  =NYV(QP5(K))                     I
+
+                       I
+
+             CALL LINEV (MX1,MY1,MX2,MY2)
+                       I
```

```
    +
    +        I MX1   =MX2                                      I
    +
    +                  I
    +
420 ++++++++I MY1   =MY2                                       I

                   I
                   I
                 --
                 I 1000I
                 --
```

CHECK CONDENSER WIDTH

```
                   I
                   I
500              . *    * .
              . *     IF      * .
            * (D5COND-QP5(1))    *
          I .* .               . * I
          I     * .         . *    I
          I         * . *          I
        - I         0 I          + I
       ----
       I 501 I     I 510 I     I 510 I
       -- *

501       ***WRITE(6,28)
                   I
                 --
                 I 1000I
                 --
```

PLOT HEAT LOAD VERSUS ABSOLUTE PRESSURE

```
                   I

510         I QT1   =R9SF5*HT1SR                               I
            I QT2   =QT1/50.                                   I
            I QLL   =QT1*.1                                    I
```

```
        I QT1  =QLL+QT1                        I

                   I

        CALL GRID1V (3,QLL,QT1,10.,0.,QT2,.2,5,5,-10,-5,-6,2)

        CALL PRINTV (72,QTITLE,244,1020)

        CALL PRINTV (-17,17HHEAT LOAD  BTU/HR,460,4)

        CALL APRNTV (0,-14,-24,24HABSOLUTE PRESSURE  IN HG,4,656)

        CALL PRINTV (-19,19HCIRC WATER VELOCITY,816,1006)

        CALL PRINTV (-17,17HIN TUBES (FT/SEC),824,990)

     SEE NEXT STATEMENT                                          QTC

                   I

        I QTC  =647.27                         I

                   I

     SEE NEXT STATEMENT                                          QPC

                   I

        I QPC  =6527.90844                     I
        I MPTS =11                             I
        I MX1  =V1WTU                          I
        I V1WTU=MX1                            I

                   I

520     I QT1  =EXP(QT3*XL1TUE/SQRT(V1WTU))    I
        I R9SW2=XN2TUT*R1V6TU*V1WTU/XN2PS      I
        I QT2  =0.                             I

                   I
                   I
          +                +
          + DO              +
+++++++++++   550            +
+         +   I=1,MPTS      +
+          +               +
+                  I
+                  I
+
+       I QT2  =QT2+QLL                        I
+       I QP1(I) =QT2                          I
+       I TE10 =TE1INJ+QT2/(500.*R9SW2)        I
+       I TE1SAT =(QT1*TE10-TE1INJ)/(QT1       I
+       I         -1.)                         I
+
+                  I
+                  I
+                  I
+             . *    * .
+          . *    IF    * .
```

```
    +       *  (TE1SAT-200.)     *
    +     I * .               . * I
    +     I      * .       . *    I
    +     I          * . *        I
    +   - I          0 I        + I
    + -- -
    + I 530 I      I 531 I     I 531 I
    + --*+
    +
    +                  I
    +
530 +        I L     =1                           I
    +
    +                  I
    +                  I
    +                --
    +                I 535 I
    +                -*
    +
    +
    +
    +
    +                  I
    +
531 +        I L     =2                           I
    +
    +                  I
    +
535 +        I TE1SAT =(TE1SAT-32.)*5./9.+273.16      I
    +        I QDX   =QTC-TE1SAT                      I
    +        I QDY   =QDX/TE1SAT*(((QPFT(3,L)+QPFT(5,L)
    +        I          *QDX)*QDX*QDX+                I
    +        I          QPFT(2,L))*QDX+QPFT(1,L))/(1.+QPFT(4,L)*QDX)
    +        I P2BDES =QPC/10.**QDY                   I
    +
    +                  I
    +
550 ++++++++I QP2(I) =P2BDES                          I
             I MX1   =NXV(QP1(1))                     I
             I MY1   =NYV(QP2(1))                     I

                       I
                       I
             +              +
            + DO              +
    +++++++++     560           +
    +       +  K=2,MPTS       +
    +         +              +
    +                  I
    +                  I
    +
    +        I MX2   =NXV(QP1(K))                     I
    +
    +                  I
    +                  I
    +                  I
    +            . *     * .
    +         . *    IF      * .
    +       *   (QP2(K)-10.)     *
    +     I * .               . * I
    +     I      * .       . *    I
```

```
      +    I           * . *          I
      +  - I           0 I          + I
      +
      + I 555 I     I 555 I     I 561 I
      +
      +
      +                  I
      +
 555  +        I MY2   =NYV(QP2(K))                    I
      +
      +                  I
      +
      +        CALL LINEV (MX1,MY1,MX2,MY2)
      +                  I
      +
      +        I MX1   =MX2                            I
      +
      +                  I
      +
 560  ++++++++I MY1   =MY2                             I

                         I

 561           I MY1   =MY1+3                          I

                         I

               CALL LABLV (V1WTU,MX1,MY1,3,1,3)
                         I

               I MX1   =MX1+24                         I

                         I

               CALL PRINTV (-4,4H FPS,MX1,MY1)
                         I

               I V1WTU=V1WTU-1.                        I

                         I
                         I
                         I
                     . *   * .
                  . *   IF    * .
                *   (V1WTU-3.)   *
              I * .            . * I
              I    * .      . *    I
              I       * . *        I
            - I       0 I        + I

          I 1000I    I 520 I    I 520 I

 1000          CALL FVEFN (1,16)

               CALL MZEFN (1,1)

               STOP
END
*       *
```

B. Program Listing

```
C    I.  IDENTIFICATION
C        A.  TITLE - STEAM CONDENSER DESIGN
C            1.  FORTRAN IV DECKNAME - COND
C            2.  REVISION - A - ORIGINAL ISSUE
C        B.  ABSTRACT - THIS PROGRAM CALCULATES ALL THE NECESSARY
C        INFORMATION REQUIRED FOR THE SELECTION OF MAIN OR AUXILIARY
C        STEAM CONDENSERS TO EITHER PRELIMINARY OR CONTRACT DESIGN
C        REQUIREMENTS.
C            FOR PRELIMINARY DESIGN A GRAPH IS ALSO PROVIDED WHICH
C        RELATES CONDENSER OVERALL LENGTH WITH TUBE SHEET DIAMETER
C        FOR A SPECIFIED SET OF DESIGN CONDITIONS.  FOR CONTRACT
C        DESIGN A GRAPH RELATING CONDENSER ABSOLUTE PRESSURE AND
C        INCREMENTS OF HEAT REJECTION AT INTEGER CIRCULATING WATER
C        VELOCITIES IS ALSO PROVIDED FOR ANALYSIS OF PART LOAD
C        PERFORMANCE.
C        C.  INPUT / CALCULATED ITEMS / OUTPUT
C            1.  INPUT
C            TUBE MATERIAL                                         XMA1TU
C            TUBE GAGE                                             GA1TU
C            TUBE OUTSIDE DIAMETER (INCHES)                        D5TU
C            NUMBER OF PASSES                                      XN2PS
C            CLEANLINESS FACTOR                                    F2TCLN
C            NUMBER OF TUBE SHEETS PER END                         XN2TSE
C            INEFFECTIVE TUBE LENGTH PER END (INCHES)              XL1TUI
C            TUBE HOLE SPACE FACTOR                                F2TUHO
C            STEAM FLOW TO CONDENSER (LB/HR)                       R9SF5
C            HEAT REJECTED PER POUND OF STEAM (BTU/LB)             HT1SR
C            DESIGN BACK PRESSURE (INCHES - HG)                    P2BDES
C            INJECTION WATER TEMPERATURE (DEG F)                   TE1INJ
C            OVERALL CONDENSER LENGTH (FT)                         XL1TT
C            DESIRED DIAMETER OF TUBE SHEET (FT)                   D5COND
C            CIRCULATING WATER VELOCITY IN TUBES (FT/SEC)          V1WTU
C            ORDERED TUBE LENGTH  SHORTEST                         XL1TUO
C            ORDERED TUBF LENGTH  LONGEST                          QL1TUO
C            2.  INTERNAL VALUES
C            TUBE WALL THICKNESS                                   TH1TU
C            BASIC HEAT TRANSFER COEFFICIENT                       C1HEAT
C            TUBE CONSTANT                                         C9TU
C            MATERIAL AND GAGE FACTOR                              F2MG
C            TEMPERATURE CORRECTION FACTOR                         F2TEC
C            GPM / 1 FPS / TUBE                                    R1V6TU
C            3.  OUTPUT
C            TEMPERATURE SATURATED LIQUID                          TE1SAT
C            ORDERER TUBE LENGTH                                   XL1TUO
C            TUBE SURFACE AREA                                     S2TU
C            EFFECTIVE TUBE LENGTH                                 XL1TUE
C            NUMBER OF TUBES                                       XN2TUT
C            TUBE SHEET DIAMETER                                   D5TUSH
C            TUBE SHEET AREA                                       A1TUSH
C            OVERALL CONDENSER LENGTH                              XL1CON
C            CIRCULATING WATER REQUIRED (GPM)                      R9SW2
C            CIRCULATING WATER OUTLET TEMP.                        TE1O
C            TERMINAL TEMPERATURE DIFF.                            TE1TD
C            CIRCULATING WATER TEMPERATURE RISE                    TE1R
C        D.  AUTHOR/DATE
C            MAXINE BOTTING      DENIS KELLY      DECEMBER 1965
C        E.  ORGANIZATION
C            COMPUTER-AIDED SHIP DESIGN DIVISION, CODE 850,
C            DAVID TAYLOR MODEL BASIN
C        F.  COMPUTER/SOURCE LANGUAGE
```

```
C          - IBM 7090     FORTRAN IV
C        G. REFERENCE TO DOCUMENTATION
C           DTMB REPORT 2255 OF JULY 1966
C        H. SECURITY CLASSIFIED
C           UNCLASSIFIED
C        I. ESTIMATED RUNNING TIME
C           1 1/2 MINUTES
      COMMON XMA1TU,GA1TU,D5TU,F2TCLN,XN2TSE,XL1TUI
      COMMON F2TUHO,XN2PS,R9SF5,HT1SR,P2BDES,V1WTU
      COMMON TE1INJ,XL1TT,D5COND,XL1TUO,QL1TUO
      COMMON S2TU,XL1TUE,XN2TUT,D5TUSH,A1TUSH,XL1CON
      COMMON R9SW2,TE1O,TE1TD,TE1R,W2COND,VL1HW
      DIMENSION QTITLE(12)
      DIMENSION QMA(2)
      DIMENSION QAA(9),QCU(7,2),QCF(15),QTH(7)
      DIMENSION QPFT(5,2)
      DIMENSION QP1(11),QP2(11),QP3(10),QP4(10),QP5(10),QP6(10),QP7(10),
     1QP8(10),QP9(10),QP10(10),QP11(10)   456 BYTES
C     SEE DATA STATEMENT                                              QAA
C     SEE DATA STATEMENT .                                            QCU
C     SEE DATA STATEMENT                                              QCF
C     SEE DATA STATEMENT                                              QTH
C     SEE DATA STATEMENT                                              QPFT
      DATA QAA/35.15789,24.592588,2.1182069,-.3414474,.15741642,
     1-.3132958E-1,.38658282E-2,-.24901784E-3,.68401559E-5/
      DATA QCU/.46,.55,.64,.71,.76,.80,.83,.55,.64,.72,.79,.84,
     1.87,.90/
      DATA QCF/.65,.7,.75,.798,.843,.886,.926,.963,1.,1.025,
     11.045,1.061,1.076,1.09,1.1/
      DATA QTH/.109,.095,.083,.072,.065,.058,.049/
      DATA QPFT/3.2437814,.00586826,1.1702379E-8,.0021878462,0.,
     13.346313,.0414113,7.515484E-9,.013794481,6.56444E-11/
      DATA QMA/6H 70-30,6H 90-10/
    1 FORMAT (12A6)
    2 FORMAT (1H1,//,24X,12A6,//,13H0INPUT VALUES,//)
    3 FORMAT (6E12.6)
    5 FORMAT (14H0TUBE MATERIAL,40X,A6    /10H TUBE GAGE,30X,F20.0,/20H
     1TUBE DIAMETER   (IN),20X,F20.4)
    6 FORMAT (19H CLEANLINESS FACTOR,21X,F20.4,/30H NUMBER OF TUBE SHEET
     1S PER END,10X,F20.0,/38H INEFFECTIVE TUBE LENGTH PER END  (IN),F22
     2.4)
    7 FORMAT (23H TUBE HOLE SPACE FACTOR,17X,F20.4,/17H NUMBER OF PASSES
     1,23X,F20.0,/28H STEAM TO CONDENSER  (LB/HR),F32.0)
    8 FORMAT (43H HEAT REJECTED PER POUND OF STEAM  (BTU/LB),F17.2,/30H
     1DESIGN BACK PRESSURE  (IN HG),F30.2 ,/39H CIRC WATER VELOCITY IN T
     2UBES  (FT/SEC),F21.2)
    9 FORMAT (37H INJECTION WATER TEMPERATURE  (DEG F),F23.2,/39H DESIRE
     1D OVERALL CONDENSER LENGTH  (FT),F21.2,/37H DESIRED DIAMETER OF TU
     2BE SHEET  (FT),F23.2)
   10 FORMAT (36H ORDERED TUBE LENGTH  SHORTEST  (FT),F24.2,/35H ORDERED
     1 TUBE LENGTH  LONGEST  (FT),F25.2)
   15 FORMAT (6E20.8)
   20 FORMAT (22H0INPUT VALUE P2BDES IS,E15.8,5X,28HSHOULD BE BETWEEN .2
     1 AND 450)
   21 FORMAT (22H0INPUT VALUE TE1INJ IS,E15.8,5X,28HSHOULD BE BETWEEN 30
     1 AND 100)
   22 FORMAT (21H0INPUT VALUE GA1TU IS,E15.8,5X,27HSHOULD BE BETWEEN 12
     1AND 18)
   23 FORMAT (22H0INPUT VALUE XMA1TU IS,E15.8,5X,16HSHOULD BE 1 OR 2)
   24 FORMAT (19H0XL1TUI IS NEGATIVE,E15.8)
```

```
 25 FORMAT (22H0INPUT VALUE XN2TSE IS,E15.8,5X,16HSHOULD BE 1 OR 2)
 26 FORMAT (19H0F2TUHO IS NEGATIVE,E15.8)
 27 FORMAT (1H0,30X,36HTERMINAL TEMP DIFF LESS THAN 5 DEG F)
 28 FORMAT (36H0DIAMETER OF TUBE SHEET IS TOO LARGE)
 39 FORMAT (14H1OUTPUT VALUES,//38H0TEMPERATURE SATURATED LIQUID  (DEG
   1 F),F22.4)
 40 FORMAT (26H0ORDERED TUBE LENGTH  (FT),4X,10F9.2)
 41 FORMAT (27H0TUBE SURFACE AREA  (SQ FT),3X,10F9.0)
 42 FORMAT (28H0EFFECTIVE TUBE LENGTH  (FT),2X,10F9.2)
 43 FORMAT (16H0NUMBER OF TUBES,14X,10F9.0)
 44 FORMAT (26H0TUBE SHEET DIAMETER  (FT),4X,10F9.2)
 45 FORMAT (25H0TUBE SHEET AREA  (SQ FT),5X,10F9.2)
 46 FORMAT (31H0OVERALL CONDENSER LENGTH  (FT),F8.2,9F9.2)
 47 FORMAT (30H0CIRCULATING WATER REQD  (GPM),10F9.0)
 48 FORMAT (32H0CIRC WATER OUTLET TEMP  (DEG F),F7.2,9F9.2)
 49 FORMAT (28H0TERMINAL TEMP DIFF  (DEG F),2X,10F9.2)
 50 FORMAT (30H0CIRC WATER TEMP RISE  (DEG F),10F9.2)
    CALL CAMRAV (35)
C
C   READ INPUT
C
C   SEE NEXT STATEMENT                                             QTITLE
    READ(5,1)QTITLE
    READ(5,3)XMA1TU,GA1TU,D5TU,F2TCLN,XN2TSE,XL1TUI
    READ(5,3)F2TUHO,XN2PS,R9SF5,HT1SR,P2BDES,V1WTU
C   SEE NEXT STATEMENT                                             QL1TUO
    READ(5,3)TE1INJ,XL1TT,D5COND,XL1TUO,QL1TUO
C
C   PRINT INPUT
C
    WRITE(6,2)QTITLE
    I=XMA1TU
    WRITE(6,5)QMA(I),GA1TU,D5TU
    WRITE(6,6)F2TCLN,XN2TSE,XL1TUI
    WRITE(6,7)F2TUHO,XN2PS,R9SF5
    WRITE(6,8)HT1SR,P2BDES,V1WTU
    WRITE(6,9)TE1INJ,XL1TT,D5COND
    WRITE(6,10)XL1TUO,QL1TUO
C   SEE NEXT STATEMENT                                             MPTS
    MPTS=0
    P2BDES=P2BDES*.49115
C
C   COMPUTE TEMPERATURE OF SATURATED LIQUID
C
    IF(P2BDES-.2) 105,106,106
105 WRITE(6,20)P2BDES
    STOP
106 IF(P2BDES-450.) 109,105,105
109 TE1SAT=QAA(1)
C   SEE NEXT STATEMENT                                             QT1
    QT1=1.
C   SEE NEXT STATEMENT                                             QT2
    QT2=ALOG(10.*P2BDES)
    DO 110 K=2,9
    QT1=QT1*QT2
110 TE1SAT=TE1SAT+QAA(K)*QT1
    WRITE (6,39)TE1SAT
C
C   COMPUTE CIRC WATER CORRECTION FACTOR
C
```

```
      IF(TE1INJ-30.) 115,116,116
  115 WRITE(6,21)TE1INJ
      STOP
  116 IF(TE1INJ-100.) 120,120,115
  120 K=TE1INJ/5.-5.
      QT1=(K+5)*5
      F2TEC=QCF(K)+(QCF(K+1)-QCF(K))*(TE1INJ-QT1)*.2
C
C     FIND WALL THICKNESS
C
      IF(GA1TU-12.) 121,122,122
  121 WRITE(6,22)GA1TU
      STOP
  122 IF(GA1TU-18.) 125,125,121
  125 K=GA1TU-11.
      TH1TU=QTH(K)
C
C     FIND MATERIAL FACTOR
C
      IF(XMA1TU-1.) 126,128,127
  126 WRITE(6,23)XMA1TU
      STOP
  127 IF(XMA1TU-2.) 126,128,126
  128 L=XMA1TU
      F2MG=QCU(K,L)
C
C     COMPUTE INEFFECTIVE TUBE LENGTH PER END
C
      IF(XL1TUI) 140,145,150
  140 WRITE(6,24)XL1TUI
      STOP
  145 IF(XN2TSE-1.) 146,147,148
  146 WRITE(6,25)XN2TSE
      STOP
  147 XL1TUI=1.0625
      GO TO 150
  148 IF(XN2TSE-2.) 146,149,146
  149 XL1TUI=6.25
C
C     COMPUTE TUBE HOLE SPACE FACTOR
C
  150 IF(F2TUHO) 151,152,160
  151 WRITE(6,26)F2TUHO
      STOP
  152 IF(P2BDES-1.25) 153,153,154
  153 F2TUHO=.22
      GO TO 160
  154 F2TUHO=.24
C
C     COMPUTE HEAT TRANSFER COEFFICIENT
C
  160 IF(D5TU-.875) 162,161,161
  161 C1HEAT=263.
      GO TO 180
  162 C1HEAT=270.
C
C     COMPUTE GPM / TUBE / 1 FPS VELOCITY
C
  180 QT2=D5TU-2.*TH1TU
      QT1=QT2*QT2
```

```
      R1V6TU =2.4479922*QT1
C
C     COMPUTE TUBE CONSTANT
C
      C9TU=.10694444*D5TU/QT1
C     SEE NEXT STATEMENT                                                QT3
      QT3=C1HEAT*C9TU*F2MG*F2TEC*F2TCLN/500.
C
C     IF CONTRACT DESIGN   FIND ORDERED TUBE LENGTH
C
      IF(XL1TT) 200,200,190
  190 XL1TUO=XL1TT-7.5
C
C     COMPUTE EFFECTIVE TUBE LENGTH
C
  200 XL1TUE=(XL1TUO-XL1TUI/6.)*XN2PS
C
C     COMPUTE CIRC. WATER OUTLET TEMP.
C
      TE1O=TE1SAT-(TE1SAT-TE1INJ)/EXP(XL1TUE*QT3/SQRT(V1WTU))
C
C     COMPUTE CIRC. WATER TEMP. RISE
C
      TE1R=TE1O-TE1INJ
C
C     COMPUTE TERMINAL TEMP. DIFF.
C
      TE1TD=TE1SAT-TE1O
C
C     STOP PROGRAM IF TERMINAL TEMP. DIFF. LESS THAN 5 DEGREE
C
      IF(TE1TD.GE.5.) GO TO 202
      WRITE(6,27)
      XL1TT=-1.
      R9SW2=0.
      S2TU=0.
      XN2TUT=0.
      A1TUSH=0.
      D5TUSH=0.
      XL1CON=0.
      W2COND=0.
      VL1HW=0.
      GO TO 300
C
C     COMPUTE CIRC. WATER REQT
C
  202 R9SW2=R9SF5*HT1SR/(500.*TE1R)
C
C     COMPUTE TUBE SURFACE
C
      S2TU=XL1TUE*R9SW2*C9TU/V1WTU
C
C     COMPUTE NUMBER OF TUBES
C
      L=(R9SW2*XN2PS/(R1V6TU*V1WTU))+1.
      XN2TUT=L
C
C     COMPUTE TUBE SHEET AREA
C
      QT1=D5TU*D5TU*XN2TUT/(F2TUHO*144.)
```

```
      A1TUSH=.7854*QT1
C
C     COMPUTE TUBE SHEET DIAMETER
C
      D5TUSH=SQRT(QT1)
C
C     COMPUTE OVERALL LENGTH
C
      IF(D5TUSH-7.5) 215,215,210
  210 XL1CON=XL1TUO+7.5
      GO TO 220
  215 XL1CON=XL1TUO+D5TUSH
  220 IF(XL1TT) 350,300,221
  221 IF(XL1CON-XL1TT) 222,222,350
  222 MPTS=0
C
C     STORE OUTPUT VALUES
C
  300 MPTS=MPTS+1
C     SEE NEXT STATEMENT                                                 QP1
      QP1(MPTS)=XL1TUO
C     SEE NEXT STATEMENT                                                 QP2
      QP2(MPTS)=S2TU
C     SEE NEXT STATEMENT                                                 QP3
      QP3(MPTS)=XL1TUE
C     SEE NEXT STATEMENT                                                 QP4
      QP4(MPTS)=XN2TUT
C     SEE NEXT STATEMENT                                                 QP5
      QP5(MPTS)=D5TUSH
C     SEE NEXT STATEMENT                                                 QP6
      QP6(MPTS)=A1TUSH
C     SEE NEXT STATEMENT                                                 QP7
      QP7(MPTS)=XL1CON
C     SEE NEXT STATEMENT                                                 QP8
      QP8(MPTS)=R9SW2
C     SEE NEXT STATEMENT                                                 QP9
      QP9(MPTS)=TE1O
C     SEE NEXT STATEMENT                                                 QP10
      QP10(MPTS)=TE1TD
C     SEE NEXT STATEMENT                                                 QP11
      QP11(MPTS)=TE1R
      IF(MPTS-10) 309,350,350
  309 IF(XL1TT) 350,310,320
  310 XL1TUO=XL1TUO+.5
      IF(XL1TUO-QL1TUO) 200,200,350
  320 IF(XL1CON-XL1TT) 321,350,350
  321 XL1TUO=XL1TUO+.5
      GO TO 200
C
C     PRINT OUTPUT
C
  350 WRITE(6,40)(QP1(K),K=1,MPTS)
      WRITE(6,41)(QP2(K),K=1,MPTS)
      WRITE(6,42)(QP3(K),K=1,MPTS)
      WRITE(6,43)(QP4(K),K=1,MPTS)
      WRITE(6,44)(QP5(K),K=1,MPTS)
      WRITE(6,45)(QP6(K),K=1,MPTS)
      WRITE(6,46)(QP7(K),K=1,MPTS)
      WRITE(6,47)(QP8(K),K=1,MPTS)
      WRITE(6,48)(QP9(K),K=1,MPTS)
```

```
      WRITE(6,49)(QP10(K),K=1,MPTS)
      WRITE(6,50)(QP11(K),K=1,MPTS)
      IF(XL1TT) 1000,400,500
C
C     PLOT DIAMETER VERSUS LENGTH
C
  400 QT1=QP5(1)
      QT2=QP5(1)
C     SEE NEXT STATEMENT                                              QLL
      QLL=QP7(1)
C     SEE NEXT STATEMENT                                              QLR
      QLR=QP7(1)
      DO 410 K=2,MPTS
      QT1=AMIN1(QT1,QP5(K))
      QT2=AMAX1(QT2,QP5(K))
      QLL=AMIN1(QLL,QP7(K))
  410 QLR=AMAX1(QLR,QP7(K))
C     SEE NEXT STATEMENT                                              QDX
C     SEE NEXT STATEMENT                                              MERR
      CALL DXDYV (1,QLL,QLR,QDX,N,I,NX,20.,MERR)
C     SEE NEXT STATEMENT                                              QDY
      CALL DXDYV (2,QT1,QT2,QDY,M,J,NY,20.,MERR)
      CALL GRID1V (3,QLL,QLR,QT1,QT2,QDX,QDY,N,M,-I,-J,NX,NY)
      CALL PRINTV (-11,11HLENGTH  FT.,492,4)
      CALL PRINTV (72,QTITLE,244,1012)
      CALL APRNTV (0,-14,-13,13HDIAMETER  FT.,4,584)
C     SEE NEXT STATEMENT                                              MX1
      MX1=NXV(QP7(1))
C     SEE NEXT STATEMENT                                              MY1
      MY1=NYV(QP5(1))
      DO 420 K=2,MPTS
C     SEE NEXT STATEMENT                                              MX2
      MX2=NXV(QP7(K))
C     SEE NEXT STATEMENT                                              MY2
      MY2=NYV(QP5(K))
      CALL LINEV (MX1,MY1,MX2,MY2)
      MX1=MX2
  420 MY1=MY2
      GO TO 1000
C
C     CHECK CONDENSER WIDTH
C
  500 IF(D5COND-QP5(1)) 501,510,510
  501 WRITE(6,28)
      GO TO 1000
C
C     PLOT HEAT LOAD VERSUS ABSOLUTE PRESSURE
C
  510 QT1=R9SF5*HT1SR
      QT2=QT1/50.
      QLL=QT1*.1
      QT1=QLL+QT1
      CALL GRID1V (3,QLL,QT1,10.,0.,QT2,.2,5,5,-10,-5,-6,2)
      CALL PRINTV (72,QTITLE,244,1020)
      CALL PRINTV (-17,17HHEAT LOAD  BTU/HR,460,4)
      CALL APRNTV (0,-14,-24,24HABSOLUTE PRESSURE  IN HG,4,656)
      CALL PRINTV (-19,19HCIRC WATER VELOCITY,816,1006)
      CALL PRINTV (-17,17HIN TUBES (FT/SEC),824,990)
C     SEE NEXT STATEMENT                                              QTC
      QTC=647.27
```

```
C     SEE NEXT STATEMENT                                                QPC
      QPC=6527.90844
      MPTS=11
      MX1=V1WTU
      V1WTU=MX1
  520 QT1=EXP(QT3*XL1TUE/SQRT(V1WTU))
      R9SW2=XN2TUT*R1V6TU*V1WTU/XN2PS
      QT2=0.
      DO 550 I=1,MPTS
      QT2=QT2+QLL
      QP1(I)=QT2
      TE10=TE1INJ+QT2/(500.*R9SW2)
      TE1SAT=(QT1*TE10-TE1INJ)/(QT1-1.)
      IF(TE1SAT-200.) 530,531,531
  530 L=1
      GO TO 535
  531 L=2
  535 TE1SAT=(TE1SAT-32.)*5./9.+273.16
      QDX=QTC-TE1SAT
      QDY=QDX/TE1SAT*(((QPFT(3,L)+QPFT(5,L)*QDX)*QDX*QDX+
     1QPFT(2,L))*QDX+QPFT(1,L))/(1.+QPFT(4,L)*QDX)
      P2BDES=QPC/10.**QDY
  550 QP2(I)=P2BDES
      MX1=NXV(QP1(1))
      MY1=NYV(QP2(1))
      DO 560 K=2,MPTS
      MX2=NXV(QP1(K))
      IF(QP2(K)-10.) 555,555,561
  555 MY2=NYV(QP2(K))
      CALL LINEV (MX1,MY1,MX2,MY2)
      MX1=MX2
  560 MY1=MY2
  561 MY1=MY1+3
      CALL LABLV (V1WTU,MX1,MY1,3,1,3)
      MX1=MX1+24
      CALL PRINTV (-4,4H FPS,MX1,MY1)
      V1WTU=V1WTU-1.
      IF(V1WTU-3.) 1000,520,520
 1000 CALL FVEFN (1,16)
      CALL MZEFN(1,1)
      STOP
      END
```

C. Special Diagnostics

(1) Design Back Pressure

Input value P2BDES is _______

should be between .2 and 450

Program stopped.

(2) Injection water Temperature.

Input value TE1INJ is ________

Should be between 30 and 100

Program is stopped.

(3) Tube Gage

Input value GA1TU is ___________

Should be between 12 and 18

Program is stopped.

(4) Effective Tube Length

XL1TUE is negative

Program is stopped.

(5) Number of Tube Sheets per end

Input value XN2TSE is ___________

Should be 1 or 2

Program is stopped.

(6) Tube Material

Input value XMA1TU is __________

Should be 1 or 2

Program is stopped.

(7) Tube Hole Space Factor

F2TUHO is negative

Program is stopped.

VII. ACKNOWLEDGMENT

This program utilizes coefficients derived by Raymond W. Yaw, Code 6436, NAVSEC.

REFERENCES

1. Design Data Sheet DDS4601-1 of 15 October 1953 - Steam Condensers.

2. Military Specification MIL-C-15430G Condensers, Steam Surface, Naval Shipboard.

3. Share Programs C3-WH58-PA-3137 (Westinghouse Corporation Properties of Steam).

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13 ABSTRACT

This program calculates all the necessary information required for the selection of main or auxiliary steam condensers to either preliminary or contract design requirements.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Computer program Steam condenser design Preliminary design Contract design						

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