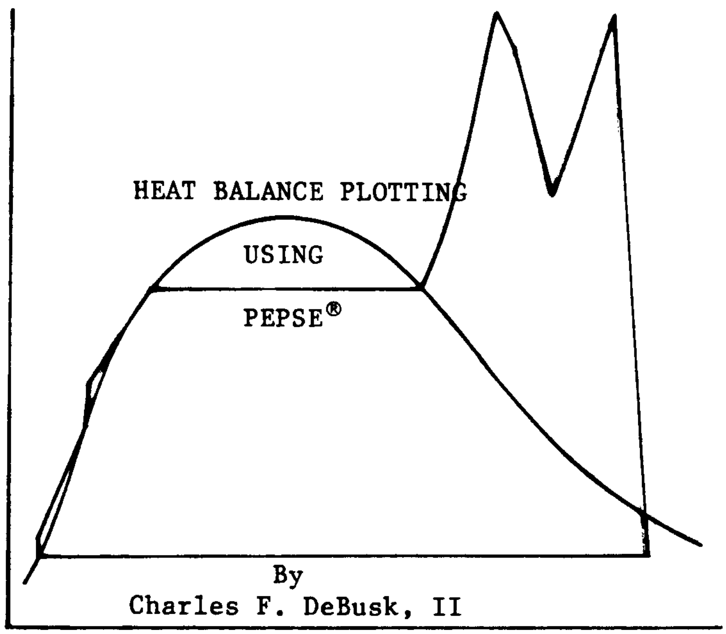

HEAT BALANCE PLOTTING USING PEPSE®

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HEAT BALANCE PLOTTING USING PEPSE

ABSTRACT

Drawing heat balance diagrams using FORTRAN and a CAL-COMP pen plotter has proven to be an effective method of illustrating the information generated from a PEPSE® code computer run. The heat balance diagram provides the engineer with a graphical picture of the steady-state thermodynamic and fluid flow data of a power plant cycle. Using another vendor's software code, SAS (Statistical Analysis System), a program was written to read the PEPSE® output data, then sort and reformat the data to interface with a heat balance plotting program. The plotting program generates the machine instructions on a computer tape which is used to run the CAL-COMP pen plotter to draw the actual picture. The advantage of this method of drawing the heat balance diagram is the accuracy of the transcribed data and the ease of revising or updating without requiring the services of a draftsperson.

1. INTRODUCTION

A heat balance flow diagram is an effective means of presenting the thermodynamic steady state conditions of a steam-generating plant and demonstrating a plant's expected operating performance. When Vepco acquired the PEPSE® code a program of revising and updating vendor thermal kits was begun. A need to draw new heat balance diagrams based on the new PEPSE® plant models immediately arose. In the past, a heat balance drawing of a typical steam-generating unit had required a minimum of 36 manhours in combined efforts of an engineer and draftsperson to generate. Total costs to produce an original heat balance diagram (i.e., excluding computer modeling costs) averaged $388.00 in 1982. This is based on 24 hours of drafting a master diagram, 8 hours of transcribing the data from a computer print-out, and 4 hours of engineering to review. Revisions or updates were impractical and uneconomical because of this untimely process.

A method that would utilize the speed and accuracy of the computer to transcribe and draw the heat balance diagram was required. Although Vepco had the necessary computer hardware and software (i.e., a CAL-COMP, California Computers, four pen plotter and CAL-COMP FORTRAN subroutines) available for this application, there had been no specific programs developed to satisfy the requirement. During the summer of 1982, Vepco hired a computer science student to write a heat balance plotting program that could interface with the PEPSE® code and utilize the CAL-COMP software and hardware. An explanation of the program development and application are presented in this paper.

2. DISCUSSION

HARDWARE DESCRIPTION

The CAL-COMP hardware is a digital incremental drum plotter that can be operated remotely off-line from a magnetic tape drive. The plotter can produce plots ranging in width from 11" to 34" in any lengths and with a selection of up to four colors. A single heat balance diagram may be produced in 20 minutes.

SOFTWARE DESCRIPTION

The digital graphic software available within CAL-COMP is an assortment of callable FORTRAN subroutines that draw straight lines, circles, boxes, etc. which can be incorporated into larger subroutines to draw generic symbols that represent feedwater heaters, pumps, turbines, etc. The software is divided into three general classifications: 1) application programs, that generate flow charts, block diagrams, and decision tables; 2) functional software that provides a specific plotting solution for the particular application, such as scientific or business type X-Y graphs; and 3) basic software that provides specific pen movement instructions for the plotter.

Examples of some names and descriptions of subroutines in the basic software plotting programs are:

Subroutine Name		Description
AROHD	-	Draws arrowheads
CIRCL	-	Draws a circle or arc
DASHP	-	Draws a dashed line to a specified point
NEWPEN	-	Calls for different color pen
PLOT	-	Pen movement, in inches
RECT	-	Draws a rectangle

Some specific parameters used in a typical CAL-COMP subroutine are shown in the example of the "CALL SYMBOL" subroutine. This subroutine is used to plot alphanumeric characters and has six input parameters that describe the characters to be plotted. The FORTRAN statement is:

CALL SYMBOL (XPAGE, YPAGE, HEIGHT, IBCD, ANGLE, NCHAR)

Where:

- XPAGE, YPAGE - X, Y coordinates of pens starting position in inches.
- HEIGHT - Height of characters.
- IBCD - Alphanumeric array or string of characters to be plotted
- ANGLE - Angle, in degrees, from x-axis, at which the text is to be plotted.
- NCHAR - Number of characters to be plotted.

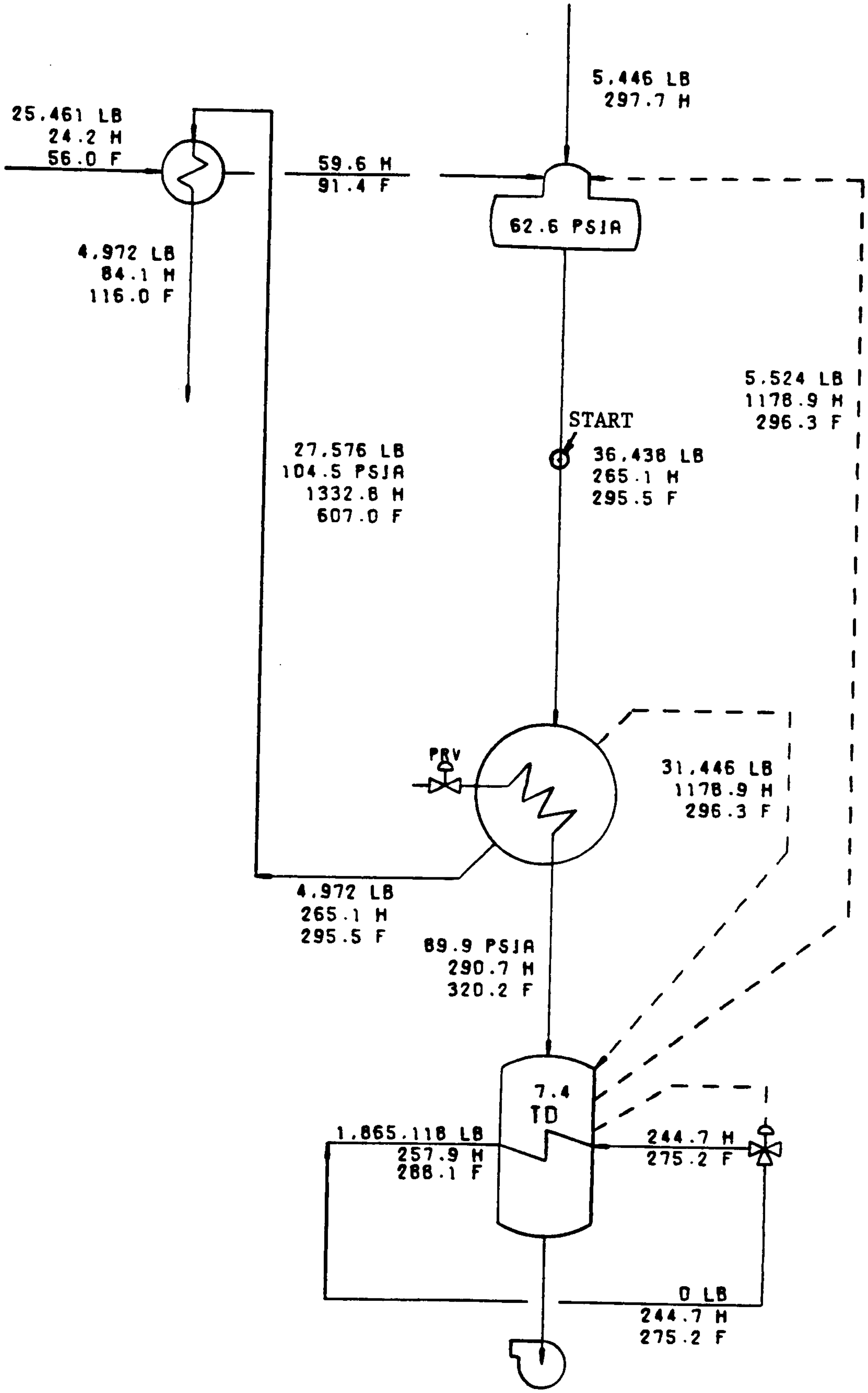
HEAT BALANCE PLOTTING

The symbols used in a schematic heat balance diagram (e.g., turbines, feedwater heaters, pumps, etc.) are described to the plotter with a combination of subroutines. The FORTRAN subroutine CH5EC, for example (see Appendix A for program listing) describes the evaporator condenser symbol and is shown in Figure 1. The CH5EC subroutine is an example of a specific generic symbol (i.e., a shell and tube evaporator) that can be used in drawing the heat balance diagrams for any plant cycles that have shell and tube evaporators. CH5EC is a combination of several small subroutines that draw specific symbols for a three-way bypass valve, an evaporator, a pressure reducing valve, a preheater and a heat exchanger. Thermodynamic data from the output data of a PEPSE® program is transcribed with "CALL SYMBOL" subroutines.

Data found on a heat balance plot is the output of the PEPSE® program's "STREAM PROPERTIES" and "SPECIAL OUTPUT" tables. This data must be reformatted and placed in special files which the FORTRAN plotting program may read. This is accomplished by first loading PEPSE® output into a temporary data file. This temporary file is then sorted and reformatted by another software program, SAS (Statistical Analysis System). The SAS program creates two separate data files that may be used as input data for the heat balance plotting program. See Appendix B for the SAS program listing. Figure 2 is a flowchart showing the steps involved in transferring the necessary PEPSE® output from a PEPSE® program to the program plotting data files.

The two data files created by the SAS program are:

1) STREAMS - This data file contains the mass flow, temperature, pressure, and enthalpy properties for the START and END of each stream identified in the PEPSE® "STREAM PROPERTIES" table. The mass flow values have commas inserted and all values have been sorted by the stream identification (I.D.) value.

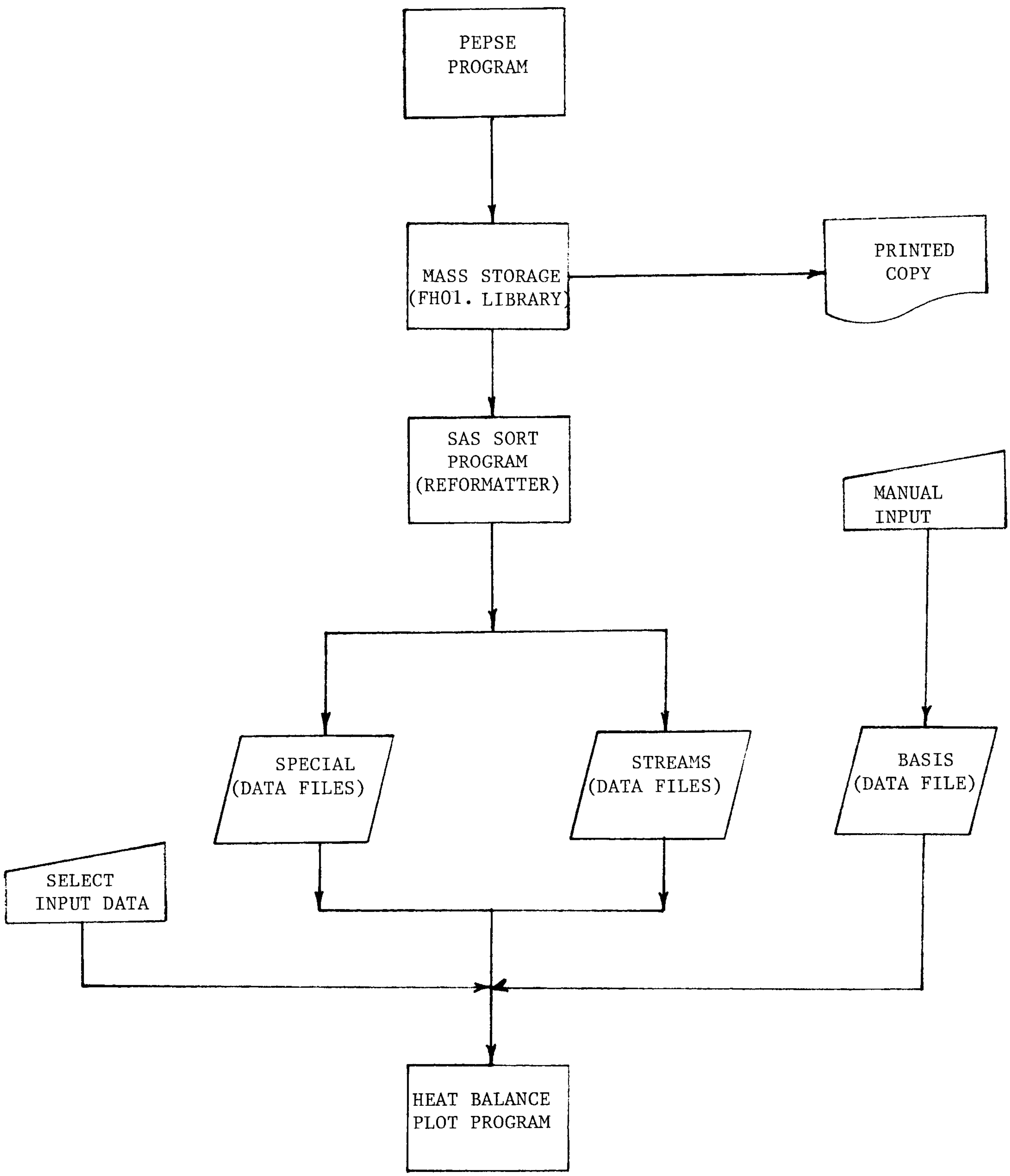


EVAPORATOR - (Chesterfield Unit 5)

SUBROUTINE: CH5EV

Figure: 1

FIGURE 2. FLOWCHART OF PEPSE DATA TO HEAT BALANCE PLOTTING PROGRAM



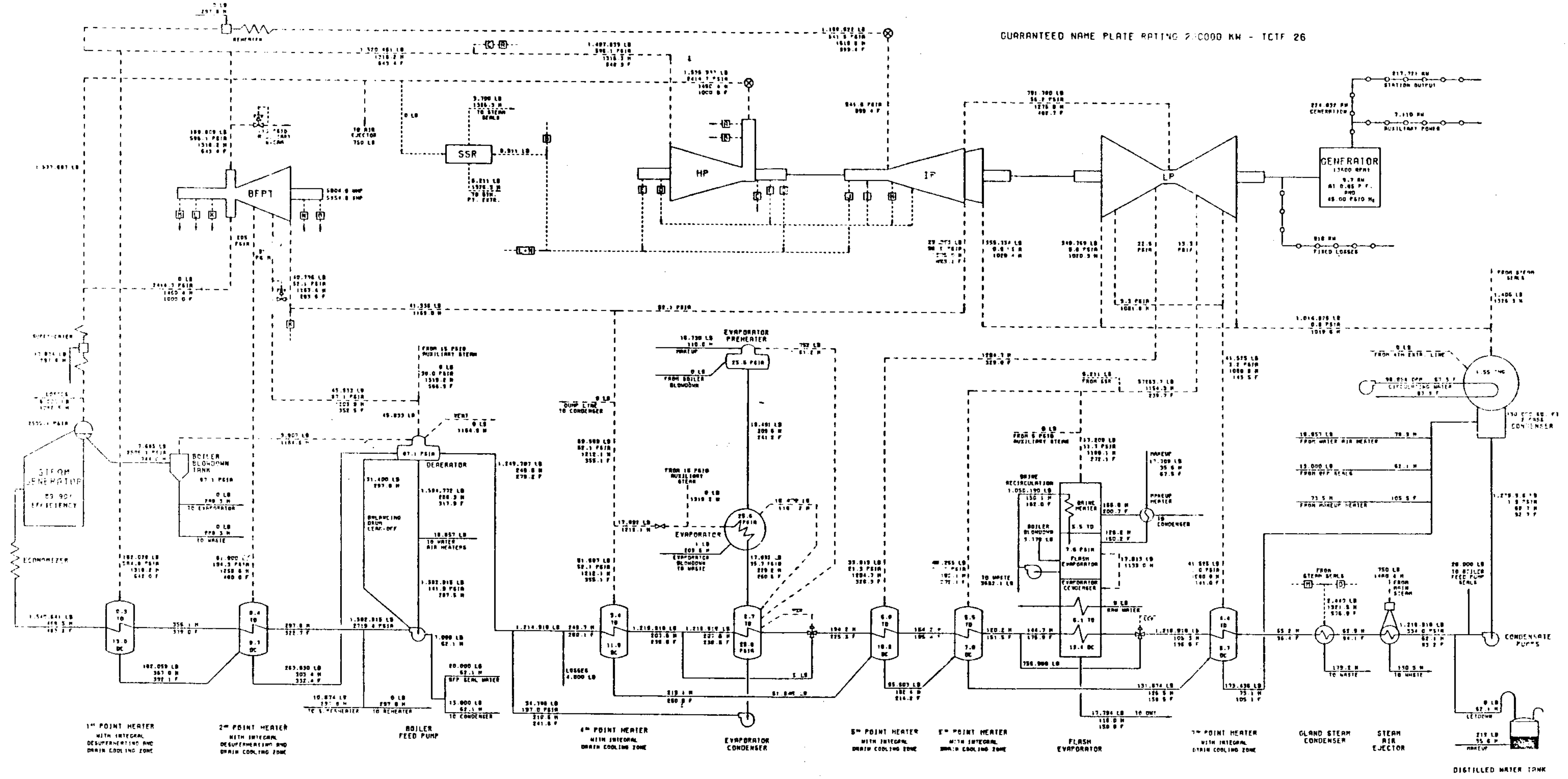
2) SPECIAL - This data file contains the same information as found in the PEPSE "SPECIAL OUTPUT TABLE", except the double precision format of the values have been converted to alphanumeric characters. This is necessary for transcribing the data with a "CALL SYMBOL" statement. The file is organized by index numbers which identify the value to be plotted.

Since the mass storage computer file of the PEPSE® output can contain multiple runs of the PEPSE model (i.e., the same model at different valve points) the SAS sort program creates a continuous data file of all load points. The heat balance plotting program identifies the correct values to be plotted by reading a third data file called "SELECT". The SELECT data file passes to the plotting program the number of streams and the number of special outputs contained in the PEPSE® model, and information to be plotted in the title block of the heat balance diagram. Appendix C includes an example of the SELECT data file.

The actual development of a heat balance plotting program begins with writing the subroutines to draw specific schematic components (i.e., feedwater heaters, condenser, turbines, etc.). Then transparencies of these component symbols are made, cut out, and then laid out on grided drawing paper. The drawing paper grid size is in tenths of an inch and is used to identify the X,Y cartesian coordinates of the starting point for a symbol plotting subroutine. Next, the X,Y coordinates for all component connecting lines are determined and then the X,Y coordinates of the labeling statements (e.g., 1st point heater) are established. The final step is to determine the X,Y coordinates of the thermodynamic states (i.e., flow, pressure, temperature and enthalpy) to be plotted for each corresponding location identified by the PEPSE® stream numbers from the specific PEPSE® model to be plotted. See Figure 3 for a typical example of the heat balance plot.

Although each heat balance plotting program is unit specific, many of the individual FORTRAN subroutine modules may be used in the construction of other plant models. Therefore, to document the work and expedite the new development of additional programs for heat balance diagrams, a subroutine module reference manual was created. The reference manual contains indexed descriptions of all the subroutines previously written. Each subroutine description includes: a picture of the symbol the subroutine draws, the required input information, and the program listing.

GUARANTEED NAME PLATE RATING 2?COOO KW - TCTF 26



BASIS OF HEAT BALANCE CALCULATIONS

LEAKAGES

LEGEND

STATION HEAT RATE = BOILER DUTY / (STATION OUTPUT X BOILER EFFICIENCY) = 9030 BTU/KWH

TURBINE HEAT RATE = BOILER DUTY / TOTAL GENERATION = 8118 BTU/KWH

Figure 1.1

VIRGINIA ELECTRIC AND POWER COMPANY
FOSSIL AND HYDRO TECHNICAL SUPPORT
PERFORMANCE, TESTS AND RESULTS

POSSUM POINT UNIT 4
HEAT BALANCE DIAGRAM
224 MEGAWATTS
--NORMAL--

DRAWING NO: HEPPT-4

SHEET NO: 1 OF 5

3. CONCLUSIONS

In June 1983, a second summer employee was hired to develop heat balance plotting programs. By using the heat balance symbol library as a reference manual, he was able to develop additional programs for the current year's developed PEPSE® models. With the reference manual new program development times were reduced by one half. Approximately eight working days are now required to complete a heat balance plot program for a specific unit. The time taken to develop the heat balance plotting programs has proven worthwhile because it provides engineers with the ability to present the PEPSE® data accurately in a graphical display of technical information. The data in this format is extremely useful for analysis work and review of plant operations and may be revised or updated quickly and inexpensively.

In fact, once this ability was made known, power station engineers requested that data from sensitivity studies and heat rate tests be plotted using these programs. Previously, a request of this nature would have been unreasonable due to the combined manpower requirements of a draftsperson and engineer, and the high possible incident of transcribed errors. Vepco has presently developed nine PEPSE® plant models that each have a heat balance plotting program.

APPENDIX A

CHESTERFIELD UNIT 5 EVAPORATOR CONDENSER
CAL-COMP SUBROUTINE - CH5EC

CHESTERFIELD UNIT 5 EVAPORATOR CONDENSER

CAL-COMP SUBROUTINE - CH5EC

```
0002        SUBROUTINE CH5EC
      C DRAW THE EVAPORATOR
0003        CALL WHERE(X,Y,FACT)
      C
      C DRAW THE FEED WATER HTR AND ITS SIDE INPUT AND OUTPUT
0004        CALL PLOT(X+2.7,Y+1.6,3)
0005        CALL FWHEAT(27,-1)
0006        CALL AROHD(X+4.3,Y+1.6,X+3.3,Y+1.6,.1,0.025,16)
0007        CALL LNE(X+2.7,Y+1.6,X+1.6,Y+1.6)
      C DRAW THE MECHANICAL CONNECTION FROM THE HEATER LEVEL TO THE THREE
      C WAY BY-PASS VALVE
0008        CALL DLNE(X+3.3,Y+1.7,X+3.8,Y+2.0,.1)
0009        CALL DASHP(X+4.4,Y+2.0,.1)
0010        CALL DASHP(X+4.4,Y+1.75,.1)
      C DRAW THE THREE WAY BY-PASS VALVE
0011        CALL PLOT(X+4.3,Y+1.6,3)
0012        CALL VALV5(5)
0013        CALL LNE(X+4.4,Y+1.5,X+4.4,Y+0.6)
0014        CALL PLOT(X+3.1,Y+0.6,2)
0015        CALL LNE(X+2.9,Y+0.6,X+1.6,Y+0.6)
0016        CALL AROHD(X+1.6,Y+0.6,X+1.6,Y-1.6,.1,.025,16)
      C DRAW THE BOTTOM OUTPUT FROM THE FW HTR AND THE PUMP
0017        CALL AROHD(X+3.0,Y+1.02,X+3.0,Y+0.2,.1,.025,16)
0018        CALL LPUMP
      C DRAW THE LINE TO THE FW HTR FROM THE EVAP;
0019        CALL AROHD(X+3.0,Y+3.6,X+3.0,Y+2.18,.1,.025,16)
      C DRAW THE ZIG ZAG HEAT SYMBOL
0020        CALL LNE(X+3.0,Y+3.6,X+3.15,Y+3.75)
0021        CALL PLOT(X+2.90,Y+3.70,2)
0022        CALL PLOT(X+3.00,Y+3.90,2)
0023        CALL PLOT(X+2.80,Y+3.80,2)
0024        CALL PLOT(X+2.85,Y+4.05,2)
0025        CALL PLOT(X+2.70,Y+3.90,2)
0026        CALL PLOT(X+2.40,Y+3.90,2)
      C DRAW THE PRV VALVE AND THE LINE INTO IT
0027        CALL PLOT(X+2.20,Y+3.9,3)
0028        CALL VALV5(4)
0029        CALL LNE(X+2.1,Y+3.90,X+2.2,Y+3.9)
      C DRAW THE EVAPORATOR
0030        CALL CIRCL(X+3.4,Y+3.85,360.0,0.0,.45,.45,0.0)
      C DRAW LINE FROM THE EVAPORATOR TO THE FW HTR UNDER IT (LINE ON RIGHT)
0031        CALL DLNE(X+3.275,Y+4.75,X+3.5,Y+4.4,.1)
0032        CALL DASHP(X+4.50,Y+44,.1)
0033        CALL DASHP(X+4.50,Y+3.5,.1)
0034        CALL DASHP(X+4.50,Y+3.5,X+3.3,Y+2.1,.1)
      C DRAW LINE FROM THE FW HTR TO THE DERTR (LINE ON RIGHT)
0035        CALL DLNE(X+3.30,Y+1.90,X+4.9,Y+3.1,.1)
0036        CALL DASHP(X+4.90,Y+7.8,.1)
0037        CALL DAROH(X+4.90,Y+7.8,X+3.15,Y+7.8,.1)
```

```
C DRAW LINE FROM THE BOILER BLOWDOWN TO THE DEAERATOR
      CALL AROHD(X+3.00,Y+8.90,X+3.00,Y+7.90,.1,0.025,16)
C DRAW THE DERTR AND BOTTOM OUTPUT
      CALL PLOT(X+3.00,Y+7.35,3)
      CALL DERTR(356)
      CALL AROHD(X+3.00,Y+7.35,X+3.00,Y+4.29,.1,0.025,16)
C DRAW THE OUTPUT FROM THE EVAP TO THE EVAP BLOWDOWN HEAT EXCHANGER
      CALL LNE(X+2.62,Y+3.52,X+2.4,Y+3.3)
      CALL AROHD(X+2.4,Y+3.3,X+1.10,Y+3.3,.1,0.025,16)
      CALL LNE(X+1.10,Y+3.30,X+1.1,Y+8.2)
      CALL PLOT(X+0.60,Y+8.20,2)
      CALL AROHD(X+0.6,Y+8.2,X+0.60,Y+8.0,.1,0.025,16
C DRAW THE EVAPL BLOWDOWN HEAT EXCHANGER
      CALL HEXCHV
C DRAW THE INPUT FROM MAKEUP
      CALL AROHD(X-0.6,Y+&.8,X+0.40,Y+7.8,.1,0.025,16)
C DRAW THE OUTPUT TO WASTE
      CALL AROHD(X+0.6,Y+7.6,X+0.60,Y+6.33,.1,0.025,16)
C DRAW THE LINE TO THE DERTR FROM THE EVAP BLOWDOWN HEAT EXCHANGER
      CALL LNE(X+0.80,Y+7.8,X+1.0,Y+7.8)
      CALL LNE(X+1.20,Y+7.8,X+2.0,Y+7.8)
      CALL AROHD(X+2.2,Y+7.8,X+2.85,Y+7.8,.1,0.025,16)
      RETURN
      END
```

APPENDIX B

SAS SORT ROUTINE FOR PEPSE OUTPUT

SAS SORT ROUTINE FOR PEPSE OUTPUT

```
DATA PEPSE2;
     INFILE CASE;
COMMENT  FIND THE WORD "START" WHICH MARKS THE STREAMS FLOW AND THE
         BEGINNING TEMPERATURE, PRESSURE, AND ENTHALPY VALUES;
  INPUT @13 STYPE $13 @45 STAR $ 45-49 @;
     IF STAR='START' AND STYPE GE '0' AND STYPE LE '5';
  INPUT @4 STREAM @56 FLOW @68 TEMPIN @79 PRESSIN @99 ENTHIN;
DATA PEPSE3;
     INFILE CASE;
COMMENT  FIND THE WORD "END" WHICH MARKS THE STREAMS ENDING TEMPERATURE,
         PRESSURE, AND ENTHALPY VALUES;
  INPUT @45 STAR $ 45-49 @;
  IF START='END';
  INPUT @68 TEMPO @79 PRESSO @99 ENTHO;
DATA PEPSE4(KEEP= STREAM FLOW TEMPIN PRESSIN ENTHIN TEMPO PRESSO ENTHO)
;MERGE PEPSE2 PEPSE3;
COMMENT  PUT THE VALUES FOR EACH STREAM INTO THE DATASET OUT WHICH IS
         SPECIFIED WITHIN THE WK.CNTL MEMBER EXECUTED;
        FILE OUT;
        PUT @1 FLOW COMMA9.0 @13 TEMPIN 6.1 @21 PRESSIN 6.1
          @29 ENTHIN 6.1     @37  TEMPO  6.1 @45 PRESSO    6.1
          @53 ENTHO  6.1     @61  STREAM 3.0;
COMMENT PROC PRINT;
DATA PEPSE5;
     INFILE CASE;
INPUT @33 X $ 33-34 @;
     IF X='XX';
     INPUT INDEX 26-27 DESCRIP $ 35-71 @96 VALUE;
DATA PEPSE6(KEEP= DESCRIP VALUE );SET PEPSE;
COMMENT  PUT THE VALUES IN THE SPECIAL OUTPUT TABLE INTO THE DATASET
         OUTA WHICH IS SPECIFIED WITHIN THE WK.CNTL MEMBER EXECUTED;
       FILE OUTA;
COMMENT  KEY OFF THE FIRST FEW LETTERS OF EACH NUMBER'S ASSOCIATED
         DESCRIPTION TO DETERMINE THE CORRECT FORMAT TO PRINT IT;
     IF DESCRIP = 'KW' OR DESCRIP = 'FLOW' THEN GO TO COM;
     IF DESCRIP = 'GROSS' OR DESCRIP = 'NET'
                    OR DESCRIP = 'STATION' THEN GO TO POW;
     IF DESCRIP = '% BOILER EFFICIENCY' OR DESCRIP =
                   '"HG' THEN GO TO TWODEC;
     IF DESCRIP = 'BOILER EFFICIENCY' THEN GO TO FOURDEC;
     IF DESCRIP = 'BACK' THEN GO TO TWODEC;
     IF VALUE   999999.0 THEN GO TO EXP;
COMMENT  THE DEFAULT FORMAT IS ONE DECIMAL PLACE;
     PUT @2 INDEX 4.0 @8 DESCRIP @44 VALUE 8.1 @57 VALUE 10.;
     RETURN;
COM:
COMMENT  PRINT THE NUMBER WITH COMMAS;
COMMENT  IF THE NUMBER IS VERY CLOSE TO 0.0 SET IT TO 0.0;
     IF VALUE  0.01 AND VALUE   -0.01 THEN VALUE=0.0;
     PUT @2 INDEX 4.0 @8 DESCRIP @44 VALUE COMMA8.0 @57 VALUE 10.;
     RETURN;
```

```
52     POW:
53   COMMENT  PRINT THE NUMBER AS A WHOLE NUMBER;
54        PUT @2 INDEX 4.0 @8 DESCRIP @44 VALUE 8.0 @57 VALUE 10.;
55        RETURN;
56      TWODEC:
57   COMMENT  PRINT THE NUMBER TO TWO DECIMAL PLACES;
58        PUT @2 INDEX 4.0 @8 DESCRIP @44 VALUE 8.2 @57 VALUE 10.;
59        RETURN;
60      FOURDEC:
61   COMMENT  PRINT THE NUMBER TO FOUR DECIMAL PLACES;
62        PUT @2 INDEX 4.0 @8 DESCRIP @44 VALUE 8.4 @57 VALUE 10.;
63        RETURN;
64      EXP:
65   COMMENT  PRINT THE NUMBER IN EXPONENTIAL FORMAT;
66        PUT @2 INDEX 4.0 @8 DESCRIP @46 VALUE E10.0 @57 VALUE 10.;
67   COMMENT PROC PRINT;
68        TITLE1 SPECIAL OUTPUT TABLE;
```

PROGRAM EXPLANATION

The above SAS program reads the PEPSE® output file with the statement "INFILE CASE" and keys on the word "Start" and the stream type as found in the PEPSE® output table "STREAM PROPERTIES". This information locates the data in the stream properties table and line 7 of the SAS program reads the stream I.D. number, flow, temperature, pressure and enthalpy. From line 8 to 14 the SAS program reads the entire PEPSE® data file only this time keys on the word "END" in the stream properties table to read again the stream I.D., flow, temperature, pressure and enthalpy. Finally in lines 15 to 22 the two data sets are merged and written to a data file with format changes (i.e., commas inserted into the flow data).

Next the SAS program (lines 24 to 51) reads the PEPSE® ouput file this time keying on special characters (XX) that designate the lines in the PEPSE® "SPECIAL OUTPUT TABLE". This data is read and converted from double precision format to alphanumeric or real number format with different significant decimal places, dependant on the variable (i.e., flow, power, efficiency, etc.)

The final results of the SAS program is the creation of two data files. One file being all the stream properties sorted by stream I.D.s and the second file a listing of the data from the "SPECIAL OUTPUT TABLE" that could have been reformatted for use as the input files for a heat balance plotting program.

APPENDIX C

"SELECT" DATA FILE

"SELECT" DATA FILE

THE NUMBER OF VALVES OPEN ___. DATA SET NUMBER TO BE READ ___.
4 1

THE SHEET NUMBER ___ OUT OF ___ SHEETS.
1 5

WRITE THE NUMBERS RIGHT JUSTIFIED UNDER THE SPACE INDICATED.
NOTE: IF PERCENT LOAD IS DESIRED PUT THAT NUMBER IN THE VALVES OPEN SPACE.

EACH UNIT'S MODEL'S CURRENT STATUS OF ITS NUMBER OF STREAMS AND THE NUMBER OF ELEMENTS IN ITS SPECIAL OUTPUT TABLE.

UNIT	STREAMS	SPECIAL OUTPUTS	
MT. STORM 1	232	63	
MT. STORM 2	232	63	THESE MUST BE UPDATED
MT. STORM 3	200	64	
CHESTERFIELD 6	216	62	CHANGED FROM 206 & 62 TEST
CHESTERFIELD 5	211	49	
PORTSMOUTH 2	100	55	
PORTSMOUTH 1	80	55	
POSSUM POINT 4	218	53	
PORTSMOUTH 4	225	68	
BREMO 4	150	43	
PORTSMOUTH 3	131	42	

INPUT DATA EXPLANATION

The SELECT data file allows the user enter data to the heat balance plot program that will determine six parameters:

1. The valve point (or load) for which the heat balance is to be drawn.

2. The data set number which determines which lines of data to read from the "STREAM" and "SPECIAL" data files.

3. The drawing sheet number.

4. The total number of drawings.

5. The total number of streams in the model.

6. The total number of special outputs in the model.