# Modeling Technique for Atypical Turbine Extraction/Feedwater Heater Demand Arrangements

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ABSTRACT

The turbine extraction/feedwater heater demand process, in PEPSE, is designed such that each feedwater heater being supplied steam references demand on a single turbine extraction port. Provided the above statement is true, the number of feedwater heaters being supplied steam can be equal to or greater than the number of turbine extraction ports feeding the heaters. This arrangement is adequate for most turbine generating cycle modeling applications.

A deficiency arises when more than one turbine extraction port supplies demand steam to a feedwater heater.

This paper will discuss a technique, using the Operations in PEPSE, to overcome this deficiency and adequately model atypical turbine extraction / feedwater heater demand arrangements.

## 1.0 Introduction

The Three Mile Island Unit 1 low pressure turbine consists of three double flow, seven stage (stages 7 - 13 overall) turbine sections. Each extraction stage feeds to a common extraction header from which two parallel feedwater heater trains are fed. This arrangement was modeled, in PEPSE, using three parallel turbine strings, combining using several mixers and splitters, feeding two parallel feedwater heater trains. Please note that each turbine stage represents two rows of blades and extraction steam is taken from the 8th, 10th, and 12th stages with the 9th and 11th stages being blowdown stages. Refer to Figure 1.

The problem with modeling this type of arrangement is that PEPSE is designed such that each feedwater heater references one turbine extraction port. From inspection of Figure 1 it can be seen that non-representative flow imbalances would be created as one of the three extraction ports feeding the two heaters is not referenced.

This problem can be overcome using a technique which uses the Operations in PEPSE interacting with the feedwater heater energy balance updating process PEPSE uses. The technique discussed herein can be used for two turbine extraction stages feeding one feedwater heater or three turbine extraction stages feeding two feedwater heaters.

## 2.0 Methods

### 2.1 Darcy's Formula[1]

In the physical plant the driving force for extraction flow is the pressure gradient which exists in the line between the extraction port and the feedwater heater shell. This can be seen from inspection of Darcy's Formula for fluid flow in a pipe:

$$\dot{w} = C_1 d^2 \sqrt{C_2 \rho \Delta P}$$

where: $C_1$ = conversion factor / Y factor
$C_2$ = inverse of resistance coefficient

From this we can see that flow is proportional to the square root of density multiplied by pressure drop.

$$\dot{w} \sim \sqrt{\rho \Delta P}$$

For flow situations where density is considered a constant between sections, flow is proportional to pressure drop alone.

$$\dot{w} \sim \sqrt{\Delta P}$$

This analysis is the basis for which the operations used in the subject technique are written.

## 2.2 Pressure Drop

Pressure drop determined from instrumentation readings is the best value to use for this technique. However, if appropriate instrumentation is not available, a representative model of the extraction line for calculating pressure drop can be obtained by using a stream type 1[*] and the controls in PEPSE.

Using either a small submodel or the plant model, the extraction line dimension are entered into the stream type 1 input cards. Friction factor may either be entered or calculated by PEPSE. Using the controls, vary the length to match either a design pressure drop for the extraction line or a value obtained from a previous test, etc. The result will be a good representative model of the extraction line which will calculate pressure drop based on elevation head, form loss, and wall friction.

## 2.3 Independent Demand Splitter

The first step of this technique is to remove or displace the capability of PEPSE for updating the extraction flows. This is done by referencing the feedwater heaters involved to an independent demand splitter, word 3I[*] on the feedwater heater input card. Refer to Figures 2A and 3A.

This essentially removes the obstacle of limited reference components in PEPSE and allows the Operations to update extraction flow from the turbines without interference from the normal PEPSE updating process.

## 2.4 Feedwater Heater Energy Balance

With each successive iteration PEPSE performs en route to convergence, an energy balance is performed around each feedwater heater to ensure the input boundary conditions are met. Steam flow is varied to achieve this balance. The amount of deficit (surplus) steam the feedwater heater (doesn't) needs to achieve energy balance is represented as a mass imbalance in the drains out flow. This value is used in the subsequent iteration. The process is repeated untill appropriate convergence criteria is met.

The Operations to be used in this technique will take advantage of this process to update turbine extraction flows.

## 2.5 Operations

The following is a guide for writing operations to update turbine extraction flows. Refer to Figure 2B.

2.5.1 Determine the density of the inlet flow to each extraction line. Note for situations where the density does not vary considerably between turbine section extraction lines, this step may be omitted.

2.5.2 Determine the extraction line pressure drop. Note this value may either be a measured value or a value obtained as discussed in Section 2.2.

2.5.3 Multiply the extraction line density by the pressure drop.

2.5.4 Take the square root of the above product for each extraction line.

2.5.5 Sum the square root quantities for each stage of extraction.

2.5.6 Calculate the extraction line flow rate multiplier by dividing the individual square root (2.5.4) for each extraction line by the calculated sum in step 2.5.5.

2.5.7 To determine the new total flow demanded by the feedwater heater, first subtract the drain inlet value ( if present ) from the drains out flow value. Next subtract this difference from the shell inlet flow. Note that a deficit condition will be negative and a surplus condition will be positive.

To dampen out any ocsillatory behavior in the convergency process a relaxation factor may be used.

Next, subtract the above difference from the inlet steam flow to obtain the new total flow demanded by the feedwater heater.

2.5.8 To determine the new extraction flow to be used in the subsequent iteration, multiply the new total calculated flow in step 2.5.7 by the flow rate multipliers calculated in step 2.5.6.

## 2.6 Special Cases

The previous discussion was based on two turbines supplying demand steam for one feedwater heater - for one stage. This process will have to be duplicated for each stage of extraction steam.

Figure 3.B outlines the operations needed for the case of three turbines supplying demand steam for two feedwater heaters.

Note in Figure 3A/B blowdown stages are considered. For sensitive models, the moisture removed from the blowdown stages may actually have to be calculated utilizing the the new extraction values to achieve convergence. This was the case for the TMI-1 model and will not be discussed herein.

## 3.0 Results

This technique has been used for the TMI-1 PEPSE model with very good success. Having the ability seperately model each extraction line has been very useful in analyzing plant performance.

For example, during Cycle 5, TMI-1 experienced expansion joint failures of several 8th stage extraction lines. This created large flow imbalances from one turbine section to the next. Having the capability to model each turbine section independent of the others allowed for a better evaluation of the failure and the subsequent effect on plant performance.

## 4.0 Conclusions

This technique can be very useful for modelling plants with turbine extraction / feedwater heater demand arrangements as discussed herein. The technique allows the plant to be modeled representatively without compromising the quality analysis PEPSE provides.

## 5.0 References


5.1 Crane Co., "Flow of Fluids Through Valves, Fittings, and Pipe", Crane Co., 13th edition, 1973

5.2 Energy Incorporated, "PEPSE Manual - Engineering Model Description", Volume II, Rev. 5, 1986

5.3 Energy Incorporated, "PEPSE Manual - User Input Description", Volume I, Rev. 12, 1986

5.4 GPUN Technical Data Report, "PEPSE Asbuilt Model Description for the TMI-1 Turbine Generating Cycle", TDR No. 676, Rev. 0, 1985


## 6.0 Figures

FIGURE 1

TMI-1 LOW PRESSURE TURBINE EXTRACTION / FEEDWATER HEATER TRAINS

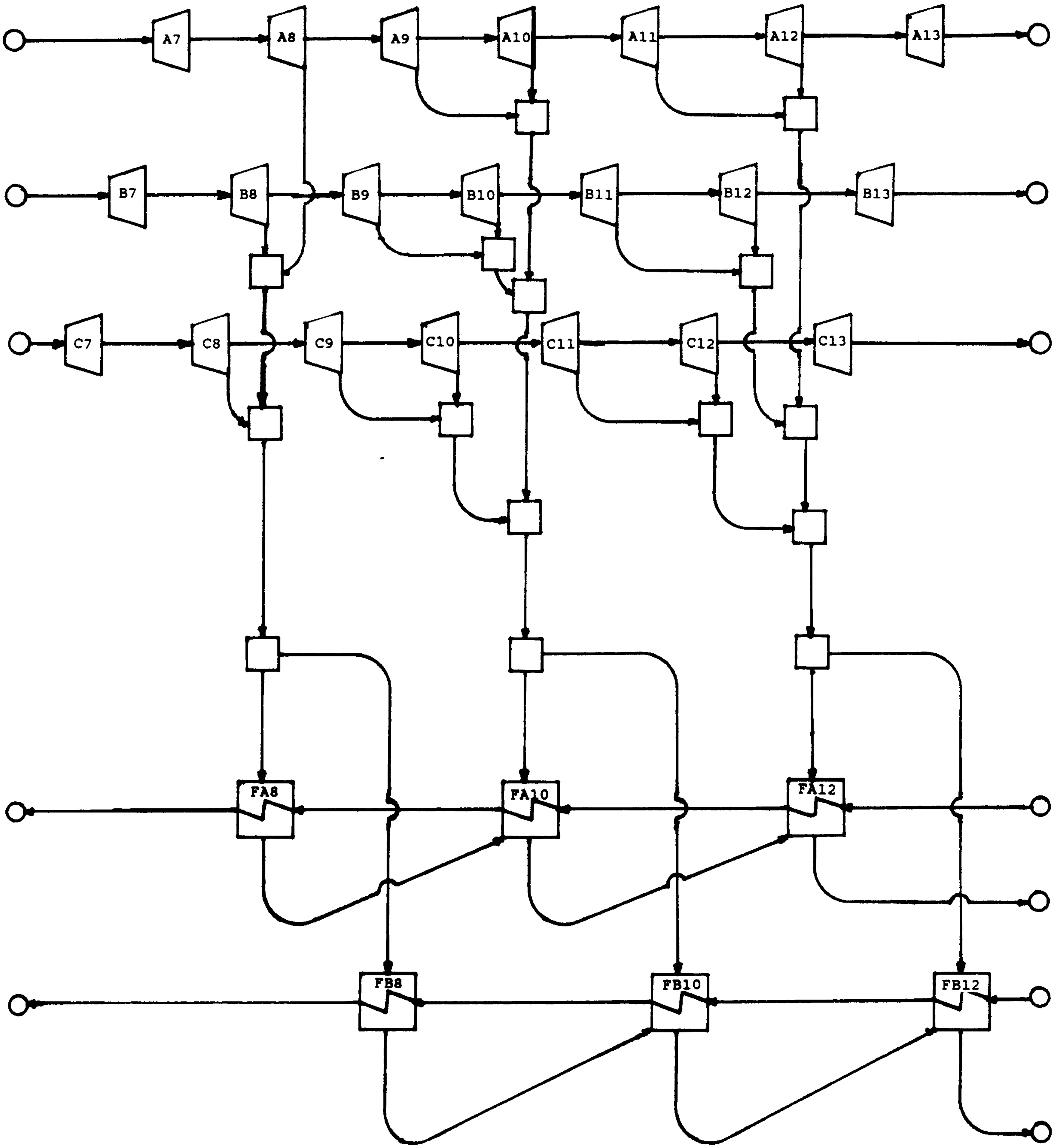

FIGURE 2A

TWO TURBINES SUPPLYING DEMAND STEAM FOR ONE FEEDWATER HEATER

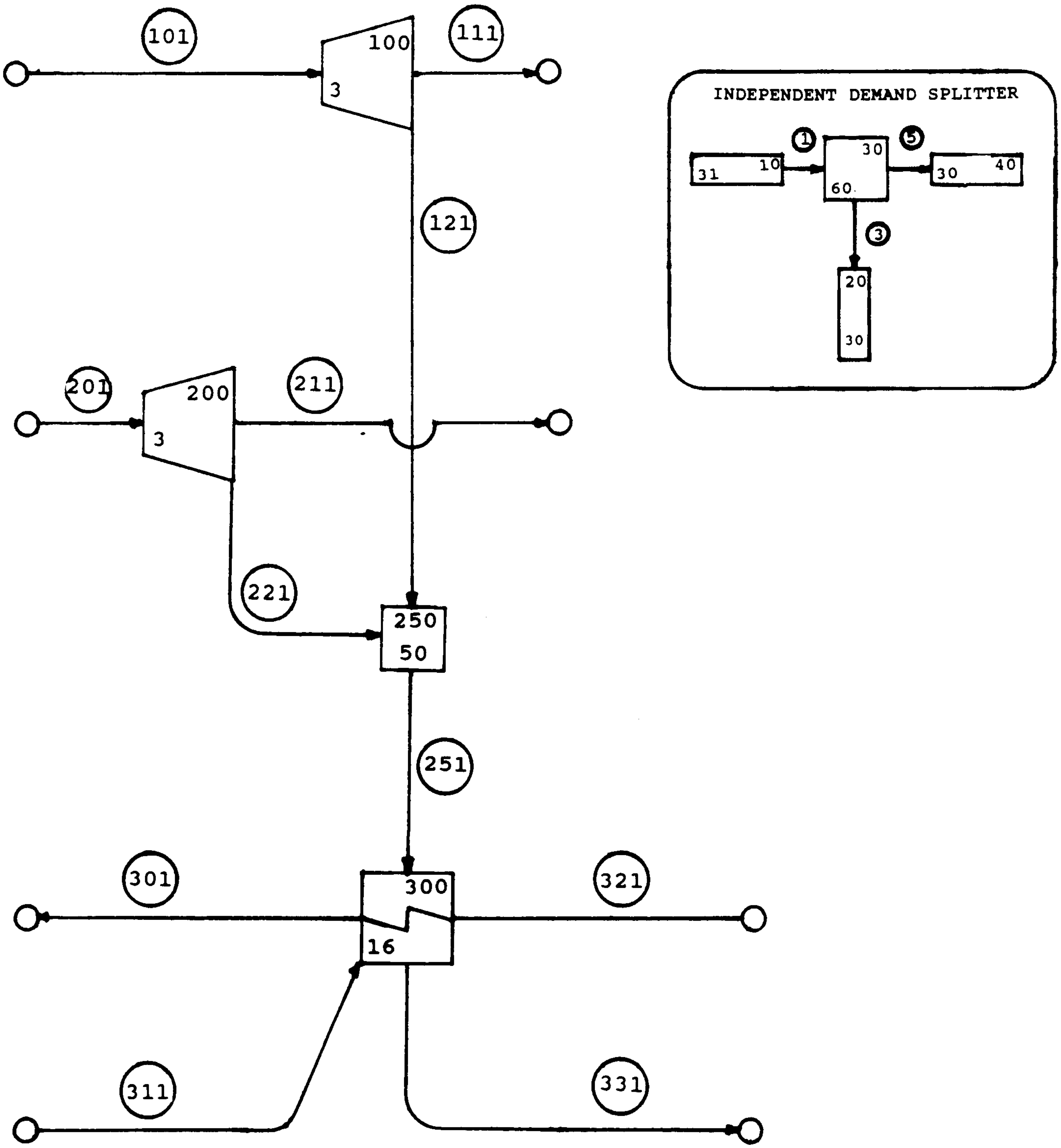

FIGURE 2B

Operations for Determining Extraction Flows for
Two Turbines Supplying Demand Steam For One Feedwater Heater

```
* OPERATIONAL VARAIABLES
870010  0.50
870020  1.00
870030  0.55
*
* OBTAINING DENSITIES OF EXTRACTION STEAM
880010  OPVB,  2,  DIV,  VV,  121,  OPVB,  5
880020  OPVB,  2,  DIV,  VV,  221,  OPVB,  6
*
* OBTAINING EXTRACTION LINE PRESSURE DROPS
880030  PP,  -121,  SUB,  PP,  121,  OPVB,  7
880040  PP,  -221,  SUB,  PP,  221,  OPBB,  8
*
* MULTIPLY EXTRACTION LINE PRESSURE DROP BY DENSITY
880050  OPVB,  5,  MUL,  OPVB,  7,  OPVB,  9
880060  OPVB,  6,  MUL,  OPVB,  8,  OPVB,  10
*
* TAKE SQUARE ROOT OF ABOVE PRODUCT
880070  OPVB,  9,  TO,  OPVB,  1,  OPVB,  11
880080  OPVB,  10,  TO,  OPVB,  1,  OPVB,  12
*
* SUM SQUARE ROOT QUANTITIES
880090  OPVB,  11,  ADD,  OPVB,  12,  OPVB,  13
*
* CALCULATE EACH EXTRACTION LINE FLOW RATE MULTIPLIER
880100  OPVB,  11,  DIV,  OPVB,  13,  OPVB,  14
880110  OPVB,  12,  DIV,  OPVB,  13,  OPVB,  15
*
* DETERMINATION OF NEW TOTAL FLOW DEMANDED BY FEEDWATER HEATER
880120  WW,  331,  SUB,  WW,  311,  OPVB,  16
880130  WW,  251,  SUB,  OPVB,  16,  OPVB,  17
880140  OPVB,  17,  MUL,  OPVB,  3,  OPVB,  18
880150  WW,  251,  SUB,  OPVB,  18,  OPVB,  19
*
* DETERMINE NEW EXTRACTION FLOW FOR EACH LP TURBINE SECTION
880160  OPVB,  14,  MUL,  OPVB,  19,  WEXTP,  100
880170  OPVB,  15,  MUL,  OPVB,  19,  WEXTP,  200
*
```

FIGURE 3A

THREE EXTRACTION TURBINES WITH BLOWDOWN STAGES SUPPLYING DEMAND STEAM FOR TWO FEEDWATER HEATERS

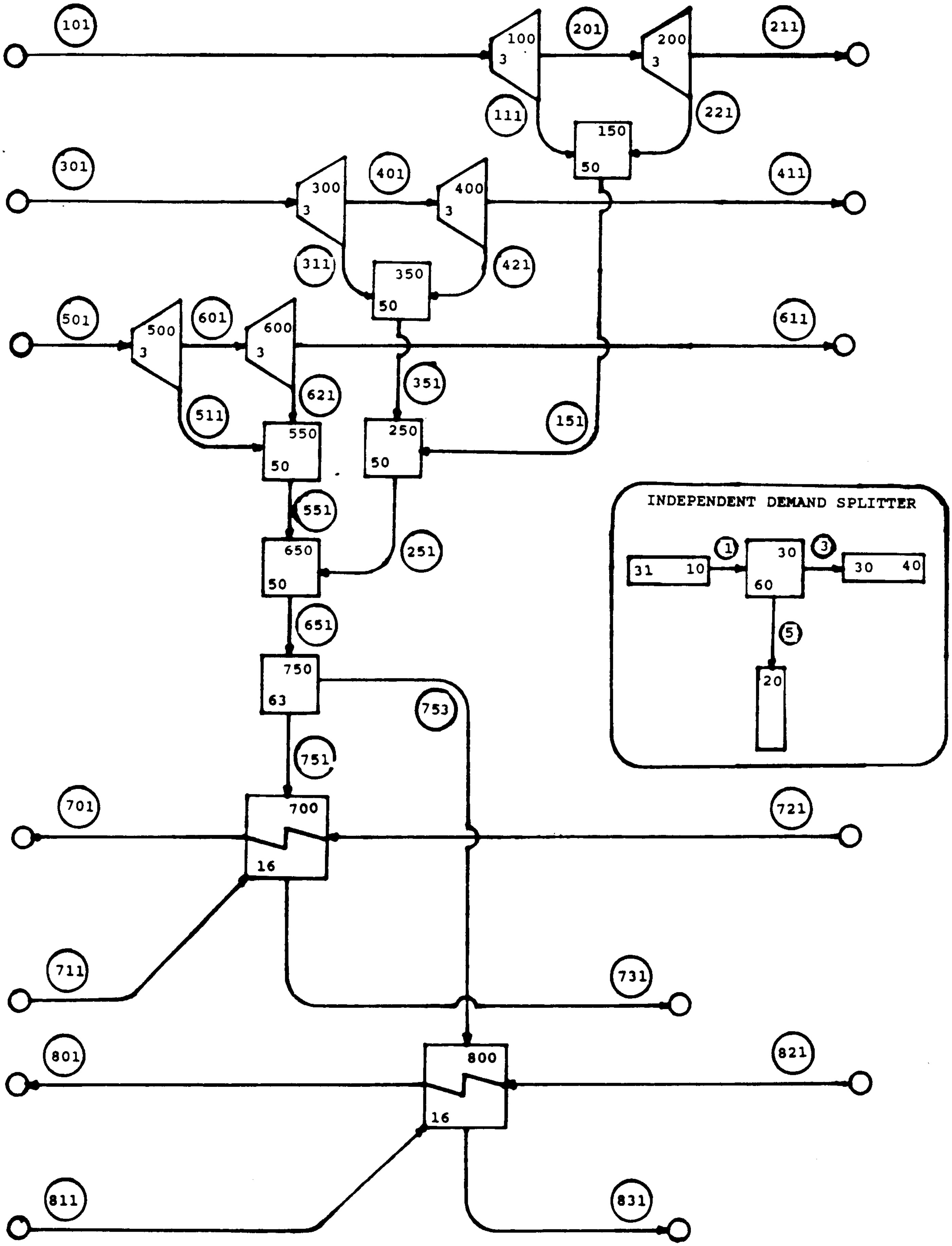

FIGURE 3B

Operations for Determining Extraction Flows for
Three Turbines Supplying Demand Steam For Two Feedwater Heaters

```
* OPERATIONAL VARAIABLES
870010  0.50
870020  1.00
870030  0.55
*
* OBTAINING DENSITIES OF EXTRACTION STEAM
880010  OPVB,  2,  DIV,  VV,  221,  OPVB,  5
880020  OPVB,  2,  DIV,  VV,  421,  OPVB,  6
880030  OPVB,  2,  DIV,  VV,  621,  OPVB,  7
*
* OBTAINING EXTRACTION LINE PRESSURE DROPS
880040  PP,  -221,  SUB,  PP,  221,  OPVB,  8
880050  PP,  -421,  SUB,  PP,  421,  OPBB,  9
880060  PP,  -621,  SUB,  PP,  621,  OPBB,  10
*
* MULTIPLY EXTRACTION LINE PRESSURE DROP BY DENSITY
880070  OPVB,  5,  MUL,  OPVB,  8,  OPVB,  11
880080  OPVB,  6,  MUL,  OPVB,  9,  OPVB,  12
880090  OPVB,  7,  MUL,  OPVB,  10,  OPVB,  13
*
* TAKE SQUARE ROOT OF ABOVE PRODUCT
880100  OPVB,  11,  TO,  OPVB,  1,  OPVB,  14
880110  OPVB,  12,  TO,  OPVB,  1,  OPVB,  15
880120  OPVB,  13,  TO,  OPVB,  1,  OPVB,  16
*
* SUM SQUARE ROOT QUANTITIES
880130  OPVB,  14,  ADD,  OPVB,  15,  OPVB,  17
880140  OPVB,  17,  ADD,  OPVB,  16,  OPVB,  18
*
* CALCULATE EACH EXTRACTION LINE FLOW RATE MULTIPLIER
880150  OPVB,  14,  DIV,  OPVB,  18,  OPVB,  19
880160  OPVB,  15,  DIV,  OPVB,  18,  OPVB,  20
880170  OPVB,  16,  DIV,  OPVB,  18,  OPVB,  21
*
* DETERMINATION OF NEW TOTAL FLOW DEMANDED BY FEEDWATER HEATER
880180  WW,  731,  SUB,  WW,  711,  OPVB,  22
880190  WW,  831,  SUB,  WW,  811,  OPVB,  23
880200  OPVB,  22,  ADD,  OPVB,  23,  OPVB,  24
880210  WW,  651,  SUB,  OPVB,  24,  OPVB,  25
880220  OPVB,  25,  MUL,  OPVB,  3,  OPVB,  26
880230  WW,  651,  SUB,  OPVB,  26,  OPVB,  27
*
* DETERMINE NEW EXTRACTION FLOW FOR EACH LP TURBINE SECTION
880240  OPVB,  19,  MUL,  OPVB,  27,  OPVB,  28
880250  OPVB,  28,  SUB,  WW,  111,  WEXTP,  200
880260  OPVB,  20,  MUL,  OPVB,  27,  OPVB,  29
880270  OPVB,  29,  SUB,  WW,  311,  WEXTP,  400
880280  OPVB,  21,  MUL,  OPVB,  27,  OPVB,  30
880290  OPVB,  30,  SUB,  WW,  511,  WEXTP,  600
*
* SET CORRECT PERCENTAGE SPLIT FOR COMPONENT 750
880300  WW,  831,  DIV,  OPVB,  24,  FRSPL,  750
*
```