REPORT NO. ACNP-6104

MASTER

PATHFINDER ATOMIC POWER PLANT

Summary Report

HYDRAULIC ANALYSIS OF PATHFINDER BOILER

Submitted to

U. S. ATOMIC ENERGY COMMISSION

NORTHERN STATES POWER COMPANY

and

CENTRAL UTILITIES ATOMIC POWER ASSOCIATES

by

ALLIS-CHALMERS MANUFACTURING COMPANY
ATOMIC ENERGY DIVISION
Milwaukee 1, Wisconsin

Ref: AEC Contract No. AT(11-1)-589

DISCLAIMER

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by N. C. Sher

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ALLIS-CHALMERS MANUFACTURING COMPANY

Under

Agreement dated 2nd Day of May 1957, as Amended
between
Allis-Chalmers Mfg. Co. & Northern States Power Co.
under
AEC Contract No. AT(11-1)-589

February 15, 1961

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Summary Report

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INTRODUCTION

An extensive hydraulic analysis of the Pathfinder boiler core has been completed. Due to the nature of the Pathfinder reactor design, it has been possible to study the boiler from a thermal and hydraulic point of view for steady-state operation essentially independent of the Pathfinder superheater core. The superheater operation does indeed impose certain requirements on the boiler, affects the boiler energy balance, and affects the boiler outlet pressure. These effects have been included in the boiler analyses; however the detailed hydraulic performance of the superheater is not treated here. The boiler hydraulic analysis is presented as follows:

1. Description of Flow Paths. . .
2. Computation of Pressure Drops - Primary Flow Paths . . .
3. Computation of Pressure Drops - Leakage Flow Paths. . .
4. Determination of Leakages. . .
5. Dependence of Pressure Drops on Core Operating Parameters. . .
6. Determination of Boiler Flow Rates. . .
7. Natural Circulation Flows. . .
8. Boiler Energy and Material Balances. .

It should be pointed out that the information herein presented is based almost completely on analyses. The analyses have been based on applicable experimental data wherever possible; however in most cases, experimental data specifically pertaining to the Pathfinder boiler were not available. Test programs are scheduled to study all the important areas of the hydraulic performance, and it is likely that the results from these programs will affect the predicted performance of Pathfinder. As such data become available, this report will be modified and up-dated whenever necessary.

It should also be pointed out that the core dimensions used herein, which are the latest available, differ somewhat from dimensions used in previous pressure drop studies. Thus, the pressure drops in this report supersede all previously reported pressure drops for the boiler.

1. DESCRIPTION OF FLOW PATHS

A schematic diagram of the primary flow paths is shown in Fig. 1. Sub-cooled water enters the lower inlet plenum from the recirculation piping, expands upward into the upper inlet plenum, enters the 96 boiler fuel elements, and leaves the fuel elements as a two-phase mixture. Steam is separated from the water at the free surface, in the demisters, and in the steam separators and then enters the superheater. The remaining water is mixed with the feedwater and enters the recirculation piping through the exit nozzles. At this point it is necessary to define "leakage" as the term is used in this analysis. All water which enters the vessel from the recirculation piping but which does not flow through the 96 boiler fuel elements is termed "leakage". The remaining water is called "active" flow. In order to simplify the analysis, the leakage flow is assumed not to be heated as it moves through the core. Therefore the power requirement for providing steam to the superheater is assigned completely to the boiler fuel. Actually, some of this power will come from sources other than the boiler fuel and will be transferred directly to the leakage flow (for example, in the superheater moderator region). Note that this technique of assigning the total power requirement to the boiler fuel does not affect the mixed enthalpy of the boiler effluent since the unheated leakage is assumed to completely mix with the active flow at the top of the core. Thus, there is a slight conservatism introduced in defining the power produced in the boiler fuel.

A schematic diagram showing both the primary and leakage flow paths is shown in Fig. 2. There are five principal areas in which leakage can occur:

1. Moderator flow to superheater .....

2. Coolant flow to boiler control rods .....

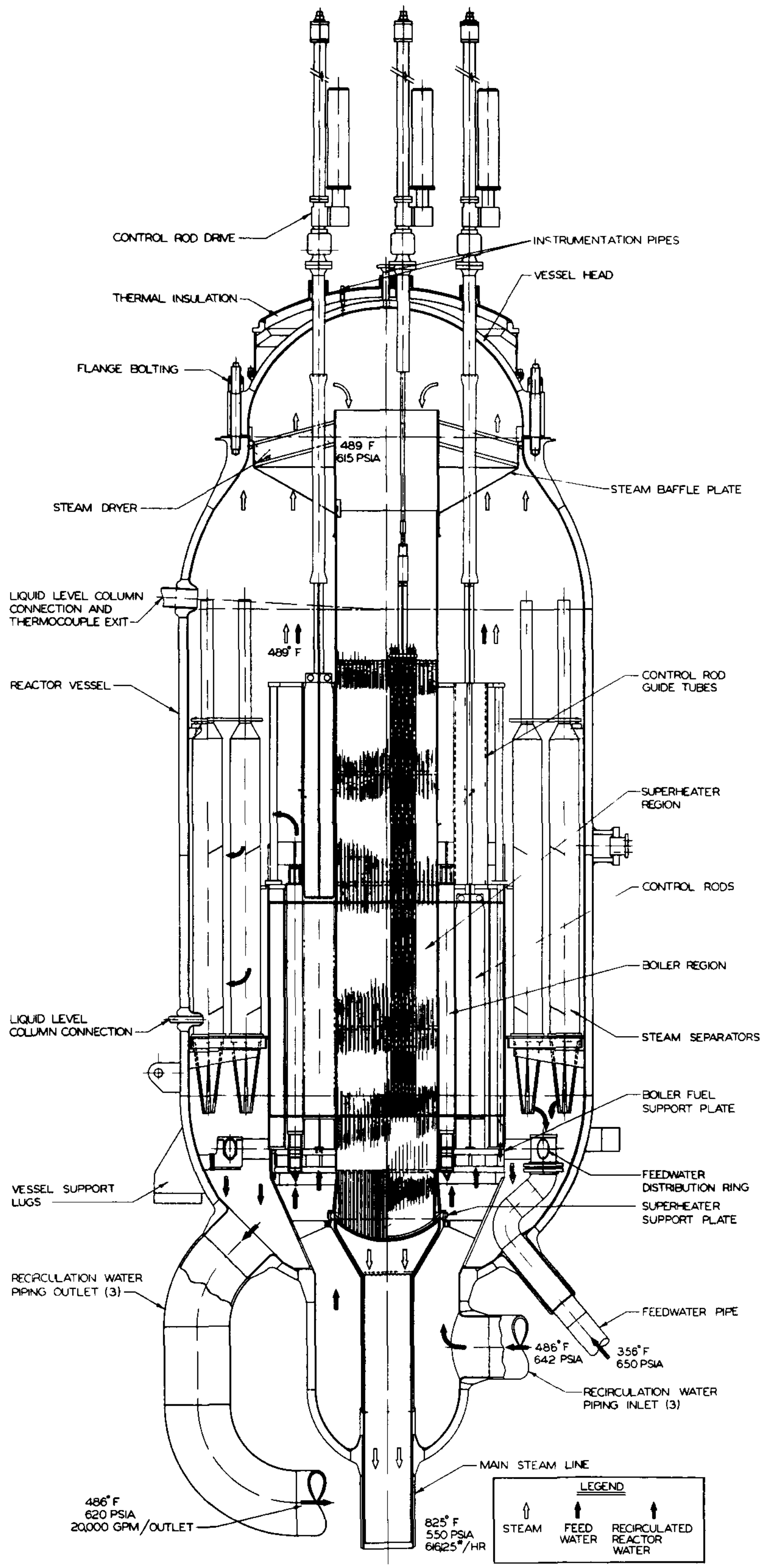

FIGURE 1 – Pathfinder Reactor

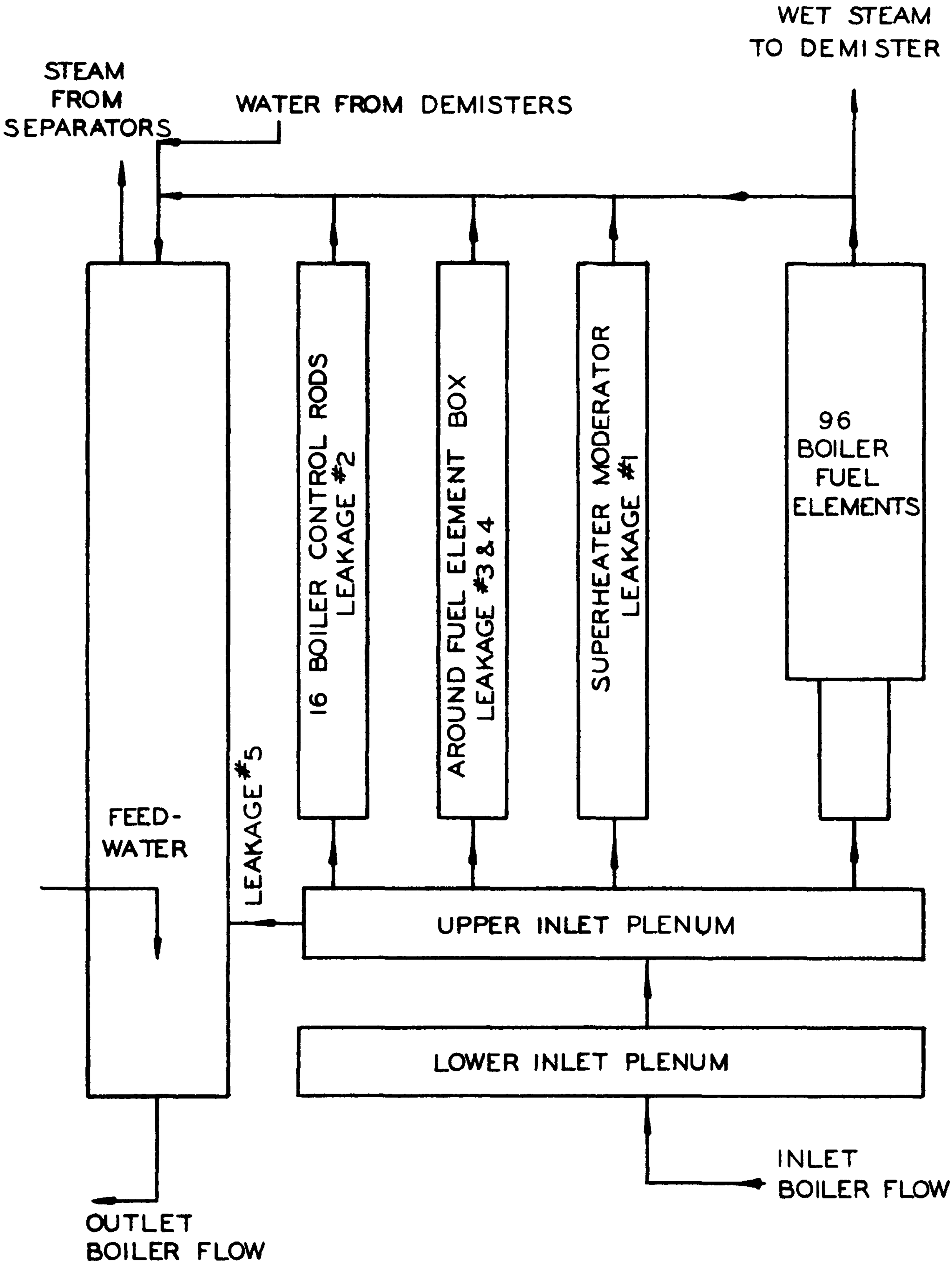

FIGURE 2 – Pathfinder Boiler Flow Paths

3. From the upper inlet plenum around the fuel element nozzles up around the boxes to the outlet region .....

4. From the upper inlet plenum through the clearance between the superheater baffle and the grid plate, up around the boxes to the outlet region .....

5. From the upper inlet plenum through the cooling holes in the under side of the grid plate out through the cooling holes on the outer edge of the grid plate.

It is recognized that the last type of leakage listed is not strictly compatible with the assumption that all of the unheated leakage is mixed with the active flow at the top of the boiler. However, this leakage will later be shown to be only 0.2 per cent of the total boiler flow, and the discrepancy has been neglected.

2. COMPUTATION OF PRESSURE DROPS - PRIMARY FLOW PATHS

The detailed discussion of the pressure drop computations will be restricted to the region between the upper inlet plenum and the boiler outlet region. The pressure drop results from calculations for the rest of the circuit are utilized in establishing the boiler flow rates.

The first portion of this section will be devoted to the calculation of single-phase friction and form losses; other pressure drop components and the effects of boiling are discussed later.

A. Contraction into nozzles.

Nozzle Area = 0.06095 ft.^{2}

Effective Upper Inlet Plenum Area ≐ 27.1 ft.^{2}

$$\Delta P_A = \frac{G^2}{2 g_c \rho} \left(1 - \sigma^2 + k \right) \qquad \text{(Ref. 1)}$$

$$G = \frac{W_A}{(96)(0.06095)}$$

(Memo: For nomenclature and subscripts, see pages 21-23)

$$\sigma = \frac{0.06095(96)}{27.1}$$

$K = 0.04$ (Ref. 1)

B. <u>Nozzle Friction</u>

Nozzle Length = 1.19 ft. $D_e = 0.2785$ ft.

$$\Delta P = \frac{G^2}{2 g_c \rho} \quad \frac{fL}{D_e}$$

$$G = \frac{W_A}{(96)(0.06095)} \qquad f = 0.0093 \quad \text{(Ref. 2)}$$

C. <u>Diffusion from nozzle to region just below fuel grid plate.</u>

Flow area just below grid = 0.1478 ft^2

$$\Delta P = \Delta P_{rec} + \Delta P_{unrec}$$

$$\Delta P_{rec} = \frac{G^2}{2 g_c \rho} (\sigma^2 - 1)$$

Where $G = \frac{W_A}{(96)(0.06095)}$

$$\sigma = \frac{0.06095}{0.1478}$$

$$\Delta P_{unrec} = \frac{(G_2 - G_1)^2}{2 g_c \rho} k$$

$$G_2 = \frac{W_A}{(96)(0.06095)}$$

$$G_1 = \frac{W_A}{(96)(0.1478)}$$

$K = 1.11$ (Ref. 3)

D. <u>Lower Fuel Element Grid Loss.</u>

Flow Area through grid = 0.0661 ft^2

Flow Area in lower half of element = 0.0997 ft^2

$$\Delta P = \Delta P_{rec} + \Delta P_{unrec}$$

$$\Delta P_{rec} = \frac{G^2}{2 g_c \rho} (1 - \sigma^2)$$

$$G = \frac{W_A}{(96)(0.0997)}$$

$$\sigma = \frac{.0997}{.1478}$$

$$\Delta P_{unrec} = \frac{G^2}{2 g_c \rho} k$$

$$G = \frac{W_A}{(96)(0.0661)}$$

k = 0.28 (Ref. 4)

E. <u>Friction in first quadrant.</u>

Length of quadrant = 1.52 ft.

D_e = 0.0386 ft.

ϵ/D_e = 1.292×10^{-4}

$$\Delta P = \frac{G^2}{2 g_c \rho} \times \frac{fL}{D_e}$$

$$G = \frac{W_A}{(96)(0.0997)}$$

f = 0.0157 (Ref. 2)

F. First tube sheet loss.

Flow area in tube sheet = 0.067 ft^2

$$\Delta P = \frac{G^2}{2 g_c \rho} k \qquad G = \frac{W_A}{96\ (0.067)}$$

$k = 0.28$ (Ref. 4)

G. Friction in second quadrant.

(Same as in E.)

H. Second tube sheet loss.

Flow area in third quadrant = 0.1141 ft^2

$$\Delta P = \Delta P_{rec} + \Delta P_{unrec}$$

$$\Delta P_{rec} = \frac{G^2}{2 g_c \rho} (\sigma^2 - 1)$$

$$G = \frac{W_A}{96} (0.0997)$$

$$\sigma = \frac{0.0997}{0.1141}$$

$$\Delta P_{unrec} = \frac{G^2}{2 g_c \rho} k$$

$$G = \frac{W_A}{96\ (0.067)}$$

$k = 0.28$ (Ref. 4)

I. Friction in third quadrant.

Length of quadrant = 1.52 ft

D_e = 0.0484 ft

ϵ/D = 1.088×10^{-4}

$$\Delta P = \frac{G^2}{2 g_c \rho} \frac{fL}{D_e}$$

$$G = \frac{W_A}{96\,(0.1141)}$$

$$f = 0.0162$$

(Ref. 2)

J. Third Tube sheet loss.

(Same as in F.)

K. Friction in fourth quadrant.

(Same as in I.)

L. Upper Grid loss.

Flow area in grid = 0.0736 ft^2

Flow area above grid = 0.1539 ft^2

$$\Delta P = \Delta P_{rec} + \Delta P_{unrec}$$

$$\Delta P_{rec} = \frac{G^2}{2 g_c \rho} (\sigma^2 - 1)$$

$$G = \frac{W_A}{96(0.1141)}$$

$$\sigma = \frac{.1141}{.1539}$$

$$\Delta P_{unrec} = \frac{G^2}{2 g_c \rho} k$$

$$G = \frac{W_A}{96(0.0736)}$$

$$k = 0.28$$

(Ref. 4)

M. Upper end fitting losses.

Flow area at top of fitting = 0.0956 ft^2

$$\Delta P = \frac{G^2}{2\ g_c \rho} (1 - \sigma^2) \qquad G = \frac{W_A}{96\ (.0956)}$$

N. Exit Loss.

The exit loss in terms of static pressure drop is taken to be zero since

$$\Delta P_{exit} = \frac{G^2}{2 g_c \rho} \left[\sigma^2 - 1 + (1-\sigma)^2 \right] \text{ (Ref. 1)}$$

and if $\sigma = 0$,

$$0 - 1 + (1-0)^2 = 0$$

From the standpoint of single-phase isothermal flow, the only pressure drop component not included in the preceding is the elevation loss which is given by:

$$\Delta P_{el} = \frac{g}{g_c} \rho \Delta Z$$

where Z is the vertical distance from the bottom of the core.

During bulk boiling, the analysis is modified as follows:

$$\Delta P_{el} = \frac{g}{g_c} \int \bar{\rho}_{tp} dZ$$

where $\rho_{tp} = R_g \rho_g + (1 - R_g)\rho_L$ and R_g is determined from the modified Martinelli Correlation. (Ref. 5)

The single-phase friction factors are multiplied by the parameter, ϕ_{Lo}^2, which is determined from the Sher-Martinelli method. (Ref. 6)

Where a two-phase mixture flows in a region with which a form loss is associated (items F, H, J, L, and M), the single phase relations are modified by substituting $\frac{1}{\bar{v}_{TP}}$ for ρ where $\bar{v}_{TP} = x v_g + (1 - x) v_f$.

An additional term is included with the friction term for each quadrant to account for fluid acceleration:

$$\Delta P_{acc} = \frac{G^2}{2 g_c} \left[\left[\frac{(1-x)^2}{1-R_g} v_f + \frac{(x)^2}{R_g} v_g \right]_{OUT} - \left[\frac{(1-x)^2}{1-R_g} v_f + \frac{(x)^2}{R_g} v_g \right]_{IN} \right]$$

where G is evaluated in the same way as for the friction term.

Although some sub-cooled nucleate boiling (local boiling) is expected to occur in the first quadrant under normal operating conditions, it has not been accounted for in the pressure drop analysis. This is because this boiling is expected to produce no steam which will significantly affect the coolant flow but only steam bubbles forming and collapsing along the heat transfer surfaces. (Ref. 7 & 8).

In order to simplify the analyses, the static pressure used to evaluate the fluid properties was assumed to be constant at the outlet value at all elevations in the fuel elements. The error due to this assumption is negligible compared to the uncertainties in the pressure drop calculations.

Throughout the preceding discussion, it has been implied that the core pressure drop could be computed from the characteristics of one typical fuel element. The particular characteristic of interest is the fuel element power level since it is known that the pressure drop flow relationship is sensitive to power level. The assumption is that the average core pressure drop is the same as the pressure drop in an average power element. This assumption has been examined analytically for the radial boiler power shapes available and found to result in errors of less than 0.1 per cent.

3. COMPUTATION OF PRESSURE DROPS-LEAKAGE FLOW PATHS

As before, this section is also devoted to the calculation of isothermal single-phase friction and form losses. The non-isothermal and/or boiling effects either do not exist or are negligible for all leakage path calculations except for the flow through a control rod channel where the rod is inserted. However, the nominal control rod cooling leakage calculations are based upon all rods being withdrawn since this represents the maximum leakage. The reduction in leakage has been accounted for in establishing the control rod cooling requirements for an inserted rod but for simplicity will be ignored here. Therefore, non-isothermal and boiling effects on the leakage pressure drops are neglected in this section.

A. Nozzle Leakage.

The calculation of the pressure drop associated with coolant flowing between the fuel element nozzles and the grid plate inserts involves a series of contractions, friction, and expansions. This calculation will not be presented in detail. Standard expressions for friction losses and sudden expansions were used. (Ref. 1)

All contractions were assumed to occur with rounded leading edges, for which an unrecoverable loss coefficient, k, of 0.04 was chosen. (Ref. 1)

ie, $$\Delta P_{contract} = \frac{G^2}{2 g_c \rho} (1 - \sigma^2 + k)$$

The result of this leakage analysis, which was based upon the nominal clearance dimensions between the nozzles and the grid plate inserts, is as follows:

$$\Delta P = 49.2 W^2$$

where ΔP is in psi and W^2 is the leaking flow per nozzle in lb/sec.

B. Grid Plate Leakage.

1. Pressure drop through holes in bottom of grid plate.

Flow area = 0.0109 ft^2

D_e = 0.0416 ft L = 0.167 ft

$$\Delta P = \frac{W_1^2}{2 g_c} \left[\frac{K + (1 - \sigma)^2}{(0.0109)^2} + \frac{fL}{D_e} \right]$$

where W_1 is the leading flow (lb/sec)

K = 0.04 (Ref. 1)

$\sigma \approx 0$

f assumed to be 0.02

2. Pressure drop through clearance between superheater baffle and under side of grid plate.

Flow area in clearance = 0.0589 ft^2

D_e = 0.0104

L = 0.167 ft

$$\Delta P = \frac{W_2^2}{2\rho g_c (0.0589)^2}\left[K + (1 - \sigma)^2 + \frac{FL}{D}\right]$$

where W_2 is the leaking flow

K = 0.04 (Ref. 1)

$\sigma \approx 0$

f assumed to be 0.02

3. Pressure drop through holes in edge of grid plate.

Flow area = 0.0109 ft^2

D_e = 0.0416 ft

L = 0.167 ft

(Same as calculation for holes in bottom of grid plate.)

4. Pressure drop through clearance between superheater baffle and top side of grid plate.

(Same as pressure drop through clearance between superheater baffle and underside of grid plate.)

C. <u>Coolant Flow to Boiler Control Rods.</u>

Here again the calculation of the pressure drop associated with the coolant flowing through the control rod channels involves a series of contractions, frictions and expansions, and will not be presented in detail. All contractions were assumed to occur with rounded leading edges ($K = 0.04$ as in A). The result of this analysis is as follows:

$$\Delta P = 0.0933W^2$$

where ΔP is in psi and W is the coolant flow per rod in lb/sec and the control rod is in the out position.

It is noted that this pressure drop relationship was established by the design requirements for control rod coolant flow of 2.5 per cent of the total boiler flow to all 16 control rods.

D. Superheater Moderator Flow.

The determination of the required superheater moderator flow and the design of the orificing to deliver this flow has been the subject of separate extensive efforts and will not be discussed here. The design of the orifices is such that nominally 6 per cent of the total boiler flow will be diverted to moderate the superheater.

4. DETERMINATION OF LEAKAGES

Once the resistance of each of the leakage paths has been identified and the available driving forces in terms of pressure drops associated with the active flow have been established, the computation of the leakage rates is straightforward. An active boiler flow rate of 54,000 GPM was assumed. Assuming an outlet pressure of 615 psia, static pressures were computed for the upper inlet plenum and the outlet region opposite the holes around the edge of the grid plate. Using these pressures and the previously computed resistances of the leakage paths, the leakage flows were computed as follows in terms of per cent of total boiler flow:

1. Moderator flow to superheater - 6% *

2. Coolant flow to boiler control rods - 2.5% *

3. Around the nozzles - 0.7%

4. Between the superheater baffle and the grid plate - 1.3%

5. Through the holes around the edge of the grid plate - 0.2%

6. Total leakage - 10.7%

* Design requirements.

Thus in order for the assumed active flow of 54,000 gpm to have been available, the total flow entering the reactor would necessarily have been 60,470 gpm.

It is noted that these leakage calculations are rigorously applicable only at nominal full power conditions with a total flow of 60,470 gpm. However, it will be assumed that the relative leakage figures (per cent of total flow) apply at all flows and all power levels. The errors due to this assumption. are negligible; it is true that the relative leakage flows will be slightly reduced as the boiler power is reduced. (Assuming total flow remains essentially constant.)

5. DEPENDENCE OF PRESSURE DROPS ON CORE OPERATING PARAMETERS

Following the determination of the core leakage as a per cent of total flow, standard procedure would call for establishing a recirculation circuit pressure drop vs total flow curve. The intersection between this curve and the pump-head curve would establish the core operating point (the actual total flow). This will be done, but not before several complicating factors have been identified. These factors all stem from the effect of boiling on the core pressure drop. Since the pressure drop is sensitive to the amount (or degree) of boiling, and the core operating point is sensitive to the core pressure drop, any variable which affects the amount of boiling in the core will affect total boiler flow.

Such variables are as follows:

A. Core Power Level ...

B. Core Inlet Subcooling ...

C. Core Pressure ...

D. Axial Power Distribution .

An additional complication arises because these variables plus total boiler flow are all interrelated due to the design of the power plant and method of control. Nevertheless, in order to establish the effect of these variables on core pressure drop, studies have been carried out in which the parameters were varied separately and independently.

The effect of separately varying flow, power, and inlet subcooling on the core pressure drop is shown in Fig. 3. Reasonable changes in the axial power shape have been shown to change core pressure drop by a total of about 0.5 psi. The effect on pressure drop of varying pressure while holding inlet subcooling fixed is considered to be negligible over a range of at least ± 65 psi.

The importance of these effects will be discussed in the next section.

6. DETERMINATION OF BOILER FLOW RATES

The first step is to determine the so-called nominal boiler flow rate. This was based upon the following boiler parameters:

Power 159.8MW (100%)

Pressure 615 psia

Inlet Subcooling 3.8 BTU/lb.

The boiler pressure drop-flow curve (obtained by adding the vessel and piping losses to the core losses) for these conditions and the latest pump head curve are shown in Fig. 4. The nominal boiler flow was established at 64,300 gpm.

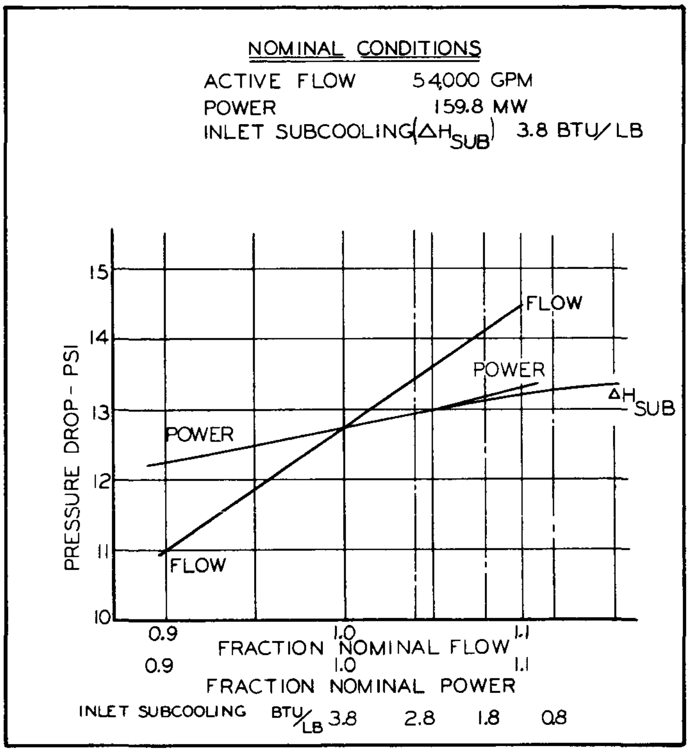

FIGURE 3 – Effects of Flow, Power and Inlet Subcooling on Boiler Core Pressure Drop.

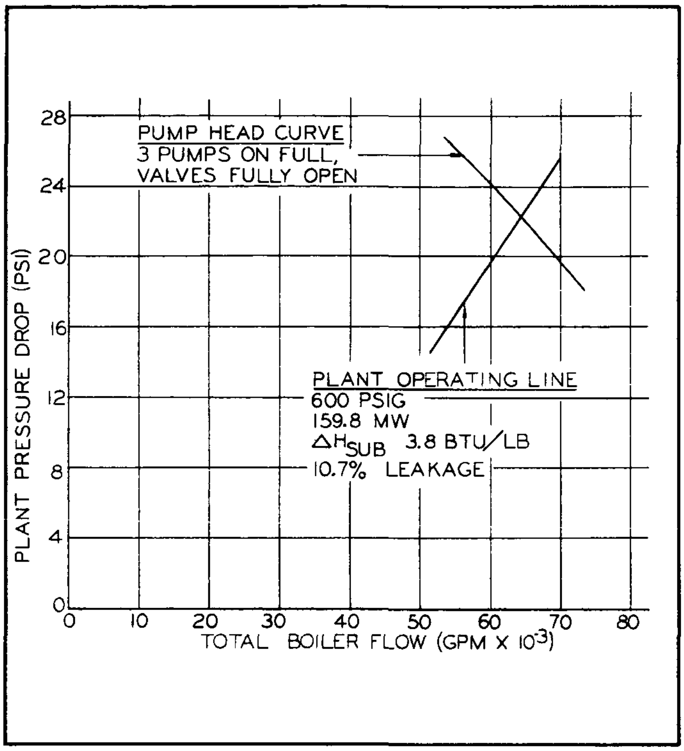

FIGURE 4 – Determination of Nominal Boiler Flow.

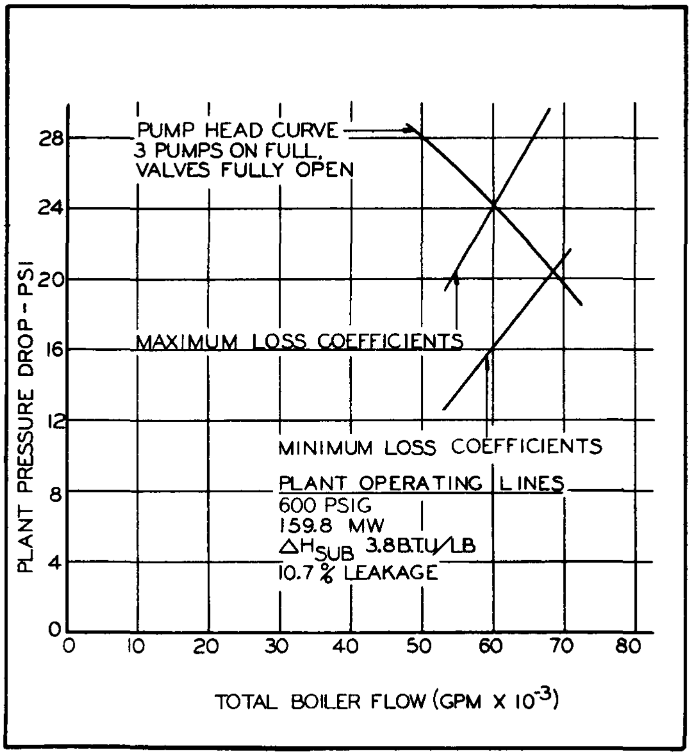

FIGURE 5 – Determination of Maximum and Minimum Boiler Flows.

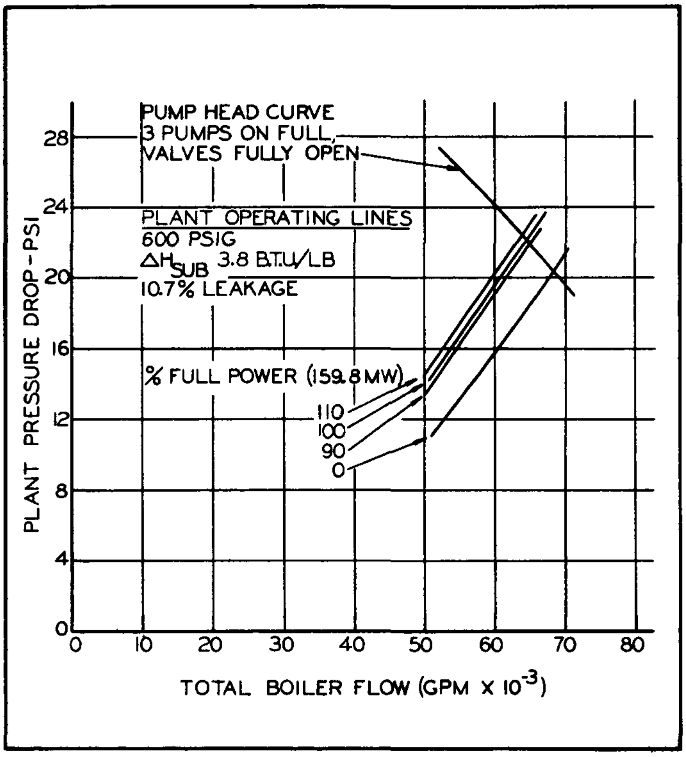

FIGURE 6 – Determination of Boiler Flow as a Function of Power.

Next, uncertainties in the hydraulic analyses were considered.

A.	Core boiling friction and form losses	+ 40% - 25%
B.	Other non-boiling losses	$\pm$ 15%
C.	Other Circuit losses	$\pm$ 10%

The pressure drop-flow curves representing these uncertainties in the extreme combinations are shown in Fig. 5. It is seen that, considering these uncertainties, the minimum boiler flow is 60,000 gpm and the maximum flow is 68,300 gpm. The active flow rates are 53,600 gpm and 61,000 gpm respectively.

The effect of power level changes was taken from Fig. 3 and a separate analysis for zero power. The corresponding pressure drop-flow curves are showing in Fig. 6 and the resulting boiler flow rates are presented as a function of power in Fig. 7.

The effect of changes in inlet subcooling was taken from Fig. 3 and the pressure drop flow curves are presented in Fig. 8.

Using the small perturbation approach, the following expression can be used to predict approximately the boiler flow as a function of power and inlet subcooling:

$$\frac{\Delta F}{F} = 0.07\,\frac{(100 - \%\ \text{Power})}{100} - 0.001597(\Delta H_{sub} - 3.8)$$

Considering that changes in axial power shape can effect core pressure drop by 0.5 psi, the corresponding effect on boiler flow would be 0.46% ($\pm$ 0.23%).

7. NATURAL CIRCULATION FLOWS

Interest in the flow decay following a complete loss of flow accident has stimulated a separate study to estimate the natural circulation flow rate as a function of power level at normal conditions of temperature and pressure. This analysis was

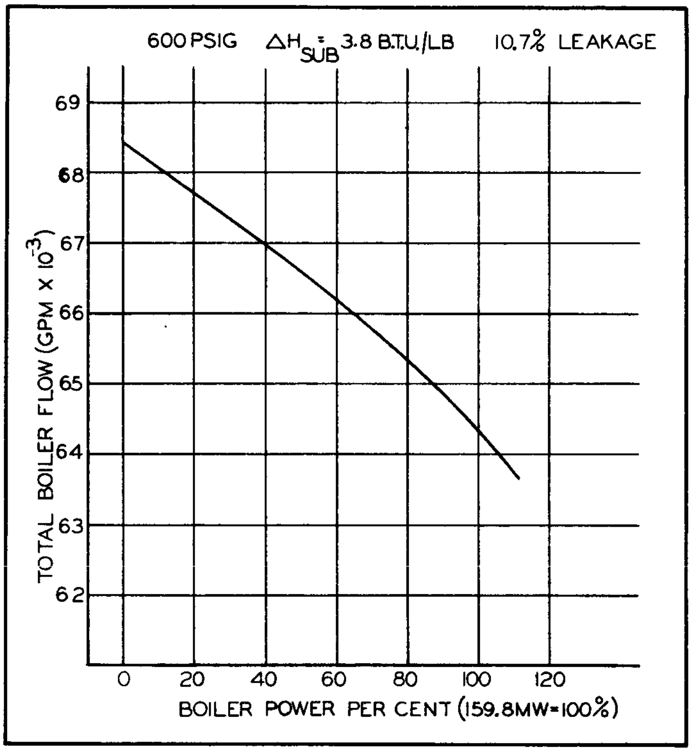

FIGURE 7 – Effect of Power on Boiler Flow.

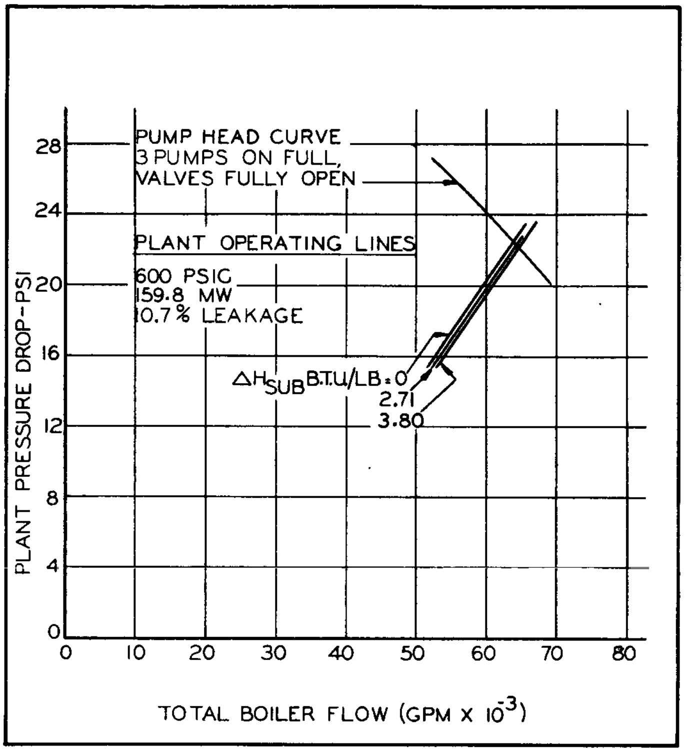

FIGURE 8 – Determination of Boiler Flow as a Function of Inlet Subcooling.

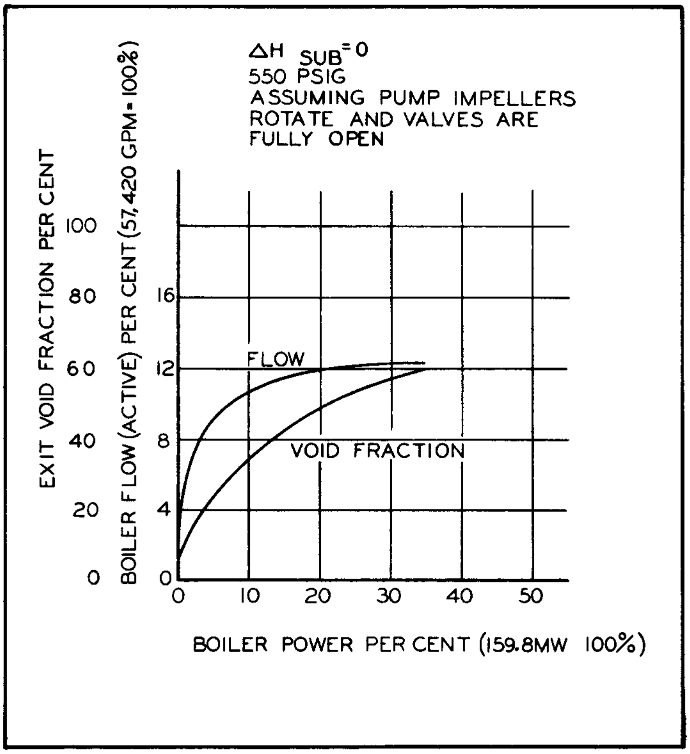

FIGURE 9 – Natural Circulation Performance of Pathfinder Boiler.

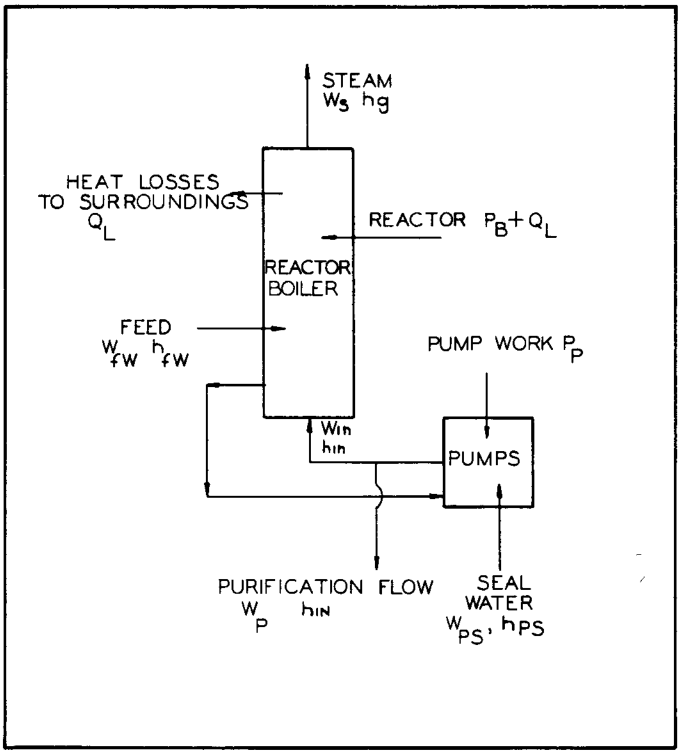

FIGURE 10 – Schematic Diagram of Boiler Mass and Energy Balances.

conducted using the principles previously described and assuming that the pump impellers continued to rotate. The results of this study are shown in Fig. 9.

8. BOILER ENERGY AND MATERIAL BALANCES

Before concluding the discussion of the Pathfinder boiler hydraulics, it is desirable to present the relationships between the boiler parameters of flow, power, pressure and inlet subcooling which arise through the laws of conservation of mass and energy.

A schematic diagram of the important mass and energy streams associated with the boiler is shown in Fig. 10. Omitting the detailed algebra, the following equations have been developed:

$$\Delta H_{sub} = \frac{(h_f - h_{f_w})\ (\eta + \chi)}{1 + \chi + \theta} + \frac{(h_{f_w} - h_{ps})\chi R}{1 + \chi + \theta} \frac{- h_{ps} E}{1 + \chi + \theta}$$

and

$$P_B = W_s \left[h_{fg} + h_f - h_{fw} \right] + W_{ps} \left[h_{fw} - h_{ps} \right] +$$

$$\left[h_{in} - h_{fw} \right] W_P - P_p$$

It is noted that for a given pressure, purification flow (W_p), seal water flow (W_{ps}) and enthalpy (h_{ps}), and power given to the coolant by the pumps (P_p), the number of variables in the two equations is reduced to four. In other words, if any two of the remaining variables are fixed, the boiler system can be completely described. Thus, it is not sufficient to fix only the steam flow (W_s) in addition to the above parameters. The total boiler flow is also important (to a very small extent) because one of the energy streams ($W_p h_{in}$) is dependent on the inlet subcooling. It would be possible to describe the boiler knowing only the steam flow if another equation were available. Such an equation is available (empirical) which relates the boiler flow to the power and inlet subcooling. However the algebraic manipulation of the three equations with four unknowns to one equation with two unknowns will not be presented. Reiterative methods of solution are adequate since the convergence is extremely rapid.

NOMENCLATURE

(In consistent units except where otherwise noted)

D_e	Equivalent Diameter
E	$P_p/W_{in}\ h_{ps}$ (See Fig. 10)
f	Friction factor
F	Total boiler flow rate
G	Mass velocity
g_c	Conversion factor
h	Enthalpy
ΔH_{sub}	Inlet subcooling
k	Pressure loss coefficient
L	Duct length
$\mathcal{L}$	W_p/W_{in} (See Fig. 10)
ΔP	Static Pressure difference
P_B	Boiler power (less heat losses)
P_p	Energy transferred to fluid from pumps
R	W_{ps}/W_p (See Fig. 10)

R_g	Void fraction
v	Specific volume
$\overline{v_{TP}}$	Mean mixture specific volume
W_A	Active flow rate
W_s	Steam flow (See Fig. 10)
X	Weight fraction of steam flowing (quality)

G R E E K

η	$\frac{P_B - Q_L}{W_{in}\ \lambda}$ (See Fig. 10)
θ	$\frac{h_f - h_{fw}}{\lambda}$ (See Fig. 10)
λ	Latent heat of vaporization (same as h_{fg})
ρ	Density
$\overline{\rho}_{TP}$	Mean mixture density
σ	Area of ratio (equal to or always less than unity)
Φ_{Lo}^2	Two-phase friction multiplier

SUBSCRIPTS

acc	Acceleration pressure drop component
f	Saturated liquid property
fw	Denotes feedwater characteristic
g	Saturated vapor property
in	Denotes inlet condition
out	Denotes outlet condition
p	Denotes purification flow characteristic
ps	Denotes seal water flow characteristic
rec	Pressure drop (or gain) which is recoverable (or is being recovered)
s	Steam property
unrec	Pressure drop which is not recoverable

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