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REPORT

DETERMINATION OF MAXIMUM NUCLEAR TUBE POWERS
BASED ON BOILING BURNOUT

DECEMBER, 1965



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DETERMINATION OF MAXIMUM NUCLEAR TUBE POWERS BASED ON BOILING BURNOUT

Ву

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Reactor and Materials Technology Department

December, 1965

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DETERMINATION OF MAXIMUM NUCLEAR TUBE POWERS

BASED ON BOILING BURNOUT

PURPOSE

This report proposes a procedure for calculating the maximum tube power of a pressure tube reactor, based on boiling burnout. A primary purpose of developing this particular procedure is to provide a method of calculating maximum tube powers for the Plutonium Recycle Test Reactor (PRTR) which is flexible enough to easily accommodate changes in reactor conditions and to incorporate new knowledge as it becomes available.

INTRODUCTION

One factor that is always considered in establishing the maximum operating limits of a water-cooled nuclear reactor is boiling burnout.* This factor is considered since it results in increases in fuel element temperatures which may cause serious damage to the fuel elements.

Several problems exist in defining boiling burnout limits for a nuclear reactor. First, the conditions causing boiling burnout are not completely understood and a theoretical solution is impossible at this time. Therefore, boiling burnout conditions are defined from experimental data - either directly or through an empirical correlation.

Second, defining local conditions within a reactor involves many variables which cannot be defined with complete certainty. Third, the administration of the limits has to be in terms of those reactor variables which are measured; namely, flows, temperatures, and powers.

Generally, these complexities and difficulties of determining boiling burnout limits are reduced by using an arbitrarily simplified analysis. Usually, such an approach applies to a specific fuel element in a given reactor for a narrow range of operating conditions. Different reactor types, new fuel elements, changes in operating conditions, or even new information concerning the boiling burnout process or reactor local conditions all require a complete new boiling burnout analysis. The lack of broad application of burnout analysis is particularly acute for test

^{*}The term, "boiling burnout" is used in this report to mean that change in boiling heat transfer which results in a severe deterioration in the heat transfer mechanism accompanied by a large increase in surface temperature. Among other names for this phenomenon are critical heat flux, peak heat flux, and DNB (departure from nucleate boiling).

reactors whose very purpose is to test different fuel elements over a range of operating conditions. What is needed is a boiling burnout analysis of sufficient generality and flexibility to accommodate a variety of reactor operating conditions and to incorporate new information as it becomes available. This report outlines such a method which was developed for the PRTR, but which is appropriate for any pressure tube reactor.

SUMMARY AND CONCLUSIONS

A method is described to define the maximum tube power of a pressure tube reactor as limited by boiling burnout. The method divides all those factors involved in a boiling burnout analysis into two groups and a factor called a consequence factor. The two groups consist of:

- 1) Those whose value and effect can be defined with reasonable accuracy, and
- 2) Those whose value or effect is uncertain but which must be estimated.

The consequence factor is determined from an assessment of the consequences of boiling burnout. These factors and the relation they impose between the boiling burnout heat flux and the average heat flux derived from the measured tube power are shown in Table I.

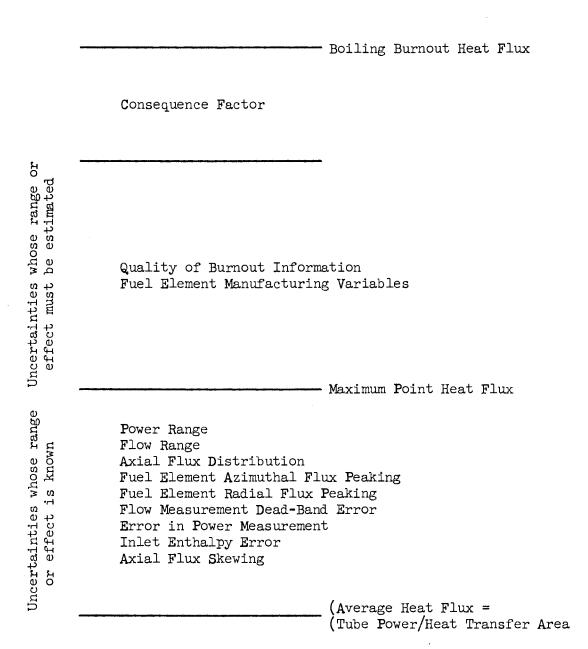
The first group of factors - those whose values and effect can be defined in an exact analytical manner - are used to define operating curves of tube power expressed as heat flux vs. coolant enthalpy. The second group of factors and a consequence factor are used to adjust boiling burnout data to define burnout curves which are also expressed as heat flux vs. coolant enthalpy. The maximum operating tube power is then defined as the greatest tube power whose operating curve is less than the boiling burnout curve at all points. This results in the maximum possible heat flux at any point along the length of the fuel element being less than the minimum possible boiling burnout heat flux by some amount determined by an evaluation of the consequences of boiling burnout.

The proposed method can be applied to any pressure tube reactor and can be extended to any pressure vessel reactor, but was developed primarily for the PRTR. It differs from the method currently used for the PRTR in that it is more flexible. It allows calculation of a maximum tube power appropriate for any fuel element and operating condition rather than a fixed maximum tube power for the reactor which must be completely reexamined for any slight change in fuel element or operating condition. Furthermore, it identifies each of the uncertainty values and allows new knowledge which affects an uncertainty to be incorporated by simply adjusting the appropriate factor.

The method requires that those factors whose value or effect is uncertain be estimated conservatively. Furthermore, it assumes that all those factors whose value and effect are known occur simultaneously in the most adverse

manner at that point in the reactor which is closest to boiling burnout. This is a highly unlikely circumstance and makes the method conservative. Higher power levels could be obtained by use of a statistical analysis of the probability of boiling burnout occurring.

TABLE I. UNCERTAINTIES IN BOILING BURNOUT ANALYSIS



BASIS

The uncertainties which enter into a reactor boiling burnout analysis are of two kinds:

Į,

- 1) Those whose range or magnitude and whose effect are known, and
- 2) Those for which either the magnitude or effect is unknown and must be estimated.

An example of the first kind might be uncertainties in a measured coolant flow rate. There are errors in flow measuring instruments and, further, the flow to a reactor may vary within prescribed limits before corrective action is mandatory. The flow at any given time could differ from the nominal value by as much as the magnitude of the flow instrument error plus the magnitude of the permitted range of flows. In this case, however, the magnitudes of both these uncertainties are known or can be estimated quite accurately. Furthermore, the effect of these errors on local conditions in the reactor can be calculated. This method will assume that errors of this type have occurred to their maximum value in the most adverse direction.

An example of the second type of error might be the boiling burnout relation used. If the boiling burnout relation were derived from data obtained with a test section different from the reactor fuel element, there are unknown uncertainties in the application of the data to the reactor. This method requires the use of a new boiling burnout relation gotten from an arbitrary reduction of the original relation to account for the differences. The reduction is inexact but is chosen to be conservative.

This proposal is appropriate for a pressure tube reactor where the coolant flow and power of each tube are measured. It proposes to calculate the expected boiling burnout heat flux at every location along the element and requires that this value be greater than the actual heat flux at each point by some amount termed the consequence factor.

A listing of the uncertainty factors and the relation they and the consequence factor impose between the average tube heat flux and the boiling burnout heat flux is shown in Table I. The listing is not necessarily complete and is somewhat arbitrary. A specific reactor and fuel element case might require the addition or deletion of items from the list, or might require the exchange of items between the categories of known and unknown uncertainties.

COMPARISON WITH OTHER ANALYSES

It is difficult to compare methods of developing boiling burnout limits because the various groups doing so have developed their own approaches and arbitrary simplifications. The general approach of the method of this report is quite similar to several of those currently in use.

The method of this report does differ from most methods in its manner of taking care of a boiling burnout safety factor. Most boiling burnout safety factors are not only safety factors, but are also intended to account for some of the uncertainties. The method of this report proposes to use a consequence factor, not to account for some uncertainties, but rather to provide any additional assurance deemed necessary that boiling burnout will not occur.

A typical example is a case where a BOSF of 1.4 is prescribed.* BOSF is defined as "(hot spot factor) x (burnout heat flux)/(nominal operating heat flux). The hot spot factor takes into account non-idealities in the flux distribution and deviations in dimensions, flow, and composition from the nominal characteristics of the assembly. The burnout heat flux is estimated from interpolation of experimental data obtained from burnout tests; the factor of 1.4 takes into account uncertainty in these data. The method of this report proposes to account for all the various uncertainties separately and to use a consequence factor strictly as a measure of the desired insurance that boiling burnout does not take place.

This method also differs from many boiling burnout analyses in that it does not give one maximum heat flux or tube power as a limit. Many analyses assume a worst set of reactor conditions and determine a maximum reactor power level or tube power for those conditions. The reactor is then limited to powers less than this, even though the operating conditions are usually less stringent than those used in the analysis. An example of this is the 1800-kw tube power and 650,000 Btu/hr heat flux currently applying to the PRTR. ** These were derived for a flow rate of about 110 gpm and a reactor inlet temperature of 443°F.† If the flow rate were greater than, or the inlet temperature lower than, those used in the calculations, a higher limit would be appropriate. In fact, in this case, the calculations were made to show that the specified limits would not cause boiling burnout, and that tube powers greater than 1800 kw could conceivably be used. This method proposes to recognize that changes in reactor operating conditions will change the possibility of boiling burnout and will provide a way to change the boiling burnout limit with changes in reactor conditions.

^{*}D. S. St. John, et al. "Preliminary Hazards Evaluation of the Heavy Water Components Test Reactor (HWCTR)," DP-383, May, 1959.

^{**}H. E. Hanthorn, W. K. Winegardner, and N. G. Wittenbrock. "Plutonium Recycle Test Reactor Final Safeguards Analysis - Supplement 6 - Revised Limits; Analysis of Uniformly Enriched Core," HW-61236 SUP 6, February, 1963.

tG. M. Hesson and J. M. Batch. "Thermal Hydraulics Analysis of PRTR Fuel Elements at 1800 KW Tube Power," HW-75728, December, 1962.

NOMENCLATURE

As Heat transfer area per unit length.

BCF Burnout consequence factor.

f() Relationship giving specific power along fuel element as a function of tube power and distance from inlet end of fuel element.

f'() Relationship giving boiling burnout heat flux as a function of flow rate, enthalpy, and pressure.

FS Flux skewing factor.

g() Relationship giving integrated power along fuel element as a function of tube power and distance from inlet end of fuel element.

g'() Relationship giving burnout safety factor as a function of enthalpy.

HE Maximum error in inlet enthalpy.

H_i Inlet enthalpy.

 $\mathbf{H}_{\mathbf{x}}$ Coolant enthalpy at any point, \mathbf{x} , along the fuel element.

P Tube power.

PE Maximum possible error in power measurement.

PR Maximum range of power drift before corrective action is mandatory.

P_x Specific power at any point, x, along the length of a fuel element.

S_x Total power transferred to the coolant up to point x along the fuel element.

W Coolant flow rate.

WC Maximum error in flow calibration.

WE Maximum error in flow measurement dead band.

WR Maximum range of flow drift before corrective action is mandatory.

φA Maximum azimuthal flux peaking.

φB Burnout heat flux.

Ψox Maximum heat flux at any point, x, along the fuel element.

φR Maximum radial peak to average heat flux due to self-shielding.

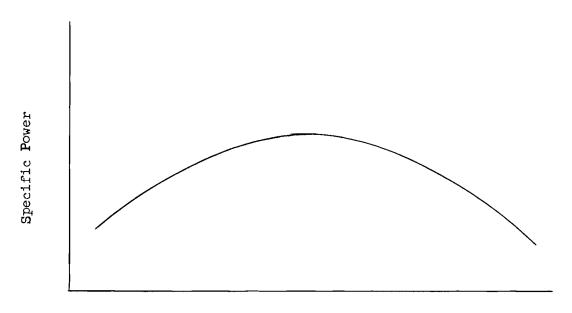
 $\phi_{\rm x}$ Radial average heat flux at any point, x.

π Pressure.

DEVELOPMENT

Proximity to Boiling Burnout

The axial power of a nuclear reactor fuel element varies and a typical distribution is shown in Figure 1.



Length

Figure 1.

The specific power at any point along the length of the test section is some function of the axial position and the total power:

$$P_{x} = f(P,x) .* \tag{1}$$

The total power transferred to the coolant up to point \mathbf{x} is the integral of the above equation evaluated at point \mathbf{x} , or

$$S_{y} = g(P,x) . (2)$$

The enthalpy of the coolant at any point, x, is the inlet enthalpy plus the power generated up to that point divided by the flow rate:

$$H_{x} = H_{1} + \frac{S_{x}}{W}. \tag{3}$$

^{*}The nomenclature is defined on page 6.

Combining Equations (2) and (3):

$$H_{x} = H_{i} + \frac{g(P,x)}{W}. \qquad (4)$$

The heat flux at any point, x, is the specific power at that point divided by the heat transfer area per unit length:

$$\varphi_{\mathbf{X}} = \frac{\mathbf{P}_{\mathbf{X}}}{\mathbf{A}_{\mathbf{S}}} \tag{5}$$

or, combining Equations (1) and (5):

$$\varphi_{X} = \frac{f(P, X)}{A_{S}}. \tag{6}$$

For a given flow rate and tube power, it is possible to eliminate the length x from Equations (4) and (6) and determine the heat flux as a function of coolant enthalpy. This is illustrated in Figure 2 as the curve identified "operating curve."

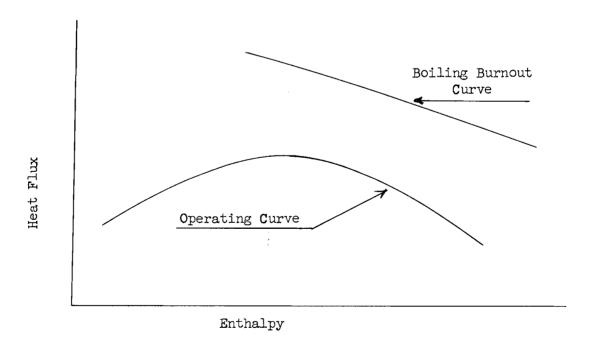


Figure 2.

Also shown in Figure 2 is a typical curve of boiling burnout heat flux vs. enthalpy. As long as the boiling burnout heat flux at any point along the fuel element is greater than the operating heat flux, boiling burnout will not occur. The problem remaining, then, is to provide adequate assurance that the boiling burnout curve will always be above the operating curve.

Uncertainties in Operating Heat Flux

The first step in providing the assurance is to modify the operating curve from the nominal to the worst case possible, with all of the uncertainties of the first group of Table I at their most adverse values. An operating reactor will have instrumentation which will measure the temperature rise and coolant flow, and hence power for each tube. However, there are inaccuracies in any instrument and the true power and flow and, hence, the heat flux and local enthalpy may be in error. That is:

$$\varphi_{X} = \frac{f[(P \cdot PE), x]}{A_{S}}$$
 (7)

and

$$H_{x} = H_{i} + HE + \frac{g[(P \cdot PE), x]}{W \cdot WE \cdot WC}. \tag{8}$$

It may be noted that, in general, the power error arises from two other measurement errors, namely, the flow error and temperature increase error. The total flow error is made up of two parts, the dead-band error and the calibration error of the flow measuring instrument. Actually, then, in Equation (8), the terms WE and WC appear in both the numerator and denominator of the last term. In practice, the WC terms will cancel, but the WE term should be assumed to be at its maximum value in the numerator and minimum value in the denominator.

Furthermore, the reactor operating conditions are not absolutely constant even during nominal steady-state operating conditions, but may wander within specified ranges before corrective action is required. The flow and tube power may, therefore, differ somewhat from the nominal values used in determining the local heat fluxes and enthalpies. The local heat fluxes and enthalpies may, therefore, be:

$$\varphi_{x} = f[(P \cdot PE \cdot PR), x]$$
 (9)

and

$$H_{x} = H_{i} + HE + \frac{g[(P \quad PE \quad PR), x]}{W \cdot WE \cdot WR \cdot WC}. \tag{10}$$

These give an operating curve different from the nominal operating curve, as shown in Figure 3. Figure 3 shows the actual operating curve nearer to boiling burnout than is the nominal operating curve. This need not necessarily be the case. The errors and wanderings of the variables are equally as likely to be such that the actual operating curve is farther from the boiling burnout curve than is the nominal curve. However, for boiling burnout considerations, the worst case operating curve is examined. It may also be pointed out that this is a conservative approach since it says that that tube which has the largest adverse error in its flow measurement also has the largest adverse flow wander and has the largest adverse temperature error. This is an unlikely set of circumstances.

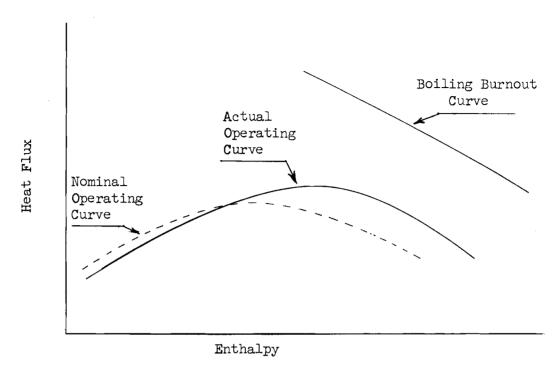


Figure 3.

There is yet another correction to be made to the operating curve. There are neutron and, hence, heat flux gradients across a fuel element at any axial location. These are of two kinds. The first is a depression of the fluxes across the fuel element due to self-shielding called radial peaking. The second is due to neutron gradients across the reactor called azimuthal peaking. A fuel element in a region of such a gradient will have a higher heat flux on the side of the fuel element facing the high neutron flux region of the reactor. The maximum local heat flux at a given axial location will be higher than the calculated average by the combined amount of these gradients. That is:

$$\varphi_{Ox} = \varphi R \varphi A \cdot f[(P \cdot PE \cdot PR), x]. \qquad (11)$$

Uncertainties in Boiling Burnout Heat Flux

Boiling burnout curves, such as shown in Figures 2 and 3, can come from several sources. One source is any one of several empirical correlations of boiling burnout data existing in the literature. None of the correlations can predict boiling burnout with even reasonable accuracy for all possible conditions. If the reactor conditions under consideration fall within the range of conditions under which the experimental data for a correlation were obtained, then that correlation may be used to develop the boiling burnout curves shown in Figure 3. In such a case, the boiling burnout curve should be placed at or slightly below the experimental accuracy of the correlation. Typically, the stated accuracy of such correlations is of the order of ± 15 to 30%. If the reactor conditions under consideration fall outside the conditions of any of the correlations, a further error term should be applied, the magnitude of which is largely a matter of judgment.

A second source of boiling burnout curves is any one of several boiling burnout design relations. These are basically the same as the boiling burnout correlations discussed above except that they are simplified for easier design use and they are developed to lie below all or almost all experimental data used in their development. They are usually quite conservative. If the conditions of the reactor under consideration fall within the range of conditions of the experiments used to develop a design relation, that relation may be used directly to develop the boiling burnout curves shown in Figures 2 and 3. Since these design relations are simplified experimental correlations, their claim to generality is nil and their extrapolation to other conditions should be done with caution.

A third choice is the plotting of experimental data points to form the boiling burnout curves such as shown in Figures 2 and 3. If the test section used in the laboratory experiments to obtain the data conforms to the fuel element geometry, such a choice is better than using a correlation where some accuracy is sacrificed for attempts at generality. The boiling burnout line through the experimental points should be drawn to reflect the experimental scatter. Any extrapolation to conditions beyond the experimental conditions should be done conservatively.

Defining the appropriate boiling burnout relation to use is difficult, particularly in the absence of direct experimental data. Careful judgment is required to establish a realistic relation which neither penalizes the reactor by being too conservative nor endangers the reactor by being too optimistic.

Whatever source of boiling burnout information is used, it is possible to define a boiling burnout relation for a given fuel element in terms of the reactor operating variables - flow rate, enthalpy, and pressure:

$$\varphi B = f'(W,H,\pi) . \tag{12}$$

This form of relation is proposed for use in this boiling burnout determination analysis. For a given flow rate and pressure, it will give curves relating burnout heat flux to coolant enthalpy such as shown in Figure 3. The development of the boiling burnout relation should account for all the uncertainties in knowledge of actual boiling burnout in the reactor. These include not only the uncertainties in the source of the boiling burnout relation, but also uncertainties in reactor conditions which affect boiling burnout. These latter include such things as geometry differences between the test section used to obtain the boiling burnout data and the fuel element used, differences in fuel elements permitted by manufacturing tolerances, and eccentricity problems between fuel element parts and pressure tube.

Axial Flux Skewing

There is one other facet of the problem to be considered. That is, the axial heat flux distribution of the reactor may be unknown, but may be something other than the relation, such as illustrated in Figure 1, which is

used to determine the heat flux-enthalpy relations shown in Figures 2 and 3. This problem is particularly acute when shim or control rods are used and are positioned in the upstream half of the reactor. In these cases, the heat flux pattern is skewed toward the downstream end as illustrated in Figure 4. The two operating curves of Figure 4 would have the same total tube power, but the skewed curve has higher heat fluxes in its downstream half and is, therefore, closer to boiling burnout than is the nominal or calculated curve. The best way to handle this problem is to eliminate it by using the worst case of skewing the reactor might have, if it is known. This is probably conservative, since those fuel elements which have the worst skewing are those which are close to the shim or control rods. Such fuel elements would have a lower power level than the average and would not, therefore, be the ones approaching boiling burnout.

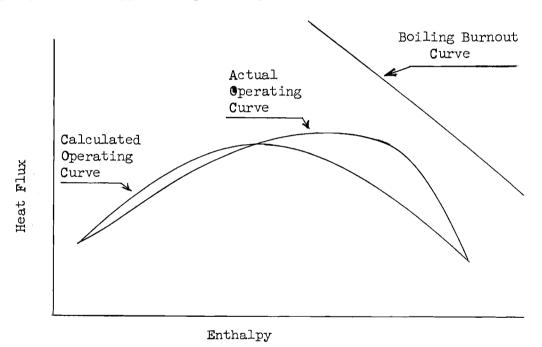
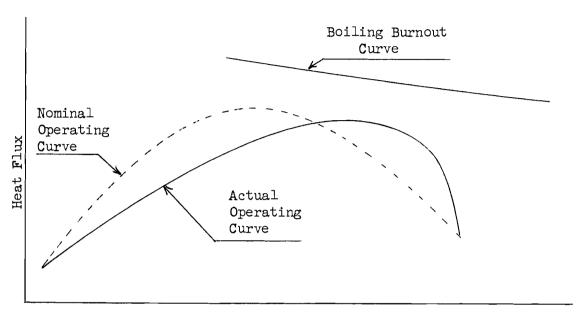


Figure 4.

If the worst case axial flux distribution is not known, a problem is posed which is somewhat more difficult than those considered thus far. The very fact that the axial flux distribution is not known forces the use of judgment to establish a somewhat arbitrary correction. Also, a flux could be quite severely skewed without significantly worsening the boiling burnout potential. This is illustrated in Figure 5. The worsening of the boiling burnout potential depends on the magnitude of the skewing, the location of the axial peak heat flux, and the shape of the boiling burnout relation.



Enthalpy

Figure 5.

It is proposed to account for axial skewing by requiring that the ratio of the boiling burnout heat flux to the operating heat flux at any point along the fuel element be larger than some arbitrary ratio

$$\frac{\varphi B}{\varphi_{\text{ox}}} \ge FS$$
 , (13)

where the flux skewing factor FS is estimated to conservatively represent the worst axial flux skewing which might occur.

Boiling Burnout Consequence Factor

Performing the calculations indicated in Equations (1) through (13) for a given flow rate, inlet temperature, and pressure will produce a tube power for an answer. If all factors which affect the possibility of boiling burnout are accounted for and are accounted for correctly, then operation at this tube power could result in operation exactly at the boiling burnout point. However, it may be pointed out that this is conservative since it assumes that all the adverse factors are operating simultaneously on that tube which is closest to boiling burnout. The probability of this is extremely small.

A further decrease in the tube power may be desired to assure that boiling burnout will not occur. It is proposed to do this by requiring that the ratio of boiling burnout heat flux to operating heat flux of Equation (13) be increased by a further term:

$$\frac{\varphi B}{\varphi_{OX}} \stackrel{>}{=} FS \cdot BCF$$
 (14)

The term BCF is the boiling burnout consequence factor and is so named because its sole purpose is to provide any additional assurance thought necessary that boiling burnout will not occur. Its magnitude is a matter of judgment and is influenced by the expected severity of the consequences of boiling burnout.

Illustrative of considerations in establishing such a boiling burnout consequence factor is the fact that experimental evidence shows that if boiling burnout occurs with highly subcooled coolant, the magnitude of the resulting fuel element temperature increase is very large. Severe damage to the fuel element would be almost certain so a reasonably large burnout consequence factor would be desired. On the other hand, experimental evidence shows that if boiling burnout occurs in a steam quality region, the temperature excursions are quite small. Indeed, there is some expectation that further experimental work will demonstrate the feasibility of deliberately disregarding boiling burnout when high quality steam is present. If quality steam is present, the boiling burnout consequence factor could be quite small, and conceivably, less than 1.0.* For a reactor which has subcooled coolant at its inlet and discharges steam, a sliding consequence factor which is high for high subcoolings and low for high qualities might be warranted.

If a sliding consequence factor were chosen, it would be some function of enthalpy; i.e.,

$$BCF = g'(H) , \qquad (15)$$

and the required boiling burnout heat flux to operating heat flux is:

$$\frac{\varphi B}{\varphi_{\text{ox}}} \stackrel{\geq}{=} FS \cdot g'(H)$$
 (16)

SUMMARY OF METHOD

The determination of a maximum tube power for a nuclear reactor as limited by boiling burnout will involve the following steps:

- l. Determine the maximum deviation from calculated nominal power. This will be $PE \cdot PR$.
- 2. Determine the maximum deviation from calculated nominal flow-
 - This will be WE . WR.

^{*}A consequence factor less than 1.0 would allow boiling burnout to occur at the highly infrequent periods when all the factors affecting boiling burnout were occurring simultaneously in their most adverse manner because the fuel temperatures reached would not be expected to be particularly serious in these cases.

3. Determine the maximum flux peaking at any axial location.

This will be $\varphi R \cdot \varphi A$.

4. Determine an axial specific power distribution.

This will be $P_X = f(P,x)$.

5. From the axial power distribution, determine the total power distribution.

This will be $S_X = g(P,x)$.

6. Using the flux peaking term, the power error correction, and the axial specific power distribution, determine the axial heat flux distribution.

This is $\phi_X = f[(P \cdot PE \cdot PR), x] \cdot \phi R \cdot \phi A$.

7. Using the power error term, the flow error term, the inlet enthalpy term, and the axial total power term, determine the axial coolant enthalpy distribution.

This is
$$H_X = H_1 + HE + \frac{g[(P \cdot PE \cdot PR), x]}{W \cdot WE \cdot WR \cdot WC}$$
.

8. Combine the Equations of Steps 6 and 7 to eliminate x. This will define the heat flux in terms of the enthalpy or

$$\phi_{OX}$$
 = f(H_i, P, W), or for a given inlet temperature, ϕ_{OX} = f(H, P, W).

9. Determine a boiling burnout relation and express it in terms of enthalpy, flow rate, and pressure.

This is $\phi B = f'(H, W, \pi)$.

10. Determine the ratio of operating flux to burnout flux.

$$\frac{\varphi B}{\varphi_{OX}} = \frac{f'(H, W, \pi)}{f(H, P, W)}.$$

- 11. Determine an appropriate skewing factor.
- 12. Determine an appropriate burnout consequence factor.
- 13. Determine the ratio of operating flux to heat flux which is equal to the product of the skewing factor and the burnout consequence factor

$$\frac{f'(H, W, \pi)}{f(H, P, W)} = FS \cdot BCF.$$

14. There are four unknowns in the equation of Step 13 - H, W, P, and π . If π , W, and H are fixed (H is fixed by fixing an inlet temperature), the equation given in Step 13 can be solved for P, the maximum permissible tube power, for those conditions.

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Doing the indicated calculations, while somewhat tedious, is quite straight-forward. An analytical solution is theoretically possible if analytic relations for the axial power distribution and burnout heat flux are used. However, the analytical relations, particularly for the axial power distribution, are usually so complex that recourse to a graphical or iterative method is required. The calculations are amenable to computer solution.

The above calculations give the maximum tube power for a specified fuel element and set of conditions. If it is desired, further calculations can be made which give both the location and the heat flux at the point of peak axial heat flux.

The above calculations can be repeated for other operating conditions within the ranges of interest to give the appropriate maximum tube power for each case. The case of a new and different fuel element can be handled by using the boiling burnout relation appropriate for that fuel element design. New information can be handled by adjusting the appropriate factor. For example, the axial flux distribution relation and the axial flux skewing factor can be adjusted when and if improved knowledge of the axial flux distribution becomes available. Or, as new and improved boiling burnout information becomes available for a given fuel element, the boiling burnout relation used in these calculations can be more realistic and probably less conservative.

This procedure can define the maximum tube power for each tube in the reactor and can do so including the most up-to-date information available.

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