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PERMEABILITY OF THE ND215 REIMPREGNATED INNER REFLECTOR
CYLINDER - DATA ANALYSIS AND DESIGN SIGNIFICANCE
(Title Unclassified)

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by H. F. C. TIC, date SEP 11 1973

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INFORMATION CATEGORY

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Westinghouse Electric Corporation
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Large, Pennsylvania
1 June 1964

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June 8, 1964

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Subject: WANL-TME-788, "Permeability of the ND215 Reimpregnated Inner
Reflector Cylinder - Data Analysis and Design Significance," dated
1 June 1964

Dear Mr. Schroeder:

Transmitted herewith are three (3) copies of the subject report.

This report is transmitted for your information.

Respectfully,

H. F. Faught
Program Manager
NERVA Nuclear Subsystem

Enclosures - 3

cc: Mr. R. Wilke, SNPO-C Resident Office at WANL
Mr. G. O'Brien, SNPO-C Resident Office at WANL

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CONCLUSIONS AND RECOMMENDATIONS

An analysis of the permeability test data obtained on a reimpregnated inner reflector cylinder, similar to that which is to be used on the NRX-A2 reactor (ND10202), indicates the following items of design significance.

- a. The reimpregnation of the ND215* inner reflector cylinder reduced the amount of porous flow by a factor of approximately 80.
- b. The porous flow through the reimpregnated inner reflector cylinder test specimen can be expressed as follows:

$$\frac{WL}{A} = 7.0 \times 10^{-10} \left[\frac{P_1^2 - P_2^2}{\mu R T} \right]^{0.725}$$

where:

- w = porous flow rate, lb_M/sec
- A = average area through which flow passes, square inches
- L = average length of porous flow path inches
- P_1 = pressure on high pressure side of reflector, psia
- P_2 = pressure on low pressure side of reflector, psia
- μ = viscosity of gas, $\text{lb}_M/\text{ft. sec.}$
- R = gas constant, $\text{ft-lb}_F/\text{lb}_M - ^\circ\text{R}$
- T = average temperature of gas flowing through the reflector, $^\circ\text{R}$

- c. The porous flow through the reimpregnated inner reflector cylinder exerts a small effect on the seal pressure distribution.
- d. The accumulated seal flow rates show a slight change from that which is calculated with no porous flow. This change would be revealed in a hot test as an increase in seal bulk fluid temperature over the dome-end half of the core and a reduced seal bulk fluid temperature over the nozzle-end half of the core. Therefore, it is recommended that

* The ND215 inner reflector cylinder was that component used in the B-4 component test, See WANL-TNR-095.

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the effect of porous flow, although small, be included in the analyses of the seal operating characteristics during any power test.

It is concluded that the magnitude of the porous flow through the inner reflector cylinder of the NRX-A2 reactor is small and will have no deleterious effects on the successful operation of the test. Moreover, a permeability data correlation has been developed which is recommended for use in the analysis of the seal operating characteristics.

BACKGROUND

Permeability test results¹ obtained with virgin H4LM test specimens and with an NRX-A1 (ND10101) type inner reflector cylinder (i.e. the cylinder was impregnated prior to the finish machining operations) indicated that the cylinder porosity was quite high, and, in fact, approached that of the virgin (i.e. unimpregnated) H4LM graphite. This porosity was deemed excessive for a "hot" reactor. Thus, the ND215 test cylinder and both the ND207 and ND10202 inner reflector cylinders were reimpregnated after the finish machining operations were complete. The inner reflector cylinders of subsequent reactors are scheduled for a single impregnation process after the completion of all machining operations.

The reimpregnated ND215 test cylinder was tested for permeability to determine the improvement obtained by the reimpregnation process and to determine the porous flow characteristics which could be expected in the Plugged Core Flow Test (ND207) and in the NRX-A2 test (ND10202).

This report, in keeping with the NRX-A2 Component Testing Prerequisites², presents the following:

- a. The effect of the reimpregnation process on the inner reflector cylinder permeability.

-
1. WANL-TME-610 Analysis and Correlation of Permeability Data on H4LM Graphite and Inner Reflector Cylinder - A. I. Miller 12/2/63
 2. WANL-TME-728 Component Testing Prerequisite to NRX-A2 Power Testing - S. L. Abramson, 3/20/64
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b. The development of a suitable permeability data correlation for use in the analysis of the Plugged Core (ND207) reactor, the NRX-A2 (ND10202) reactor, and subsequent reactors.

c. The effect of the inner reflector cylinder permeability on both the seal pressure distribution and flow rates.

ANALYSIS AND DESIGN SIGNIFICANCE

Effect of Reimpregnation on Inner Reflector Cylinder Permeability

The experimental permeability data for the ND215 inner reflector cylinder obtained before and after reimpregnation is plotted in figure 1. As can be seen, the porous flow rate was reduced by a factor of approximately 80. Moreover, the reimpregnated cylinder data is in the range of small sample test data obtained from the control samples impregnated at the same time. The differences between the two control samples is attributed to an improvement in the impregnation process³ which was incorporated prior to the reimpregnation of the ND215 cylinder. This improvement is probably the result of higher impregnation pressure.

The shapes of the data curves for the two impregnated control samples differ from that of the inner reflector cylinder. This difference is thought to be the result of coating the periphery of the control sample with glyptal prior to the permeability test. The glyptal is supposed to act merely as a surface coating to maintain one-dimensional flow. However, the glyptal undoubtedly penetrates radially inward through the sample depositing in the interstitial flow passages, thereby changing the resistance to porous flow as a function of radial position.

Reimpregnated Inner Reflector Cylinder Permeability Correlation

The permeability of the ND215 inner reflector cylinder prior to reimpregnation has been shown to correlate by an expression of the form

$$\frac{WL}{A} = m \left[\frac{P_1^2 - P_2^2}{\mu R T} \right]^n \quad (1)$$

3. WANL Specification PDS 294545

Figure 1 Permeability Test Data

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where:

- w = porous flow rate, lb_M/sec
A = average area through which flow passes, square inches
L = average length of the flow path, inches
P₁ = pressure on high pressure side of reflector, psia
P₂ = pressure on low pressure side of reflector, psia
μ = viscosity of gas, lb_M/ft-sec
R = gas constant, ft-lb_F/lb_M - °R
T = average temperature of gas flowing through reflector, °R
m and n are experimentally determined constants

This form of expression, with n = 1, is representative⁴ of a classical type of porous flow where all the small flow passages are operating in the laminar flow regime. At the other extreme, when n = 0.5, and gas viscosity is not a controlling variable, all of the flow passages would be operating in the turbulent flow regime. For exponents between these two limits, as is the case for the inner reflector cylinder before reimpregnation, some flow passages are in the laminar regime and some are in the turbulent regime. The predominance of one over the other is probably dependent upon the comparative numbers of flow channels in each regime. The ND215 cylinder permeability data obtained prior to reimpregnation showed that the porous flow was predominantly laminar, as evidenced by the strong viscosity effects.

The experimental data for the reimpregnated inner reflector cylinder, obtained with both hydrogen and nitrogen as the flow medium, correlates in the same manner as before reimpregnation.

$$\frac{WL}{A} = 7.0 \times 10^{-10} \left[\frac{P_1^2 - P_2^2}{\mu R T} \right]^{0.725} \quad (2)$$

4. Nuclear Graphite - R. Nightengale, Editor

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Figure 2 Effect of Porous Flow Through a Reimpregnated Inner Reflector Cylinder on Seal Pressure Distribution

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where the units are specified by Equation (1). Thus, it can be concluded that the porous flow through the reimpregnated inner reflector cylinder is also predominantly laminar in nature. This is also shown by the strong flow dependence upon viscosity as evidenced by the excellent correlation between the hydrogen and nitrogen test data. Under the conditions of the tests the viscosities of the two gases differed by a factor of 2.

The data correlation for the reimpregnated ND215 test cylinder given by Equation (2) can be used in analyzing the performance of both the Plugged Core Reactor (ND207) and the NRX-A2 reactor (ND10202). Both of these reactors have inner reflector cylinders which have undergone similar impregnation and machining processes and sequences.

Inner Reflector cylinders for reactors following NRX-A2, (i.e. NRX-A3 and NRX-A4) are to undergo only a single impregnation subsequent to the machining operations. However, since it has been shown that the initial impregnation, prior to machining, added very little to porous flow resistance over that of the virgin H4LM graphite, it is likely that the correlation of Equation (2) would also be applicable to these inner reflector cylinders as well.

Effect of Inner Reflector Cylinder Permeability on Seal Pressure Distribution and Flow Rates

The reimpregnation process greatly reduced the amount of porous flow through the inner reflector cylinder (by about a factor of 80). An analysis of the seal pressure distribution with this reduced amount of porous flow shows a very minor change over that obtained with no porous flow. This is in marked contrast to that obtained before reimpregnation. These are seen in figure 2 where typical seal pressure distributions for ambient test conditions are plotted. The addition of the porous flow results in a maximum increase in seal pressure of about 1 psi. This can be compared with the pressure distribution obtained with the inner reflector prior to reimpregnation. The latter exhibited a maximum seal pressure increase of 25 psia.

The corresponding comparison of seal flow rates is plotted in figure 3. The permeability

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Figure 3 Effect of Porous Flow Through a Reimpregnated Inner Reflector Cylinder on Seal Flow Rates

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of the inner reflector cylinder produced a slight increase (about 2%) in the exit flow rate and a slight reduction (about 1.5%) in the inlet flow rate as compared to the flow rates obtained with an impermeable cylinder. However, the porous flow amounted to only about 3.5% of the total accumulated seal flow, while the plunger leakage flow was about 5% of the total accumulated seal flow. Thus, the plunger annulus flow for the case illustrated was about 1.5 times as great as the porous flow. This can be contrasted with the conditions existing prior to the reimpregnation whereby the porous flow was greater than the plunger annulus flow by about a factor of 40.

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