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on Thermal Instability Conditions in
Air-Cooled Channels**

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The Effect of Graphite Chemical Reactivity
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The chemical reactivity of moderator graphite in an operating reactor may be increased over the "virgin" value by neutron and gamma irradiation and the introduction of impurities by the coolant stream, etc. Previous work^(1,2,3,4,5) can be used to show that if the value of the reactivity of BGRR virgin graphite⁽³⁾ is increased by a factor of 1000 at 400°C or by a factor of 300 at 600°C, the thermal stability of a BGRR system will not be appreciably altered.

When the "effective" reactivity⁽³⁾, $(\bar{R})$, of the graphite in a channel is expressed in units of gm/cm²-sec or cal/cm²-sec (where the area corresponds to the area cooled by the gas stream), the conditions leading to thermal instability are given by the equilibrium equation^(3,4)

*Work performed under the auspices of the United States Atomic Energy Commission.

$$(1) \quad \bar{R}_{T_g} = h (T_g - T_a)_{eq.}$$

where

T_g and T_a are the graphite and air temperatures in °C. In the following calculations, a turbulent heat transfer coefficient (h) of the order of 10^{-3} cal/cm²-sec-°C (maximum available flow in an orificed channel in the Brookhaven Graphite Research Reactor) is used to calculate the conditions that lead to instability when the reactor graphite is at 600°C.

Values of $\bar{R}_{600}$ were found to be about 2×10^{-7} gm/cm²-sec⁽³⁾ (i.e., 10^{-3} cal/cm²-sec) for unirradiated BGRR graphite. Upon substitution of $\bar{R}_{600}$ in equation (1), the air temperature which leads to instability is

$$T_a = 599^\circ\text{C}.$$

This calculation shows that thermal instability will occur only if the air temperature approaches the graphite temperature (600°C). Of importance to reactor operation is the length of channel required to heat the inlet air to the instability value. Should the required length be greater than the length of the

reactor channel, no instability will result. The length (X) of a BGRR channel necessary to yield a particular air temperature can be obtained from

$$(2) \quad (T_g - T_a) = K_1 - K_2 (X)^{(2,4)}$$

or the "stable" length ($X_{eq.}$) can be obtained directly from

$$(3) \quad X_{eq.} = 1.4 f/D^2 - T/8 + 85 + 5 \times 10^{-5} / \bar{R}_{705^\circ C}^{(4)}$$

where

$$K_1 = T_g - T_a \text{ inlet}$$

where

$$T_a = 599^\circ C$$

$$T_g = 600^\circ C$$

$$T_a \text{ inlet} = 30^\circ C$$

and

$$K_2 = 1.5^\circ C/in^{(2,4)}$$

Substituting

$$(T_g - T_a) = (600^\circ C - 599^\circ C) \text{ in equation (2)}$$

$$X = 380 \text{ inches} = 32 \text{ ft.}$$

An independent value of $X_{eq.}$ obtained from Eq. (3) for

$$h = 10^{-3} \text{ cal/cm}^2\text{-sec-}^\circ C$$

$$f = 90 \text{ SCFM}$$

$$D = 2.63 \text{ inches}$$

gives $X_{eq.} = 1.4(90/7) - 600/8 + 85 + 8 = 36 \text{ ft.}$

Therefore, at 600°C and the flow conditions selected, instability should not occur in the 12 ft. channel length of the BGRR.

It will be shown that the effects of enhanced reactivities may or may not appreciably alter the "instability" conditions. In the above example, an increase in $\bar{R}_{600}$ of a factor of ten changes the air temperature instability value from 599°C to 590°C. The length of channel required to preheat the air to this new temperature is only seven inches shorter than the length (more than thirty feet) necessary to reach 599°C. A factor of 100 increase in $\bar{R}_{600}$ would still not produce instability in a BGRR channel since the "stable" channel length is reduced only six feet. However, a factor of 350 increase in $\bar{R}_{600}$ will cause instability at the end of the 12 ft. channel. A factor of 570 increase in the original $\bar{R}_{600}$ results in the whole length of channel becoming unstable. Thus, if it were possible to obtain contaminated graphite with a value of $\bar{R}_{600}$ of $3.5 \times 10^{-1} \text{ cal/cm}^2\text{-sec}$ ($= 10^{-4} \text{ gm/cm}^2\text{-sec}$) a factor of less than two increase in $\bar{R}_{600}$ (due to irradiation, etc.) would cause a 12 ft. BGRR channel to change from complete

"stability" to complete "instability". Similar calculations for graphite temperatures of 400°C (maximum BGRR "anneal" temperature⁽¹⁾) show that a factor of 1000 increase in $\bar{R}$ at 400°C (10^{-9} gm/cm²-sec., i.e., 8×10^{-6} cal/cm²-sec)⁽³⁾ does not significantly reduce the length of stable channel.

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