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POSSIBLE EXPLANATION OF 105-K
GRAPHITE STACK DISTORTION

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POSSIBLE EXPLANATION OF 105-K GRAPHITE STACK DISTORTION

In the course of trying to predict the shape of NPR horizontal rod and process tube channels after several years of operation, data from 105-K were referred to. While looking at the 105-K data the following possible explanation of the "K" reactor distortion phenomenon occurred to me. It is written up in this document as a possible aid to those responsible for evaluating the stack distortion problem in the "K" reactors. Data and references to data are presented first and then an analysis of the data is presented. The author does not purport to be an expert on the "K" stack distortion or graphite technology but has written this analysis because it appears to be a plausible explanation of existing conditions.

It is understood that the four sides of the 105-K stack appear to be bulged out more than one inch each and that the top center of the reactor is depressed. In addition, side-to-side traverses through middle layers of the stack show 3/8 inch to 1/2 inch gaps between tube bearing and filler blocks whose extrusion direction runs front to rear at a distance of approximately six feet in from both sides.

Document No. HW-41048 presents data on graphite temperatures during the early months of "K" operation. The fringe and reflector temperatures in many of the temperature curves presented are below 200°C. However, the central portion of the reactor (inside the boundary where the 3/8 inch and 1/2 inch gaps occur) are over 200°C. More recent data at power levels over 3000 MW show that temperatures below 200°C still exist in the graphite fringes and that temperatures near 100°C exist in bottom graphite layers.

Figures 1 and 2 of Document No. HW-55363 show graphite growth and/or contraction curves for 30°C and 400 - 500°C, respectively. The curves for the transverse directions are reproduced here in Figure 1. Curves for other temperatures have been sketched in on an interpolation basis and are not supported by actual data other than the 30°C and 400 - 500°C curves presented. However, it is generally agreed that graphite growth is small or non-existent at temperatures above 200°C.

FIGURE 1 GRAPHITE TRANSVERSE DIMENSION CHANGES UPON IRRADIATION

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HW-57869
Page 4

With this data, let us consider a single graphite layer at the middle of the pile, similar to that shown in Figure 2. For simplification

Figure 2 - Typical Temperature Plot of Middle Graphite
Layer During 1000 MW Operation in 1955

the isotherms plotted can be considered circles. (In a three dimensional picture the isotherms would form spherical or ellipsoidal surfaces.) Since start-up, the area inside the 200°C isotherm has been at temperatures above 200°C and its diameter has increased only slightly during the first 1000 - 2000 MD/AT exposure (as indicated by growth at low exposures in Figure 1 for 200°C operation) but subsequently has been controlled by contraction rates rather than growth rates. The diameters of isotherm circles outside the 200°C isotherm were controlled by growth rates. The keying of blocks in adjacent layers effectively produces structural rings such that growth within the peripheral dimension of the isotherm ring will tend to enlarge the diameter of the isotherms. In zones where the temperature is greater than 200°C, contraction occurs and therefore gaps will develop in the zone between greater-than-200°C isotherm circles and less-than-200°C circles.

The forces acting to enlarge the less-than-200°C isotherm circles can be better visualized by considering the three dimensional shape of the less-than-200°C temperature region; namely a square prism with a spherical (ellipsoidal) void inside. As the concentric spheres grow peripherally, the sides of the

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HW-57869
Page 5

prism will tend to bulge. The lower radiation exposure of the corners of the prism will result in less movement or growth of the corners.

If it is assumed that the graphite temperatures in the fringes remained below 200°C for two years before higher power levels and reduced graphite thermal conductivity (due to irradiation) increased the fringe temperature above the 200°C threshold of significant graphite growth, growth of the less-than-200°C isotherms would occur. Assuming that the fringe exposure in the first two years amounted to 2000 MD/AT, the growth in this exposure period would be approximately 0.7 percent (taken from 100°C curve in Figure 1 at exposure of 2000 MD/AT), the increase in the over-all side-to-side dimension would be approximately:

$$40 \times 12 \times .007 = 3.36 \text{ inches}$$

or, bulging of 1.68 inch on the two sides with slightly less bulging at the front and rear.

In summary, then, isotherm spheres with temperatures less than 200°C have expanded or are expanding at rates dependent on temperatures and exposure. The isotherm spheres with temperatures greater than 200°C are contracting. Therefore, gaps will develop in the zones between isotherm spheres above and below 200°C. This accounts for the bulging of the four sides and the gaps in the graphite several feet in from the sides. The top does not bulge but is depressed because gravity acting in the vertical direction, forces the upper portion of the "below-200°C spheres" downward against the contracting "above-200°C spheres".

As temperatures throughout the pile exceed 200°C, growth will decrease and contraction will occur. This has probably already occurred at the middle of each side. Contraction will probably not draw the stack back together but will leave the blocks where they moved to, except in the tube zone where the tendency of the process tubes to remain straight (due to end cap pressure) will gradually move the blocks horizontally to their original locations. The low temperatures that still exist in the lower graphite layers will result in continued growth until growth saturation occurs. (The approximated 100°C curve in Figure 1 indicates that saturation might occur at two percent or about 9 inches increase in reactor width.) The temperatures in the upper graphite layers are probably higher than those in the lower layers because of greater thermal resistance between the cooled top thermal shield and graphite than occurs at the bottom thermal shield to graphite interface. Therefore growth in the upper layers will probably be less than in lower graphite layers.

If growth has occurred in the fringes as assumed above, consideration should be given to stored energy phenomenon that accompany growth. As the fringe temperatures increase above 200°C, as a result of reduced thermal conductivity of graphite, or power level increases, temperature transients in the fringes

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HW-57869
Page 6

will occur or may have occurred from Wigner-type energy releases. Due to the presence of water around the fuel elements in the process tubes, local energy releases in the fringes probably would not be dangerous but might have significant effect on operating continuity and stability.

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