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~~K REACTOR~~ GRAPHITE DISTORTION DATA

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K REACTOR GRAPHITE DISTORTION DATA

INTRODUCTION

Recent observations and measurements of the K Reactor stacks have revealed that horizontal shifting of the graphite has occurred. This shifting has caused the stack sides to bow outward as much as three inches. In addition, gaps large enough to admit 3X balls have been observed between blocks in certain regions of the stack. The term "distortion" as used in this report refers to this horizontal shifting and the resulting formation of gaps. The vertical growth and contraction that have been observed

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are primarily exposure phenomena and are similar to the radiation damage experienced at other HAPO reactors. (9) Considerable data have been accumulated in an attempt to define the magnitude and patterns of the distortion, its cause or causes, and the effects it will have upon reactor operation. This report compiles the known data and discusses what is known or suspected about the causes and effects of the distortion. As additional data and information become available, supplements to this report will be issued.

SUMMARY AND CONCLUSIONS

This report presents a history of the graphite distortion problem at the K Reactors and presents in both graphical and tabular form the results of horizontal and vertical traverses of process tubes and traverse holes. Also presented are the results of borescope observations of various vertical and horizontal channels. The data show that the distortion occurs principally in the lower half of the reactor, outside of the VSR pattern. The maximum distortion observed was a 3.01 inch outward bowing of tube 1341-KW at approximately 24 feet from the front Van Stone flange.

At the present time, the mechanism or cause of distortion is not known. However, it is believed that the distortion is not the result of some cataclysmic type of event but is probably a gradual, continuing type of occurrence. The basis for this conclusion is the similarity of the distortion at both reactors in both magnitude and shape.

DISCUSSION

History

On June 5, 1958, KW Operations had HCR Channel 16 borescoped to determine why the rod could not be inserted on May 3. Observations revealed 3X balls in the channel and horizontal separations ranging in size from 1/4 to 2-1/4 inches between graphite blocks. The separations were noted only in the first and last few feet of the channel and no significant deterioration of individual blocks, such as breakage, was observed. As a result of these findings, additional borescope observations were scheduled to determine the condition of the graphite and to confirm the apparent shift in the graphite stack.

Outer Ball Channel 51 was borescoped on June 9, 1958. This channel was selected because it lies only one and a half lattice units to the rear of HCR 16 and is within the area of horizontal separations previously observed. Channel 51 was therefore considered to be the most likely source for the 3X balls found in HCR Channel 16. The inspection of this vertical channel revealed the upper half to be normal, but starting approximately at the stack centerline and extending down to tube row 03, horizontal gaps up to 3/4 of an inch were observed between tube and filler blocks. In general, these gaps contained trapped 3X balls. In addition, apparent shifting of tube blocks into the channel of as much as 1/2 to 3/4 of an inch was also observed in this area. Again no significant deterioration of individual blocks was observed.

By mid-September the six outer ball channels plus VSR Channels 43 and 49 has been bore-scoped at both KE and KW Reactors. In addition, the horizontal traversing of process tube channels had been initiated. An analysis of the observations led to the

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following general conclusions:

1. Side to side horizontal separations as large as two to three inches exist at both reactors.
2. The significant separations appear to lie outside of the VSR pattern. This pattern does not include the six outer ball 3X channels.
3. The majority of the distortion is concentrated in the lower half of the stack.

It was also concluded that the immediate operational problem was to keep the 3X balls out of the control rod channels and other void areas of the stack. In order to eliminate unnecessary ball drops resulting from circuitry failure or personnel error, a Process Change Authorization was issued to permit the switching of the seismoscope trips from the No. 3 Safety Circuit to the No. 1 Safety Circuit. In addition, installation of the air-accelerated rods in the six outer ball channels (Project CG-708) was suspended until the distortion could be examined further. ⁽¹⁾

Future operational problems that could result should the distortion continue were considered to be:

1. the inability to charge standard length fuel elements in certain regions of the reactors,
2. the interference with retubing of process channels, and
3. the interference with operation of HCR's and VSR's resulting from distorted channels.

However, before these problems could be evaluated, more information on the current status of the distortion, its rate of change and possibly the mechanism by which it occurs would have to be determined.

On September 17, 1958, a team was established to evaluate and provide information on alternate courses of action for eliminating or alleviating the operational problems. The findings of this team are recorded in Reference (2). The team's recommendation that improved ball 3X circuitry be installed was incorporated in Design Change 240. The improved circuitry should eliminate unnecessary ball 3X trips. Design Change 240 has been completed at KW and is scheduled to be completed during the extended outage at KE (tentatively scheduled for April 1, 1959).

Other alternatives that were evaluated include the use of ceramic-Cd 3X balls to reduce the long term poison effect should balls become trapped in the stack voids, the use of HCR or VSR channel sleeves to prevent the balls from entering the voids, and the elimination of critical voids by either restoring the stack to its original position or plugging the voids with graphite foam. For a detailed discussion of the various alternatives the above referenced document should be consulted.

Discussion of Figures and Tables

Figure 1 is an isometric elevation of the K Reactor graphite stack and shows the

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location of the various openings into the stack. Figure 2 is a K Reactor front-face map upon which have been shown the relative locations of HCR and vertical channels with respect to the process tubes. Figures 1 and 2 were intended to be used as handy references for determining the locations of the various reactor openings discussed herein.

Figures 3 and 4 show the keying arrangement around the VSR and ball channels. They were included to show how it is possible for vertical channels to become enlarged without breaking any of the keys surrounding them.

Figures 5, 6, and 7 are plots of horizontal traverses of process tubes at KE. In general, traverses of tubes lying inside the area bounded by the outer vertical channels (between tube columns 46 and 93) show a characteristic "S" shape. The S shape is in agreement with expected fringe growth and central contraction caused by radiation damage; however, the mechanism that causes the central portion of the tube to move toward the center of the stack is unknown.

A comparison of Figures 5 and 6 shows that the magnitude and pattern of the distortion is essentially the same for the tubes on rows 13 and 20 between tube columns 51 and 88. However, it should be noted that tubes 1382 and 1388 are shifted farther toward the center of the reactor than are tubes 2082 and 2088. The significance of this difference in displacement is unknown. Figure 6 also shows that the near (rod) side of the reactor is bowed outward slightly more than two inches midway between the front and rear faces of the stack. The plots of tubes 2045 and 2051 show that at the center line of the stack approximately 1.6 inches of gaps exist between these tubes. It is likely that much of this displacement exists between tube columns 45 and 46 and has resulted in a widening of Ball Channel 42.

Figure 8 shows the horizontal distortion of side-to-side traverse holes W-1 and W-2. W-1 and W-2 are located midway between the top and bottom of the stack and four feet in from the front and rear faces, respectively. Borescope observations⁽³⁾ indicate that VSR Channel 23 is relatively undistorted. Therefore, it would appear that gaps occur between blocks located between traverse hole W-1 and VSR Channel 23. These gaps amount to approximately 1.5 inches. It is likely that a similar condition exists at the rear of the stack; however, this has not been verified by the borescoping of VSR Channel 69. The magnitude of the distortion is greater in the rear than in the front by approximately 0.2 inches.

It was not possible to sight through either of these side-to-side traverse holes. Alignment of the transit was achieved by sighting on marks on the X-1 level floor and wall. The transit did not then line up with the end of the traverse holes as can be seen from Figure 8. Also, there has been relative front-to-rear movement between the graphite and the thermal shield at the side of the reactor as is shown by the discontinuities in the plots at the edge of the stack.

Figure 9 shows the plots of traverses of the Y-2 traverse hole at KE on dates about two years apart. The curves show that there has been some graphite growth in the fringes of the stack and that in the past two years the top of the stack has dropped approximately 0.95 inches at its center. This gives us a gross contraction rate of approximately one-half inch per year for present conditions.

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Figure 10 shows the plots of traverses of the Y-1 and Y-3 traverse holes at KE on dates approximately 22 months apart. These plots show the fringe graphite growth shown by the Y-2 hole plots, but the magnitude of the growth is not as great.

Figure 11 shows the plots of vertical traverses of some process tubes on row 20 at KE. These traverses were made by sighting with a transit on a target which was pulled through the tube. The vertical offsets were read only to the nearest 1/20 of an inch.

Figure 12 shows how the graphite varies in height from one side of the reactor to the other at the stack center line on row 20. The dotted line of Figure 12 is an estimation of the shape of the plot, because data in that region have not been obtained.

Figure 13 is a plot of the borescope observations of 1-C test hole⁽⁴⁾ at KE and shows the locations of the gaps which were observed between the blocks in the top, bottom, and sides of the channel. These borescope observations confirm the existence and location of the gaps which are indicated by the tube traverses of previous figures.

Figure 14 is a plot of the borescope observations of vertical channels at KE. The plot is based on information contained in References (3), (5), (6), (7), and (8) and shows the locations of gaps between the tube and filler blocks. In certain of these channels a light was lowered into the channel and an estimation made of the relative sizes of the sides of the rectangle of light which was then visible from above the channel. A square indicated little or no bowing, and a large difference in the relative lengths of adjacent sides of the rectangle indicated that considerable bowing exists.

At the right of the line representing each vertical channel is a note which shows the extent of the area in which tube blocks appeared to be projecting into the channel. In this area each tube block appears to project into the channel beyond the filler layer blocks above and below it. It is not known whether the tube blocks actually project into the channel or whether the filler layer blocks have moved out of the channel.

Figure 15 is a plot of horizontal traverses of tubes on rows 01, 05, 08, and 40 at the KW Reactor and shows that only a little distortion exists within the tube pattern on 01 and 40 rows, and that considerable distortion exists on 05 and 08 rows. There may be considerable distortion outside the tube pattern on 01 row, but this has not been determined.

Figure 16 shows the results of horizontal traverses on row 13 at KW. Tube 1341 shows the greatest distortion observed in any tube traversed - 3.01 inches at 24 feet from the front Van Stone. It is likely that tube 1397 is bowed very nearly as much as is 1341, but the center line of the target was lost to view at 18 feet from the front Van Stone, and readings at a greater distance were not obtained.

Figure 17 is a plot of horizontal tube traverses on row 20 at KW. The distortion on row 20 is not as severe as it is on rows 08 and 13.

Figure 18 is a plot of the horizontal traverses of tubes on row 27 at KW. Also shown are the traverses of the V-1 and V-2 holes at KW. The V-1 and V-2 holes are front-to-rear traverse holes in the same graphite layer as tube row 29 and are one lattice unit outside the tube pattern. Tubes on row 27 are distorted less than tubes on row 20.

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The dotted line in the upper end of the plot of the V-2 traverse hole represents the data taken at the time the traverse was made. It is thought that the data are in error and that the solid line more nearly represents the true shape of the tube.

Figure 19 is a plot of the W-1 and W-2 traverse holes at KW. A comparison of this figure with Figure 8 shows that the distortion is very nearly the same at both reactors. KW however, appears to be slightly less distorted than KE. Borescope observations of VSR Channel 23 at KW show that this channel also appears to be straight. Thus there should be gaps located between the V-1 hole and VSR Channel 23.

Figure 20 shows that the distortion in several tube columns changes with height in the stack. The points plotted represent the distortion values midway between the front and rear faces of the stack where the maximum distortion generally occurred. Column 46 was superimposed on the plot of column 45 to show the difference in the amount of distortion in those two adjacent tube columns. It is therefore concluded that Ball Channel 42, which lies between these two columns, is bowed toward the near (rod) side of the reactor and also has become enlarged in cross section.

Figure 21 shows the results of vertical traverses of the Y-2 traverse hole at KW on dates about two years apart. The same general pattern as was observed at KE (see Figure 9) is shown here. KW appears to have contracted slightly more than KE - 1.13 inches as compared to 0.93 inches. The dotted portion of the plot of the recent traverse follows the data as read; the solid line shows the probable true profile of the traverse hole.

Figure 22 shows the plots of the vertical traverses of the Y-1 and Y-3 holes at KW. A comparison of this figure with Figure 10 will show that the Y-1 and Y-3 holes at the two reactors are similar.

Figure 23 shows the plots of three tubes which are centrally located between the reactor sides. One tube is near the bottom of the tube pattern, one at $1/3$, and one at $2/3$ of the height of the reactor. The traverse of Y-2 is plotted on this same figure for comparison purposes. These plots indicate that some effect in addition to neutron irradiation damage may be involved in causing the graphite to contract. The basis for this statement lies in the apparent discrepancy in the distance between the plots of 0271 and 2070 and between 4072 and Y-2. It may be that the compression load on a block of graphite affects its rate of contraction under irradiation.⁽⁹⁾

The data from vertical traverses of four additional process tubes at KW are plotted in Figure 24. These tubes were traversed to provide additional data on graphite contraction rates. It is interesting to note that all of these tubes slope downward through the "B" shield. This downward slope is very likely caused by the weight of the cast iron thermal shield blocks which are hung on the gunbarrels. The gunbarrels are free to move downward within the "B" shield approximately 0.3 inches. A similar downward slope can also be seen in Figures 11 and 23.

The results of borescope observations⁽¹⁰⁾⁽¹¹⁾⁽¹²⁾ of HCR Channels 13 and 16 at KW are plotted in Figures 25 and 26. These borescope observations confirm the existence of the gaps indicated by the horizontal traverses of process tubes.

Table I presents the borescope observation data⁽¹³⁾ of three additional HCR channels

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at KW, Numbers 4, 10, and 11. Only a few small gaps were observed in these channels. Thus the borescope observations again confirm the horizontal traverse data in that most of the distortion is in the lower half of the reactor.

Figure 27 is a plot of borescope observations of vertical channels at KW and is similar to Figure 14 which is the corresponding figure for KE. The data for the KW plots were obtained from References (11), (12), (13), and (14).

Table II is a history of ball drops at KE and KW and shows the date of each ball drop, the number of hoppers dropped, and the cause of the drop. This table will be used in the discussion of the hypothesized mechanisms of distortion.

Tables III through XII present in tabular form the horizontal and vertical traverse data upon which the figures of this report are based. They are presented for the benefit of those who might wish to construct cross plots or who might wish more exact data than can readily be obtained from the plots presented herein.

Investigation to Determine the Cause of the Distortion

The first field of investigation was to determine if there has been any shifting of the pedestal upon which the stack rests. Elevation surveys of the base plate along both sides and the front of each reactor were conducted. (15)(16)(17) The maximum variation in level noted was 0.144 inches which is not believed to be sufficient to cause the graphite to shift. In addition, visual examination of the three tunnels that run through each pedestal revealed only minor cracks not believed to be significant to the overall integrity of the pedestal. (18)(19)(20)

Another rather obvious line of pursuit was to examine the construction logs to determine if any lay-up difficulties or field changes might shed light upon the observed distortion. No new information was found. (21) The required lay-up tolerances and the methods employed to meet these tolerances are in themselves a good argument that the stack was laid up as designed. In order to be acceptable, "as built" dimensions were required to be within 1/16 of an inch of design dimensions. The center line of each layer was established by fixed optical instruments. After each layer was completed a set of five measurements was taken. The length of the two diagonals was checked and three width measurements were made perpendicular to the long axis of the blocks. Assurance that the laying of succeeding layers did not cause the lower layers to shift was provided in two ways. First, square plugs, which extended down through about five layers, were kept in each of the 51 VSR and ball 3X openings to assure alignment and to prevent foreign material from falling into the holes. Second, periodic visual checks were made of the gaps between the stack and the thermal shield. Although this inspection was primarily to assure that foreign material had not fallen into the plenums, shifting of graphite layers into the plenums, especially if of the magnitude that exists today, certainly would have been noted. It is concluded that the stack originally was as indicated on the "as built" prints.

If we accept the fact that the stack was not distorted during lay-up, it then becomes necessary to explain how the graphite has since become distorted. Various hypothesized mechanisms of distortion are discussed in the next section.

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Hypothesized Mechanisms of Distortion

At the present time there have been six different hypotheses suggested as possible mechanisms causing the distortion of the K Reactor graphite stacks. Each hypothesis suffers from at least one serious deficiency in attempting to satisfy the known data. The hypotheses are discussed below in the hope that they might stimulate interest in and discussion of the problem.

1. Pressure of 3X Balls

It has been suggested that the distortion of the stack was caused by the pressure of the 3X balls when they were dropped into the reactors. The stack is distorted more at the bottom than at the top as might be expected if ball pressure caused the distortion. Also, the distortion seems to be generally outward outside of the outer ball channels and inward inside of these channels as might be expected to happen if only the outer sixteen hoppers were dropped as has occurred on several occasions. However, the following calculations indicate that ball pressure is not sufficient to be the cause of the stack distortion.

Consider a vertical section of stack bounded by and including rows 08 and 13 and extending outward from the outer ball channels to the edge of the stack. Take as a free body a part of this section which is 37-1/2 inches long and is centered on one of the outer ball channels. Calculations show that the total load on the bottom surface of this free body is approximately 66,000 pounds. The total load on the top surface of this free body is approximately 59,000 pounds. If a coefficient of friction of 0.3 is used, the force required to move the free body is $0.3 (66,000 + 59,000) = 37,000$ pounds.

If the balls are assumed to act as a perfect fluid, the pressure exerted by a full channel of balls would be about 90 psi at tube row 08 and about 83 psi at row 13. The total force exerted by ball pressure on the free body would be

$$\frac{90 + 83 \text{ lbs.}}{2 \text{ in}^2} \times 3.75 \text{ in} \times 6 \text{ lattices} \times 7.5 \text{ in/lattice} = 14,600 \text{ lbs.}$$

It is evident from this rather crude calculation that even if the balls acted as a perfect fluid they could not exert enough pressure to distort the stack. Limited laboratory data⁽²²⁾ indicate that the actual pressures exerted will be smaller by at least a factor of four than the pressure used above because of the wedging and bridging effect of the balls in the channel.

The free body used in this calculation is probably larger than the free body which could have been considered realistic. There is reason to believe that at most three or four lattices move as a unit rather than the six lattices assumed here. It is even very likely that a single lattice or even a single layer moves with respect to the layers above and below it. If the free body is assumed to be three lattices high, rather than six, the force required to move it is increased slightly and the available force is reduced by nearly half from the above calculated values.

In addition to the above arguments, it should be pointed out that the graphite to

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the front and rear of the outer ball channels will exert a restraining force on the free body considered above. This restraint increases the force required to move the free body by an unknown but significant amount. Another point against the above theory is that the distortion is similar in magnitude and location at both reactors while ball drop history at the two reactors is quite dissimilar (see Table II).

2. Rods Dropping Into Partly Filled Channels

It has been suggested that if a VSR were dropped into a partly filled channel of balls the sideways forces generated might be enough to shift the graphite. There is very limited data concerning the magnitude of such forces. In a laboratory test⁽²²⁾ using C Reactor configurations, a VSR was dropped free fall for a distance of about 26 feet into a partially filled channel. A momentary pressure of 340 psi was exerted against the side of the channel at a position approximately eight inches below the original level of the balls. Although pressures of this magnitude would be sufficient to cause graphite displacements if extended over an area of four lattice units or more, there are two major arguments that discredit this hypothesis. First, the majority of the observed distortion lies around and outboard of the six outer Ball 3X channels which to date have not contained operable VSR's. Second, with the exception of a few isolated individual channel incidents during construction, there have been only one or two incidents in which rods were thought to have dropped into partially filled channels. One of these incidents occurred at KW on May 1, 1958. Ball 3X drop history is given in Table II.

3. Ball Expansion Because of Thermal Heating

Another suggested mechanism has been the thermal expansion of the balls after they have been dropped into the hot graphite. This would cause expansion in all channels outward from the center of the reactor. At the KE Reactor there has been only one instance where the balls were dropped into the hot graphite; at the KW Reactor there have been four such instances.

The average coefficient of thermal expansion for mild steel is about 14.3×10^{-6} in/in - °C for a range of 20°C to 600°C. Therefore, if we assume that the balls pack tightly enough into the channel so that all expansion is relieved by displacing the graphite, the expansion per channel per ball drop will be:

$$14.3 \times 10^{-6} \text{ in/in - } ^\circ\text{C} \times 3.75 \text{ in} \times 600^\circ\text{C} = 0.0322 \text{ in.}$$

Therefore, the total expansion for four ball drops should be:

$$4 \text{ drops} \times 9 \text{ channels} \times 0.0322 \text{ in/channel/drop} = 1.16 \text{ inches, or } 0.58 \text{ inches on each side.}$$

Thus we might be able to account for about 0.6 inches of outward distortion on each side at the KW Reactor by thermal expansion of the balls, but only for 0.15 inches at KE. In addition, if thermal expansion were the cause of the distortion we would expect to see a more or less uniform distortion from top to bottom, with some tapering in at the extreme top and bottom. We would not expect to see little

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or no distortion at the top and a great deal of distortion at the bottom.

4. Thermal Walking

Another suggested mechanism has been that of thermal walking or thermal ratcheting. This supposes that as the graphite heats up and expands outward the stack moves outward from the center. Then as the stack cools, the filler layer blocks are restrained in such a fashion that the outer ends of these blocks remain in place and the inner ends move outward carrying the tube blocks with them. On the next cycle of heating the point of restraint has changed so that now the inner ends of the filler layer blocks are restrained and the outer ends expand outward. On cooling the point of restraint reverses itself again. Thus, on each cycle of heating and cooling the filler layer "walks" or "ratchets" outward carrying the tube blocks along.

In order for such a hypothesis to be acceptable it becomes necessary to explain why the point of restraint changes from one end of the block to the other as the graphite heats and cools. It also becomes necessary to explain why such a mechanism would cause greater distortion in the lower part of the reactor than in the upper part. No satisfactory explanations of these things have as yet been suggested.

5. Vibration

It has been suggested that the water flowing through the tubes causes the tubes to vibrate and that this vibration causes the graphite to shift. The sideways force needed to cause the graphite to move can be provided in either of two ways, graphite growth and contraction which causes the blocks to want to slide downhill or the tubes could be vibrating in a skewed plane which would cause them to move preferentially in one direction. An examination of Figure 12 will show that the combined effects of growth and contraction are such that the inner part of the stack would tend to slide toward the center and the outer part would tend to slide toward the outside. Tube traverses show that this is essentially what has occurred (see Figures 6, 15, 16, 17, and 18). In this respect the vibration theory seems to fit the observed data.

Graphite growth and contraction are cumulative so that the maximum differences in elevation from point to point will be at the top layer of the stack. Therefore, any sideways forces caused by differences in elevation will be greater at the top of the reactor than at the bottom. If vibration plus growth and contraction effects were the cause of the distortion, greater distortion would be expected in the upper part of the stack than in the lower part, instead of the reverse condition as it actually exists.

In the case of a skewed plane of vibration causing the stack to move preferentially in one direction it again seems reasonable to expect greater movement in the upper part of the reactor than in the lower because frictional restraint will be smaller in the upper part. Because the water enters all tubes from the same direction, the plane of vibration should be the same for all tubes. Thus, any skewed plane of vibration should cause all tubes to move in the same direction rather than causing the outer tubes to move outward and the inner tubes to move toward the center.

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6. Growth-Contraction Shells

G. T. Haugland⁽²³⁾ has suggested that the K graphite distortion might be caused by a growth-contraction effect. He assumes that the different temperature zones of the graphite can be considered as more or less concentric spherical or ellipsoidal isotherm shells. Then in the fringes where the graphite has been below 200°C these shells will expand and their diameters will increase because 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 isotherm ring. In the 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 shells and less-than-200°C shells. Haugland's assumptions account for a total of 3.36 inches of expansion from side-to-side or 1.68 inches on each side.

If Haugland's theories are correct, one would expect to see more or less uniform bulging of the sides from top to bottom. An examination of Figures 6, 7, 15, 16, 17, 18, and 20 will show that the stack is relatively undistorted in its upper half and the greatest distortion occurs at about tube row 13. An examination of the graphite layer prints of the K Reactor stacks has led the authors to the conclusion that it is extremely unlikely that the keying of blocks can produce structural rings which will behave in the fashion hypothesized. In addition, only half of the maximum observed distortion can be accounted for by the above hypothesis - 1.68 inches as compared to 3.01 inches measured at the center of tube 1341 KW.

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- (18) Letter, J. L. Benson to J. T. Baker, Inspection of KE Pedestal, 10/14/58.

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Legend:

- * VSR Channels D 1 thru 16 HCR Channels
- ② Ball Channels Only
- Z-1 thru 5 Side to Side Traverse Holes

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FIGURE 2 RELATIVE LOCATIONS OF PROCESS TUBES AND
HORIZONTAL AND VERTICAL CHANNELS

FIGURE 3 - VSR KEYING ARRANGEMENT

FIGURE 4 - CROSS SECTION* OF OUTER BALL 3X CHANNEL SHOWING TYPICAL DISTORTION

* This postulated cross section is based upon the assumption that the surrounding vertical keying has not sheared.

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FIGURE 5- PLOT OF
HORIZONTAL TRAVERSE
DATA OF PROCESS TUBES
ON ROW 13, 105 KE

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FIGURE 6 - PLOT OF
HORIZONTAL TRAVERSE
DATA OF PROCESS TUBES
ON ROW 20, 105 KE

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FIGURE 7.- PLOT OF
HORIZONTAL TRAVERSE DATA
OF PROCESS TUBE 2747KE

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FIGURE 9 - VERTICAL TRAVERSE OF TRAVERSE HOLE Y-2, 105 KE

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FIGURE 10 - VERTICAL TRAVERSE OF TRAVERSE HOLES Y-1 & Y-3, 105 KE

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FIGURE 11 - VEX.

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note: Y H₀z values were obtained by scaling down the observed offsets by the relative height ratio $49/129$.

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FIGURE 12 - VERTICAL HEIGHT PROFILE OF TUBE ROW 20 TAKEN AT THE FRONT-TO-REAR STACK ϕ, 105 KE

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Figure 13 - PLOT OF BORESCOPE OBSERVATIONS OF TEST HOLE I-C KE

FIGURE 14 - PLOT OF BORESCOPE OBSERVATIONS OF VERTICAL CHANNELS AT 105 KE

* Relative dimensions of channels as viewed from the top with a drop light in the bottom of the channel. The first figure is the relative front-to-rear dimension.

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~~CONFIDENTIAL~~

HORIZONTAL TRAVERSE DATA OF
ROWS 01, 05, 08 AND 40, 105 KW

Sight

Target out of sight

05/02/01

0845 MW 5480

05/02/01

0846 MW 5480

05/02/01

0850 MW 5480

05/02/01

0840 MW 5480

05/02/01

0847 MW 5480

08 04 00 24 20 16 12 08 04 00 08 04 00 04 08 04 00 08 04 08
22 Offset, inches

FIGURE 16 - PLOT OF HOR
OF PROCESS TUBES

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HORIZONTAL TRAVERSE DATA
ON ROW 13, 105 MW

105 MW
ROW 13

105 MW

105 MW

00

58322

105 MW

105 MW

Target out of sight

00000000

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DEM 100000
0000000000

Target out of sight

2088 KW

2098 KW

FIGURE 17 - PLOT OF HORIZONTAL
TRAVERSE DATA OF PROCESS TUBES
ON ROW 20, 105 KW

0.4 0.8
set, inches

0.4 0.8 1.2 1.6 2.0 2.4 2.8

ASC-GE RICHLAND, WASH.

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V-2 TRAVERSE HOLE 8/11/58

2788 KW 8/11/58

2983 KW 10/20/58

FIGURE 10 - PLOT OF HORIZONTAL TRAVERSE DATA OF PROCESS TUBES ON ROW 27 AND OF TRAVERSE HOLES V1 AND V2
105 KW

inches

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FIGURE 20
PROFILES OF VERTICAL COLUMNS TAKEN AT THE FRONT-TO-REAR STACK & 105 MW

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FIGURE 21 - VERTICAL TRAVERSE OF TRAVERSE HOLE Y-2, 105 KW

AEC-82 RICHLAND, WASH.

FIGURE 22 - VERTICAL TRAVERSE OF TRAVERSE HOLES Y-1 & Y-3, 105 KW

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FIGURE 23 - VERTICAL TRAVERSE OF PROCESS TUBES 0271, 2070 AND 4072, 105 KW
Distance from Front Van Stone, feet

FIGURE 24 - VERTICAL TRAVERSE OF PROCESS TUBES AT KW

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Distance From Rod Side - Feet

Figure 26 - PLOT OF BORESCOPE OBSERVATIONS OF HCR CHANNEL 16 AT 105 KW

TABLE I

BORESCOPE OBSERVATIONS OF HCR CHANNELS AT KW ON 11/5/58

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HCR Channel No. 4

1. Width of plenum⁽¹⁾ and distance from reactor face to stack approximately as built.
2. One-quarter inch to three-eighths inch gaps between blocks in the bottom of the channel at 11'3-5/8", 11'7-3/8", and 11'11-1/8" from the reactor face.
3. One inch gap between rod track blocks at 15'2-1/2" from reactor face.
4. One and one-quarter inch gap between rod track blocks at 17'1" from the reactor face.
5. One-half inch gap between the blocks on both sides of the channel at approximately 41'5" from the reactor face.
6. One-half inch gap between blocks in the top of the channel at 41'11-1/8" from the reactor face.

HCR Channel No. 10

1. Width of plenum⁽¹⁾ and distance from reactor face to stack approximately as built.
2. One-quarter inch gaps between blocks in bottom of channel at 10'11-7/8", 11'3-5/8", 11'7-3/8", and 11'11-1/8" from the reactor face.
3. One-half inch gap between rod track blocks at 15'2-1/2" from reactor face.
4. One-half inch gap between blocks above the channel at 23'2-1/8" from the reactor face.
5. One-half inch gap between rod track blocks at 32'1" from the reactor face.

HCR Channel No. 11

1. The plenum is three inches wide⁽¹⁾.
2. Distance from reactor face to graphite stack⁽¹⁾ is 6'6-1/2".
3. One inch gap between rod track blocks at 15'2-1/2" from the reactor face.

(1) "As built" plenum width is 3-7/8 inches. "As built" distance from reactor face to edge of graphite stack is 6'7-3/8".

Legend:

3" gaps

1" gaps

1/2" gaps

3/8" gaps

1" gaps

Note: The gaps indicated are gaps between tube and filler blocks in the tube layers. Gaps less than 3/8" are not shown.

TABLE IIK REACTORS BALL DROP HISTORY

<u>Date</u>	<u>Number of Hoppers Dropped</u>	<u>KE Reactor</u>
		<u>Remarks</u>
11/23/55	16	Apparently caused by a defective seismoscope selector switch. The reactor was shut down at the time.
11/24/55	1	The corresponding VSR failed to drop during a scram.
3/16/56	51	Caused by pressure fluctuations when the cross tie valve at KW closed in four seconds. Closing time has been adjusted to 30 seconds. The reactor had been scrambled just prior to this incident.
7/?/56	2	The corresponding VSR's did not enter within the 3.5 seconds required to prevent ball drops in those hoppers.
7/?/56	3	Same as above.
8/19/57	51	Caused by burned out selenium rectifiers in seismoscope system.
11/14/57	16	The drop occurred while a continuity check was being made on a dual sensing line which had been installed from a riser to the mercoids. The reactor was down at the time.

KW Reactor

11/13/55	48	Caused by a faulty seismoscope selector switch. The reactor was shut down at the time.
2/2/56	16	Seismoscope was tripped during start up preparations. Selector switch was set to ball 3X.
3/15/56	1	The corresponding VSR failed to enter during a scram.
3/15/56	51	Caused by a defective seismoscope selector switch. The reactor was down at the time.
3/21/56	1	The limit switch which indicates the VSR has entered the reactor failed to operate.
4/11/56	19	The power supply to the seismoscope relays was interrupted by an incorrect switching procedure. The reactor was down at the time.

(Continued)

TABLE II (Continued)K REACTORS BALL DROP HISTORY

<u>Date</u>	<u>Number of Hoppers Dropped</u>	<u>KW Reactor</u>
		<u>Remarks</u>
7/?/56	1	The corresponding VSR failed to enter in 3.5 seconds during a scram.
7/28/57	49	A soldered joint on the sensing line from "C" riser failed.
4/10/58	2	Excessive vibration of the relay cabinets while additional relays were being installed caused two hoppers to trip. The reactor was down at the time.
5/1/58	51	The high-speed transfer switch failed and caused a seismoscope trip of the ball 3X system. The VSR's entered at the same time.

HORIZONTAL OFFSETS OF PROCESS TUBES AT KE

(1) Distance From Front Van Stone	Offset (2) - Inches					
	2041 (4)	2045 (5)	2051	2057	2082	2088
0' - 0.00		0.00	0.00	0.00	0.00	0.00
2' - 0.04		LO.01	LO.06	0.00	RO.02	LO.05
3' - 0.00		LO.07	LO.16	LO.10	RO.10	LO.12
		LO.16	LO.24	LO.10	RO.19	LO.22
		LO.31	LO.37	LO.25	RO.30	LO.34
		LO.50	LO.43	LO.26	RO.35	LO.48
		LO.75	LO.48	LO.25	RO.33	LO.55
		LO.86	LO.40	LO.16	RO.18	LO.52
		LI.05	LO.36	LO.10	0.00	LO.39
		LI.10	LO.18	RO.07	LO.14	LO.21
		LI.13	0.00	RO.24	LO.28	0.00
		LI.19	RO.17	RO.30	LO.34	RO.13
		LI.20	RO.32	RO.32	LO.37	RO.18
		LI.19	RO.45	RO.35	LO.40	RO.10
		LI.06	RO.37	RO.32	LO.32	0.00
		LO.74	RO.17	RO.23	LO.28	LO.23
		LO.72	LO.12	RO.12	LO.12	LO.42
		LO.64	LO.38	LO.08	0.00	RO.32
		LO.54	LO.60	LO.13	RO.13	RO.47
		LO.43	LO.64	LO.21	RO.28	RO.49
		LO.44 (3)	LO.52	LO.22	RO.30	RO.44
		LO.00	LO.23	LO.16	RO.23	RO.31
			LO.00	0.00	RO.08	RO.24
			LO.00	0.00	0.00	RO.17
			LO.00	0.00	0.00	0.00

factor face.

to the left or right, respectively, of the original tube center line

from that shown in the first column of the table, the correct distance

ected on work area wall. It was not possible to see completely

ed by estimation. Calculated offsets adjusted to give a more realistic

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TABLE IVHORIZONTAL OFFSETS OF SIDE-TO-SIDE TRAVERSE HOLES AT KE

Distance ⁽¹⁾ From End of Hole	Offset ⁽²⁾ Inches	
	W-1	W-2
0'	FO.20	FO.09
2'	FO.17	FO.06
4'	FO.23	FO.05
6'	FO.21	FO.02
6' - 6"	FO.50	RO.15
8'	FO.58	RO.36
10'	FO.68	RO.45
12'	FO.84	RO.60
14'	FO.98	RO.89
16'	Fl.09	Rl.19
18'	Fl.21	Rl.43
20'	Fl.20	Rl.57
22'	Fl.31	Rl.66
24'	Fl.37	Rl.79
26'	Fl.32	Rl.82
28'	Fl.41	Rl.84
30'	Fl.38	Rl.84
32'	Fl.29	Rl.83
34'	Fl.29	Rl.74
36'	Fl.29	Rl.63
38'	Fl.15	Rl.36
40'	FO.90	Rl.12
42'	FO.86	(43')RO.81 ⁽³⁾
44'	FO.73	RO.68
46'	FO.76	(45')RO.43
48'	FO.80	(47')RO.37
50'	FO.83	
52'	FO.57	
54'	FO.60	
54' - 6"		

NOTE: The transit was aligned by back-sighting on marks on the X-1 level floor and wall. The transit did not then line up with the center line of the end of the traverse hole in either case.

- (1) The end of the hole is approximately two inches out from the reactor face.
- (2) For R before the offset reading means that the offset is to the front or rear respectively of the hole center line.
- (3) Where the point at which an offset reading was taken is different from that shown in the first column of the table, the correct distance is shown in parentheses to the left of the offset reading.

TABLE VVERTICAL OFFSETS⁽¹⁾ OF THE Y TRAVERSE HOLES AT KE

Distance ⁽²⁾ From End of Gunbarrel	Offset - Inches		
	<u>Y1</u>	<u>Y2</u>	<u>Y3</u>
1'	0.00	0.00	0.00
3'	-0.02	-0.02	-0.02
5'	-0.04	-0.04	-0.01
7'	-0.06	-0.02	-0.02
9'	±0.04	±0.14	±0.09
10'		±0.25	
11'	±0.15	±0.33	±0.18
12'		±0.25	
13'	±0.14	±0.11	±0.19
14'		-0.04	
15'	±0.14	-0.21	±0.16
16'		-0.33	
17'	±0.11	-0.44	±0.12
19'	±0.10	-0.62	±0.12
21'	±0.08	-0.77	±0.12
23'	±0.07	-0.91	±0.13
25'	±0.07	-0.93	±0.13
27'	±0.08	-0.87	±0.09
29'	±0.09	-0.73	±0.13
31'	±0.10	-0.57	±0.16
33'	±0.10	-0.36	±0.18
34'		-0.25	
35'	±0.12	-0.11	±0.19
36'		±0.01	
37'	±0.10	±0.13	±0.21
38'		±0.11	
39'	±0.04	±0.06	±0.16
40'		-0.01	
41'	±0.01	-0.02	±0.13

(1) Offsets obtained by use of mercury manometer equipment.

(2) The end of the gunbarrel is six inches from the reactor face.

TABLE VIVERTICAL OFFSETS⁽¹⁾ OF PROCESS TUBES AT KE

Distance ⁽²⁾ From Front Van Stone	Offset ⁽³⁾ Inches					
	2041 ⁽⁴⁾	2045 ⁽⁴⁾	2051	2057	2082	2088
0' - 0"	0.00	0.00	0.00	0.00	0.00	0.00
2'	0.00	0.00	0.00	0.00	-0.05	0.00
4'	-0.05	-0.05	-0.05	0.00	-0.05	-0.05
6'	-0.10	-0.10	-0.10	-0.10	-0.15	-0.15
8'	-0.15	-0.05	-0.15	-0.10	-0.15	-0.15
10'	0.00	0.00	-0.10	-0.10	-0.10	-0.05
12'	0.05	0.10	-0.05	0.00	0.00	-0.05
14'	0.10	0.05	-0.10	0.00	-0.10	-0.05
16'	0.05	0.05	-0.20	-0.10	-0.15	-0.20
18'	0.05	0.00	-0.30	-0.15	-0.25	-0.30
20'	0.05	0.00	-0.30	-0.20	-0.30	-0.30
22'	0.05	0.00	-0.30	-0.25	-0.30	-0.30
24'	0.10	0.00	-0.35	-0.25	-0.30	-0.35
26'	0.10	0.00	-0.30	-0.30	-0.35	-0.40
28'	0.10	0.00	-0.30	-0.25	-0.40	-0.40
30'	0.10	0.00	-0.35	-0.25	-0.35	-0.40
32'	0.10	0.00	-0.30	-0.25	-0.25	-0.40
34'		0.05	-0.30	-0.15	-0.25	-0.35
36'		0.10	-0.25	-0.10	-0.20	-0.35
38'		0.10	-0.25	-0.10	-0.20	-0.35
40'			-0.25	-0.10	-0.25	-0.35
42'			-0.25	-0.10	-0.25	-0.35
44'			-0.25	0.00	-0.20	-0.30
46'			-0.20	0.00	-0.10	-0.25
47' - 2"			-0.10	0.00	0.00	-0.10

- (1) Offsets obtained by using a transit to sight on a target in the tube.
 (2) The Van Stone flange is approximately 12 inches from the reactor face.
 (3) Offsets were read to nearest 1/20 of an inch.
 (4) Could not see through tube.

TABLE VII

HORIZONTAL OFFSETS OF PROCESS TUBES AT KW

Distance ⁽¹⁾ From Front Van Stone	Offset ⁽²⁾ - Inches			
	0149	0545 ⁽⁴⁾	0845 ⁽⁴⁾	0846 ⁽⁴⁾
0' - 0"	0.00	0.00	0.00	0.00
2'	10.03	0.00	10.03	10.04
4'	10.07	0.00	10.09	10.05
6'	10.12	10.06	10.18	10.10
8'	10.22	10.20	10.23	10.25
10'	10.33	10.43	10.48	10.48
12'	10.45	10.61	10.75	10.81
14'	10.57	10.87	11.09	11.14
16'	10.57	11.15	11.44	11.55
18'	10.42	11.54	11.99	11.94
20'	10.32	11.91	12.50	12.26
22'	10.26	12.08	12.68	12.46
24'	10.29	12.16	12.77	12.50
26'	10.31	12.15	12.73	12.49
28'	10.37	12.12	12.65	12.37
30'	10.58	11.91	12.44	12.22
32'	10.70 (31'8")	11.80 ⁽³⁾	(31') 12.33 ⁽³⁾	(31') 12.09 ⁽³⁾
34'	10.66		(33') 11.88	
36'	10.55			
38'	10.34			
40'	0.00			
42'	RO.16			
44'	(46'6") RO.06 ⁽³⁾			
46'				
47'2"				

- (1) The Van Stone flange is approximately 12 inches from the reactor face.
- (2) L or R before the offset reading means that the offset is to the left or right, respectively, of the original tube centerline as viewed from front to rear.
- (3) Where the point at which an offset was taken differs from that shown in the "distance" column, the correct distance is given in parentheses to the left of the offset reading.
- (4) The original centerline of the tube was established by back-sighting on a mark erected on the work area wall. It was not possible to see through the tube.

TABLE VII (continued)HORIZONTAL OFFSETS OF PROCESS TUBES AT KW

Distance ⁽¹⁾ From Front Van Stone	Offset ⁽²⁾ - Inches			
	0850	1341 ⁽⁴⁾	1345 ⁽⁴⁾	1389
0'-0"	0.00	0.00	0.00	0.00
2'	0.00	RO.09	0.00	RO.06
4'	LO.06	RO.09	LO.07	RO.12
6'	LO.12	0.00	LO.15	RO.23
8'	LO.22	LO.19	LO.35	RO.36
10'	LO.39	LO.48	LO.52	RO.43
12'	LO.50	LO.85	LO.81	RO.40
14'	LO.43	LO.34	LO.18	RO.26
16'	LO.26	LO.86	LO.57	RO.07
18'	0.00	LO.33	LO.06	0.00
20'	RO.35	LO.58	LO.47	LO.11
22'	RO.56	LO.81	LO.78	LO.21
24'	RO.74	LO.01	LO.93	LO.22
26'	RO.80	LO.97	LO.86	LO.10
28'	RO.85	LO.88	LO.77	LO.11
30'	RO.74	(29') LO.64(3)	LO.53	0.00
32'	RO.36		(30'4") LO.55(3)	RO.12
34'	0.00			RO.39
36'	LO.35			RO.41
38'	LO.65			RO.44
40'	LO.30			RO.46
42'	0.00			RO.32
44'	RO.16			0.00
46'	RO.34			0.00
47'2"	0.00			(46'6") 0.00(3)

TABLE VII (continued)

HORIZONTAL OFFSETS OF PROCESS TUBES AT KW

Distance ⁽¹⁾ From Front Van Stone	Offset ⁽²⁾ - Inches			
	1397 ⁽⁴⁾	2041 ⁽⁴⁾	2045 ⁽⁴⁾	2046 ⁽⁴⁾
0'-0"	0.00	0.00	0.00	0.00
2'	R0.05	0.00	L0.02	R0.07
4'	R0.12	0.00	L0.09	R0.10
6'	R0.14	L0.08	L0.22	R0.19
8'	R0.35	L0.27	L0.35	R0.29
10'	R0.67	L0.43	L0.48	R0.38
12'	R1.00	L0.76	L0.58	R0.53
14'	R1.56	L1.00	L0.54	R0.57
16'	R2.25	L1.34	L0.65	R0.57
18'	R2.38	L1.63	L0.86	R0.63
20'		L1.96	L1.02	R0.70
22'		L2.16	L1.20	R0.76
24'		L2.24	L1.25	R0.70
26'		L2.21	L1.19	R0.58
28'		L2.07	L1.01	R0.36
30'		L1.82	L0.74	R0.27
32'	(30'10")	L1.75 ⁽³⁾	(31') L0.47 ⁽³⁾	R0.25
34'			(31'7") L0.42	R0.31
36'			(36') L0.32	R0.46
38'			(39') L0.17	R0.48
40'			(43') R0.08	R0.36
42'				R0.16
44'				(43'5") R0.16 ⁽³⁾
46'				
47'2"				

TABLE VII (Continued)

HORIZONTAL OFFSETS OF PROCESS TUBES AT KW

Distance ⁽¹⁾ From Front Van Stone	Offset ⁽²⁾ - Inches			
	2051	2088	2098 ⁽⁴⁾	2745
0'-0"	0.00	0.00	0.00	0.00
2'	0.00	RO.01	RO.01	LO.08
4'	LO.06	RO.08	RO.07	LO.11
6'	LO.09	RO.09	RO.17	LO.15
8'	LO.18	RO.15	RO.32	LO.20
10'	LO.26	RO.19	RO.62	LO.33
12'	LO.28	RO.22	RO.89	LO.40
14'	LO.14	RO.24	R1.20	LO.38
16'	RO.10	RO.09	R1.61	LO.39
18'	RO.36	0.00	R2.03	LO.36
20'	RO.55	LO.11	R2.33	LO.35
22'	RO.68	LO.26	R2.54	LO.34
24'	RO.83	LO.32	R2.72	LO.32
26'	RO.90	LO.41	R2.69	LO.35
28'	RO.80	LO.36	R2.44	LO.37
30'	RO.62	LO.23 (29'10")	R2.35 ⁽³⁾	LO.40
32'	RO.36	LO.04		LO.42
34'	RO.13	RO.13		LO.38
36'	LO.13	RO.28		LO.27
38'	LO.21	RO.34		LO.21
40'	LO.22	RO.36		LO.15
42'	LO.16	RO.21		0.00
44'	0.00	RO.17		RO.16
46'	RO.17	0.00		RO.17
47'2"	0.00 (46'6")	0.00 ⁽³⁾		0.00

TABLE VII (continued)

HORIZONTAL OFFSETS OF PROCESS TUBES AT KW

Distance ⁽¹⁾ From Front Van Stone	Offset ⁽²⁾ - Inches			
	2746	2751	2783	2788
0'-0"	0.00	0.00	0.00	0.00
2'	LO.05	LO.04	0.00	0.00
4'	LO.11	LO.06	0.00	RO.08
6'	LO.16	LO.09	RO.06	RO.18
8'	LO.22	LO.11	RO.11	RO.28
10'	LO.30	LO.13	RO.17	RO.26
12'	LO.38	LO.13	RO.15	RO.23
14'	LO.34	LO.05	RO.11	RO.16
16'	LO.26	RO.13	RO.06	RO.19
18'	LO.07	RO.32	0.00	RO.21
20'	RO.16	RO.47	0.00	RO.24
22'	RO.25	RO.56	0.00	RO.26
24'	RO.37	RO.60	0.00	RO.28
26'	RO.40	RO.55	0.00	RO.30
28'	RO.32	RO.48	0.00	RO.32
30'	RO.11	RO.23	RO.11	RO.34
32'	0.00	RO.06	RO.12	RO.24
34'	LO.13	LO.13	RO.19	RO.26
36'	LO.27	LO.20	RO.20	RO.27
38'	LO.21	LO.21	RO.21	RO.28
40'	LO.22	LO.22	RO.22	RO.37
42'	0.00	LO.16	RO.15	RO.23
44'	0.00	0.00	RO.08	RO.08
46'	0.00	0.00	0.00	0.00
47'2"	0.00	0.00	0.00	0.00

TABLE VII (continued)HORIZONTAL OFFSETS OF PROCESS TUBES AT KW

Distance ⁽¹⁾ From Front Van Stone	Offset ⁽²⁾ - Inches	
	4044	4097
0'-0"	0.00	0.00
2'	LO.05	LO.04
4'	LO.11	LO.02
6'	LO.15	0.00
8'	LO.18	RO.09
10'	LO.17	RO.17
12'	LO.25	RO.22
14'	LO.23	RO.26
16'	LO.19	RO.29
18'	LO.14	RO.32
20'	LO.08	RO.35
22'	0.00	RO.38
24'	0.00	RO.41
26'	0.00	RO.44
28'	0.00	RO.47
30'	0.00	RO.51
32'	LO.06	RO.36
34'	LO.13	RO.38
36'	LO.20	RO.27
38'	LO.21	RO.21
40'	LO.15	RO.23
42'	LO.07	RO.16
44'	0.00	RO.16
46'	0.00	RO.08
47'2"	0.00	0.00

TABLE VIIIHORIZONTAL OFFSETS OF FRONT-TO-REAR TRAVERSE HOLES AT KW

Distance ⁽¹⁾ From End of Hole	Offset ⁽²⁾ Inches	
	V1	V2
0'	0.00	0.00
2'	0.00	RO.05
4'	LO.05	RO.11
6'	LO.19	RO.31
8'	LO.27	RO.58
10'	LO.41	RO.68
12'	LO.52	RO.78
14'	LO.65	RO.89
16'	LO.73	RI.00
18'	LO.84	RI.03
20'	LO.92	RI.04
22'	LO.96	RI.09
24'	LO.94	RI.13
26'	LO.86	RI.11
28'	LO.70	RI.03
30'	LO.69	RO.92
32'	LO.55	RO.79
34'	LO.52	RO.65
36'	LO.41	RO.61
38'	LO.43	RO.57
40'	LO.38	RO.60
42'	LO.16	LO.24 ⁽³⁾
44'	LO.08	LO.16 ⁽³⁾
46'	0.00	0.00

- (1) The end of the traverse hole is approximately 6" from the reactor face.
 (2) L or R before the offset means that the offset is to the left or right respectively of the tube center line as viewed from front to rear.
 (3) The data show these offsets to be to the left, but there is reason to believe that they are actually to the right (see Figure).

TABLE IXHORIZONTAL OFFSETS OF SIDE-TO-SIDE TRAVERSE HOLES AT KW

Distance(1) From End of Hole	Offset(2) Inches	
	W1	W2
0'	0.00	FO.12
2'	FO.04	FO.06
4'	FO.06	FO.06
5' - 8"	FO.08	FO.05
6' - 4"	FO.26	(7')RO.31(3)
8'	FO.52	RO.35
10'	FO.61	RO.50
12'	FO.71	RO.68
14'	FO.80	RO.89
16'	FO.89	R1.13
18'	FO.99	R1.25
20'	F1.00	R1.37
22'	F1.09	R1.48
24'	F1.04	R1.51
26'	F1.11	R1.52
28'	F1.08	R1.51
30'	F1.15	R1.44
32'	F1.10	R1.34
34'	FO.97	R1.22
36'	FO.96	R1.09
38'	FO.86	R1.00
40'	FO.75	RO.75
42'	FO.55	RO.47
44'	FO.49	RO.25
45'		RO.25
46'	FO.34	RO.16
46' - 8"	FO.35	RO.10
47' - 5"		FO.20
53' - 8"	0.00	

NOTE: The transit was aligned by back-sighting on marks on the X-1 level floor and wall. The transit did not then line up with the center of the traverse hole in the case of W-2.

- (1) The end of the traverse hole is approximately two inches out from the reactor face.
- (2) F or R before the offset reading means that the offset is to the front or rear respectively of the hole center line.
- (3) The distance at which this offset was taken is shown in the parenthesis to the left of the reading.

TABLE XVERTICAL OFFSETS⁽¹⁾ OF THE Y-2 TRAVERSE HOLE AT KW

<u>Distance⁽²⁾ From End of Gunbarrel</u>	<u>Offset-Inches</u>
1'	0.00
3'	-0.01
5'	-0.04
7'	-0.04
9'	+0.04
11'	+0.08
13'	+0.15
15'	-0.09
17'	-0.43
19'	-0.69
21'	-0.91
23'	-0.92 ⁽³⁾
25'	-1.13
27'	-1.09
29'	-0.98
31'	-0.63
33'	-0.40
35'	-0.16
37'	+0.12
39'	+0.07
41'	0.00

(1) Offsets were obtained by use of mercury manometer equipment.

(2) The end of the gunbarrel is six inches from the reactor face.

(3) Reading questionable.

TABLE XI

VERTICAL OFFSETS⁽¹⁾ OF PROCESS TUBES AT KW

Distance ⁽²⁾ From Front Van Stone	<u>Offset - Inches</u>		
	0271	2070	4072
1'6"	0.00	0.00	0.00
6'3" ⁽³⁾	-0.18	-0.18	-0.30
7'7" ⁽⁴⁾	-0.15	-0.16	-0.30
8'7"	-0.12	-0.13	-0.26
9'8"	-0.09	-0.12	-0.23
10'8"	-0.12	-0.01	-0.09
11'9-3/4" ⁽⁵⁾	-0.07	+0.03	-0.03
12'10"	-0.13	+0.11	-0.05
13'11"	-0.08	+0.02	-0.10
14'11"	-0.09	-0.04	-0.19
15'11" ⁽⁵⁾	-0.07	-0.18	-0.28
16'11"	-0.12	-0.08	-0.39
18'0"	-0.09	-0.18	-0.53
19'0"	-0.12	-0.23	-0.61
20'0" ⁽⁵⁾	-0.08	-0.23	-0.70
21'0"	-0.09	-0.23	-0.79
22'1"	-0.11	-0.31	-0.85
23'1"	-0.10	-0.34	-0.96
24'1-1/4" ⁽⁵⁾	-0.10	-0.36	-1.03
25'1"	-0.10	-0.38	-1.03
26'2"	-0.10	-0.35	-1.00
27'2"	-0.09	-0.36	-0.97
28'2-1/4" ⁽⁵⁾	-0.09	-0.36	-0.92
29'2"	-0.06	-0.33	-0.86
30'3"	-0.07	-0.31	-0.76
31'3"	-0.05	-0.32	-0.68
32'3-1/2" ⁽⁵⁾	-0.05	-0.25	-0.57
33'4"	-0.03	-0.22	-0.47
34'4"	-0.05	-0.17	-0.40
35'4"	-0.03	-0.11	-0.26
36'4-3/4" ⁽⁵⁾	-0.07	-0.06	-0.19
37'7"	-0.05	-0.02	-0.16
38'7"	-0.09	+0.01	-0.12
41'1-1/4" ⁽⁶⁾	-0.06	-0.02	-0.17
42'5"	-0.06	-0.03	-0.11
46'2"	0.00	+0.17	-0.02

(1) Offsets obtained by use of mercury manometer equipment.

(2) The front Van Stone flange is 12 inches from the reactor face.

(3) Inner edge of "B" shield.

(4) Front edge of graphite stack.

(5) Trunnion block locations.

(6) Rear edge of graphite stack.

NOTE: Surrounding graphite temperatures were in the range of 20°C to 50°C while the offsets on the above three tubes were being obtained.

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TABLE XII
VERTICAL OFFSETS⁽¹⁾ OF PROCESS TUBES AT KW

Distance ⁽²⁾ From Front Van Stone	Offset - Inches			
	0149	1345	1389	2040
1'6"	0.00	0.00	0.00	0.00
6'3"(3)	-0.13	-0.15	-0.17	-0.15
7'7"(4)	-0.13	-0.15	-0.16	-0.14
8'7"	-0.12	-0.13	-0.13	-0.11
9'8"	-0.09	-0.10	-0.07	-0.00
10'8"	-0.07	-0.06	-0.03	0.00
11'9-3/4"(5)	-0.05	-0.03	+0.01	+0.03
13'	-0.03	-0.03	0.00	+0.04
14'	-0.05	-0.04	-0.04	+0.01
15'	-0.04	-0.05	-0.08	-0.02
15'11"(5)	-0.04	-0.06	-0.11	-0.05
17'	-0.05	-0.07	-0.15	-0.08
18'	-0.06	-0.08	-0.18	-0.10
19'	-0.06	-0.09	-0.19	-0.11
20'(5)	-0.05	-0.07	-0.18	-0.12
21'	-0.05	-0.07	-0.17	-0.13
22'	-0.05	-0.08	-0.16	-0.14
23'	-0.05	-0.07	-0.18	-0.14
24'1-1/4"(5)	-0.05	-0.07	-0.20	-0.13
25'	-0.05	-0.08	-0.21	-0.14
26'	-0.06	-0.08	-0.21	-0.15
27'	-0.05	-0.08	-0.21	-0.15
28'2-1/4"(5)	-0.05	-0.08	-0.21	-0.16
29'	-0.04	-0.09	-0.20	-0.17
30'	-0.05	-0.10	-0.19	-0.17
31'	-0.05	-0.10	-0.19	-0.17
32'3-1/2"(5)	-0.04	-0.08	-0.17	-0.14
33'	-0.04	-0.06	-0.16	-0.12
34'	-0.03	-0.05	-0.14	-0.10
35'	-0.01	-0.04	-0.10	-0.06
36'4-3/4"(5)	0.00	-0.02	-0.06	-0.03
37'6"	-0.01	-0.03	-0.06	-0.03
38'6"	-0.02	-0.05	-0.07	-0.05
41'1-1/4"(6)	-0.05	-0.08	-0.10	-0.08
42'5"	-0.04	-0.07	-0.09	-0.08
46'2"	+0.04	+0.02	+0.01	0.00

See preceding page for footnotes.

NOTE: Surrounding graphite temperatures were less than 20°C while the offsets on the above four tubes were being obtained.

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