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FINAL REPORT
B, D, F REACTOR SIDE SHIELD HOLE BORING
TECHNOLOGY

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FINAL REPORT
B, D, F REACTOR SIDE SHIELD HOLE BORING TECHNOLOGY

By

W. H. Clemans

February 3, 1964

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February 3, 1964

FINAL REPORT
B, D, F REACTOR SIDE SHIELD HOLE BORING TECHNOLOGY

SUMMARY

Four years of intermittent development has culminated in the successful test drilling on-reactor, of one step plug hole.

Since 1960, several different drive units and many diamond, carbide, and tool steel cutting heads were tried unsuccessfully in attempts to bore a stepped hole in a mockup of B, D, F side shielding. Success was finally achieved in 1963 using a standard horizontal boring mill and tool steel cutters. With slight modifications, this same equipment was successfully used in an on-reactor test drilling at F Reactor in December of that year.

The on-reactor test revealed the need for improvements in the equipment. Chip flow was inadequate and appeared to be caused by poor air flow in the core receiver. Cast iron cutting technology used on the mockup did not work on-reactor and had to be revised on the spot. The graphite did not break up into chunks as desired and had to be manually removed. This would imply the need for a re-designed cutter which will take a full cut in the graphite, rather than a core cut.

None of the steel cores were more radioactive than 50 mr/hour at approximately 2", but the cast iron core read 300 mr/hour at 10 feet. It had to be handled very quickly. The dose rate for handling the graphite was 400 mr/hour. It, too, was handled quickly. The beam coming from the hole before removal of the cast iron was about 15 mr/hour. After the cast iron and graphite were removed, the beam was about 2 R/hour.

Due to the necessity of manual core handling, contamination was easily spread about the workplace. With proposed changes in material handling, particulate matter can be contained.

The test also led to the conclusion that the techniques used can provide the accuracy of hole location and straightness needed to avoid the thermal shield cooling tubes. There was an accumulated droop of only 5/32 inch at the face of the cast iron.

The over-all cost of the operation of physically drilling the hole, as accumulated by construction forces, was approximately \$13,500. It is estimated that future holes, exclusive of needed further minor development costs, will cost about \$6,000 each. This would include all hardware with the exception of a neutron chamber and instrumentation.

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HISTORY

For a number of years there has been an interest in drilling stepped holes through the type of shielding found in the three oldest Hanford Reactors, (See Fig. 1). A search for tools and equipment to drill such a hole was begun in February, 1960 by Ezra Hollister. Ezra first made contacts with vendors who had experience in diamond bit core boring and trepanning. Several bits were purchased for test and two different machines were ordered, one a Joy hydraulic drilling machine with screw feed, and the other a Boyles air-driven drilling machine with hydraulic feed. A four-foot square shielding mockup was built and in October, 1960, testing began. The carbide trepanning cutters were tried using the Joy machine. Feed and speed seemed too great, so the Boyles machine was tried with both types of bits. No success was achieved. A machinist's experience was used as an aid to the J. A. Jones millwrights, who claimed jurisdiction for the job. By January, 1961, some success had been achieved with the trepan cutter and Boyles machine, but vibration, chipped carbides, and stringy chips persisted. The millwrights continued to claim jurisdiction and would not allow application of the machinist's experience to solve these problems.

In February, a Houston tool bit with four tool steel cutters was tried with the Boyles machine. Cutting characteristics were good but the Boyles machine could not provide the torque required at low rpm. At this point, a Gilbert horizontal boring mill was acquired through Naval excess. In May of 1961 the Gilbert machine was tried with the tool steel trepan cutter, but the cutter was immediately ruined by maloperation. In July of 1961, Hollister published a report, HW-70342, detailing his progress to this point.

In June, H. F. Jensen was assigned development control of the job. A Jones machinist made a cutter head with three cutters and it showed good cutting characteristics. One of the major problems appeared to be the millwright's lack of machinist know-how. For this reason, the machine and mockup were moved to the J. A. Jones machine shop in the 3000 Area. Lack of priority and funds delayed further work until May, 1963.

In May, when the program was reactivated, the machinist drilled four feet into the mockup using the three-cutter design. Long stringy chips plugged the system, so the cutters were reground with various chip breakers.

In June, W. H. Clemans was assigned to the job. The first hole was completed, although the four-inch cutter was damaged while cutting through the junction between cast iron blocks. Stringy chips were still plugging the system. A second hole was drilled to test additional cutter changes. Some stringy chips were still persisting. A core receiver with a trap door was added to the machine for easy removal of cores and more cutter changes were made. A third hole was successfully drilled in the mockup and in August, off-reactor development was considered complete.

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OUTAGE PREPARATION

J. A. Jones submitted an estimate for drilling one hole at F Reactor, based on an outage beginning November 19. The estimate was \$12,793. Production Scheduling moved the outage date to December 2, and then to December 4. A Production Test Authorization was written and approved and the month of November was spent in preparing for the outage. E. A. Wegener was assigned as development consultant at this time.

A steel sleeve, aluminum thimble, paraffin filled bonnet, and an epoxy iron step plug were fabricated. A steam ejector vacuum unit and miscellaneous other gear were located at the reactor. The boring machine location was surveyed and cross-checked within 1/64 inch, using a test hole on the X-1 level and the fourth cooling tube. A strong steel framework was used to support the machine both front and rear and the machine's mounting flange was bolted solidly to the side of the reactor.

A fifty-gallon chip receiver barrel was placed on the floor below the machine and was connected to the vacuum takeoff on the machine and to the steam ejector unit outside.

Fabrication of the steel sleeve was unsatisfactory. Tolerances were not as specified. Eccentricity, runout, inside and outside diameters and weld flash required correction before the thimble would fit into the sleeve or the sleeve into the mockup holes. In the future, the importance of the tolerances which appear on the drawings should be stressed to the vendor. (See Fig. 6.)

Personnel of the Instrument and Electrical Development Unit had previously installed an epoxy iron* step plug at DR Reactor in an octant hole. Inspection of this plug showed satisfactory performance so the concept was used for the plug for the new hole. A steel mold was fabricated but an attempt to line it with General Electric Co.'s RTV silicone rubber failed when air bubbles became trapped in it. Since there was not time for another start, most of the rubber was salvaged and the pieces were patched together on the aluminum mandrel that had been used in the first attempt. The entire assembly was then coated with cloth and plaster and allowed to harden. The aluminum mandrel was removed and the mold anchored in plaster. A helically bent tube was assembled to the mold, and the mold was poured full of epoxy iron. After a two-day cure, the plug was machined to size. The end which had been embedded in plaster was very brittle, probably because of the moisture in the plaster. To prevent further cracking, an aluminum sleeve was pressed over the end of the plug. Future plugs should be made in a moisture free mold. (See Fig. 5.)

It was later determined that the neutron chamber would be too deep in the hole, with the dimensions of the step plug as designed. Two iron epoxy donuts were fitted to the step plug so that it could be installed four inches further removed without unnecessary loss of shielding. Finalized dimensions are shown in Figure 4 of the Appendix.

A hinged bonnet was fabricated of steel and its hollow wall was filled with paraffin. (See Fig. 2 & 3.)

*Ecco Shield I-3, Emmerson and Cumming Inc.

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In mockup tests a lobe blower was used to provide the vacuum. This was not readily adaptable to the more efficient filter equipment needed on the reactor. One of the steam ejector systems¹ used for graphite removal in the K channel renovation was borrowed for the job and moved into position at F Reactor.

J. A. Jones proposed coverage of the on-reactor work by two millwrights, an electrician, and a pipefitter, each with their respective foreman. The use of millwrights to run the boring machine was thought to be inadequate, but was approved by Equipment Development after assurance was given that machinists could not be used except in an emergency.

The Outage--Problems Encountered and Their Proposed Solutions

Before the reactor was actually shut down, permission was granted by Processing to take a light cut on the side of the reactor so that the equipment could be operationally demonstrated and deficiencies corrected. The six-inch sleeve and cutter were mounted on the receiver and the six-inch ID bushing bolted to the mounting flange. (See Figs. 9 through 16 for illustrations of the boring equipment.) The vacuum was turned on and the fog spray² was adjusted and directed at the cut. The cutters were fed into the steel at 30 RPM and 0.003 inches/rev. Cutting characteristics appeared to be excellent, with no vibration and good chip formation. However, it appeared that there would not be proper chip removal. Chips lodged in large quantities in the receiver and twice jammed in the vacuum take-off. These problems had not occurred in the final tests on the mockup, and a restriction in air flow was anticipated as the problem. The rubber vacuum hose from the receiver barrel to the steam ejector vacuum unit was replaced with a relatively smooth plastic pipe with a 2-1/2 inch inside diameter. This did not greatly improve the situation but boring was continued with the belief that the buildup of radioactive chips would not become serious. A new design receiver is proposed (see Fig. 8) which will reduce the chance for chips to lodge there. The new design is reduced in diameter and contains a spiral vane to help move any reluctant chips to the rear of the receiver and dump them into the vacuum take-off.

After the skim cut had been taken, Equipment Development engineers operated the equipment to gain a degree of familiarization and to further test the vacuum producing equipment. While hand feeding chips into the system, the vacuum take-off jammed. It could not be broken loose by rotating in the opposite direction so it was removed and repaired in the J. A. Jones machine shop. It was returned and installed several hours before boring was to begin. There was a fault in the design of this take-off unit but it was corrected as it was repaired. There were no further problems with it.

Boring was begun at 9 a.m. December 4, 1963. No problems were encountered in the six-inch cut, although the distance through layer eleven was about 1/2 inch greater than predicted from drawings. This may have been partly due to shield bowing but masonite cores near the skin were actually thicker than 4-1/2 inches. The 6" cutter was fed at 30 FPM and .003 in./rev.

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1. Reference Drawing No. SK-1-5800
 2. A 20:1 mixture of water and Hocut No. 237.

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The five-inch ID bushing was placed in the hole against layer eleven to guide the five-inch cutter. The six to five-inch reducer, five-inch sleeving, and five-inch cutter were assembled to the receiver and guided into the five-inch bushing. This cutter was fed at 37 RPM and 0.003 inches/ rev. Steel cores were usually reluctant to slide back into the receiver. It was not determined whether this was because of the way in which the last of the cut released the core, or that the vacuum was not strong enough. At any rate, the sleeve sections had to be removed to retrieve the core each time. It may be beneficial to relieve the ID of the cutters so there is less surface to restrain the core.

The four-inch ID bushing was placed in the hole against layer 2 to guide the four-inch cutter. The four-inch cutter, two four-inch sleeves, and one five-inch sleeve were assembled in the hole and mounted on the receiver. This cutter was fed at 44 RPM and 0.003 inches/ rev. The steel cores were still reluctant to slide back into the receiver. The last core in this cut had a flange of metal attached to it which was broken from the main body as the cutter neared the end of the cut.

The four-inch cutter was reinserted and a light cut was taken into the cast iron at 30 RPM and 0.003 inches/rev. The tools were then pulled out and the hole was borescoped. A clean cut was revealed in layers 18 through 5. Layer 4 masonite was intact but brittle. The layer 1 masonite was badly deteriorated. It was crumbly, and the top half of the cut was void for 1/2 inch or more. The color was a yellowish red, not charred, and its texture gave it the appearance of having no binder left in it. The cut into the cast iron was clean. There was no evidence of chatter. The face of the cast iron was scaly and probably rusty, as were several of the steel cores that had been removed. The steel wool appeared to be intact but was mildly rusted. It broke up more easily than fresh steel wool. The beam of radiation coming from the hole at this time read about 15 mr/hr, a lower level than was anticipated. This was about 27 hours after the reactor had shut down.

A target was inserted in the hole and a transit used to determine the deviation from the horizontal. Measurements were as follows: at face of unit, no deviation; at end of six-inch cut, down 1/32 inch; at beginning of five-inch cut, down 3/64 inch; at end of five-inch cut, down 1/64 inch; at beginning of four-inch cut, down 9/64 inch; at end of four-inch cut, down 5/32 inch. These deviations were comparable with those found in the mockup and in agreement with Production Test limitations, so boring was continued. The offset between the five and four-inch cuts, however, indicated a loose fitting guide bushing. It was assumed that no side-to-side deviation had occurred, as was the case on the mockup.

The four-inch cutter was again inserted and boring was begun in the cast iron at 30 RPM and 0.003 in./rev. It was realized quite suddenly that no progress was being made although the machine acted as though it were cutting. The machine had been pushed back on its way about six inches and the cutters were dulled. Inspection of the hole revealed a polished surface on the cast iron. At this time it was believed that the boring machine had not been clamped tightly enough to force the cutters into the metal. The machine was moved back into position and firmly clamped.

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[REDACTED]

The spare cutting head was attached and placed in the hole. Again the machine was pushed back, and the cutters were dulled. While one cutting head was being repaired with carbide inserts, the other was resharpened and tried without success at 60 RPM and 0.009 inches/rev. The carbide cutters were tried at 106 RPM and 0.009 inches/rev. Considerable noise and vibration accompanied the penetration of the work-hardened surface, then the cutting went smoothly for 3-1/4 inches. At this point, all three carbide bits had been knocked off the cutting head. The tool steel cutters were resharpened and used to finish the cut at 44 RPM and 0.009 inches/rev. There was no apparent wear or damage to the cutters. The core was not sucked back into the receiver because a thin flange was still attached to it. A steel rod was used to break the flange into small pieces. It was brittle and easily broken. These pieces fell into the space between the cast iron and the graphite and were not retrieved. The core was pulled out with a hooked rod and dropped through a chute into a cask below. Readings on the core were about 300 mr/hour at 10 feet.

The cutters which had been used to finish the cut in the cast iron had all been sharpened full width. If they had been resharpened with the inner tooth advanced as before, the flange may not have been a problem and the core could have been discarded through the receiver. Feeds and speeds used in boring cast iron in the future should be in the neighborhood of 106 RPM for carbide and 44 RPM for tool steel, both at 0.009 inches/rev.

The four-inch cutter was reinserted and the graphite was cut by hand feeding at 106 RPM. Two graphite blocks were entered on the long axis. The cut was ended about half way through the blocks, and the core was left attached to the main body. The core was broken with a stick and the two halves pulled out with a rod. The dose rate for handling the graphite was about 400 mr/hour. The beam coming from the hole read about 2 r/hour.

To prevent problems in handling the graphite in future holes, a full cut is suggested with a special cutter so that all graphite can be removed as chips.

The hole was completed in 39 hours. Step plug installation was completed without incident. The sleeve was not grouted or bolted in place because the several hours required for this step were not available, but this can be done at any future outage if desired. Film tests have shown that it is not necessary to use the grout.

All cores taken from the shielding and graphite were made available for analyses to Hanford Laboratories and Research and Engineering.

Throughout the boring, considerable difficulty was encountered in disconnecting the joints between sleeves, reducers, and cutter heads. Suggestions are included for redesign with a triple Acme thread seating on a brass ring. A lead hammer and spanner could be used to break them free.

To facilitate changing sleeve sections and reduce the total length required, the entire boring machine can be made movable on its ways. (See sketch, Fig. 7.)

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Two large lamps on stands were provided on the platform, but because of the type of stand, they could not be located close enough to the machine to provide adequate light. It is suggested that temporary overhead lighting be installed at the machine controls and near the face of the reactor.

JOB HAZARDS

Operation of the boring machine was relatively safe. There was some danger from getting SWP clothing tangled in the rotating drive between the machine and reactor face.

Overhead clearance was limited on the work platform due to the elevation of the hole on the side of the reactor. It might be feasible to build the platform lower but elevate the portion used as a work station for operating the machine. It is recommended that all personnel wear hard hats both on and beneath the platform.

The scaffolding used in the F outage was safe, since it had a railing all around it. However, the access ladder was an aluminum step ladder which was not anchored. This presented a definite hazard to tired personnel.

Unnecessary doses of radiation were taken in removing and disposing of cast iron and graphite cores. If this phase of the boring had been accomplished according to plan, exposure would have been minimized. Also, because of this manual handling of cores, contamination spread was excessive. An air sampling device should be kept near the hole site at all times to make sure contamination does not become airborne.

COST ESTIMATE FOR FUTURE HOLES BASED ON EXPERIENCE AT F

Additional equipment changes needed, including new design receiver, new design sleeves with triple Acme threads, traversing mechanism for the boring machine, new design graphite cutter, as building, and testing.	\$8,200
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Construction forces to supply new work platform	2,000
---	-------

Train craftsmen	500
-----------------	-----

TOTAL	\$10,700
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Cost <u>per reactor</u> in addition to above for drilling holes and installing sleeves and thimbles (3 holes)	\$14,000
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Cost of bonnet and step plug, <u>per hole</u>	1,500
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Engineer
Mechanical Development

WH Clemans:hr

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TIMING OF EVENTS

TIMING OF EVENTS

<u>Operation</u>	<u>Hours From Start</u>
Completed 6" cut	5
Completed 5" cut and 4" cut to cast iron	17½
Completed Borescoping	18½
Completed Traverse	18½
Dulled Cutters in CI and put on spare set	18-3/4
Started Carbide Cutters into CI	34½
Cut Graphite Core	38
Cleared channel ready for hardware	39
Completed Gas Seal	42-3/4

TABLE 1

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INTERMEDIATE RANGE NUCLEAR
MONITORING STEP PLUG HOLE
CROSS SECTION

FIG 1

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BONNET DETAILS

FIG 2

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BONNET ASSEMBLY

FIG 3

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STEP PLUG
MOLDED OF ECCOSHIELD I-3
EMMERSON & CUMING, INC.

FIG 4

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(SUGGESTIONS FOR DESIGN OF)
STEP PLUG MOLD HALF (MAKE TWO).
MILD STEEL

FIG 5

A SUGGESTED METHOD FOR
MAKING THE BORING MACHINE
MOVABLE ON ITS WAYS

FIG 7

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SECT A-A

DOOR FOR REMOVING CORES

FIG 8

SUGGESTED IMPROVEMENTS
FOR CORE RECEIVER & VACUUM
TAKE-OFF ASSEMBLY

FIG 9

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**CORE RECEIVER AND
VACUUM TAKE-OFF ASSY**

FIG 10

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FIG 11

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FIG 12

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4" SLEEVE WITH REDUCER AND
CUTTING HEAD ATTACHED

FIG 13

AEC-GE RICHLAND, WASH.

FIG 14

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FIG 15

F16 16

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