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December 31, 1969

Dr. Peter A. Morris, Director
Division of Reactor Licensing
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Dr. Morris:

Subject: Proposed Modification No. 70-1 to the Safety Analysis Report, DPR-19, Dkt 50-237 to permit irradiation of cobalt during Cycle 1

Pursuant to 10 CFR 50.59, Commonwealth requests that the Safety Analysis Report (SAR) of License DPR-19 be revised to allow operation of Dresden Unit 2 in Cycle 1 with four capsules containing cobalt 60 located in the core to provide data on cobalt 60 production in boiling water reactors. The revisions are as follows:

(1) Revise section 3.6.1 (Design Basis) of the SAR of DPR-19 by the addition of the following item after item n.: o. Cobalt 59 irradiation capsules.

(2) Revise section 3.6.2 (Description) of the SAR of DPR-19 by the addition of the following paragraph at the end of the section:

"During Cycle 1 the reactor will be operated with up to four capsules containing cobalt 59 installed in the narrow water gaps between fuel assemblies. These capsules will be installed in the core and supported in the same manner as the core sources. The purpose of these capsules is to demonstrate the ability to generate cobalt 60."

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Pursuant to 10 CFR 50.59, an appropriate safety analysis report in support of these revisions to the SAR is attached hereto as Appendix A. In our opinion, the proposed revisions shall not result in hazards which are greater than or different from those analyzed in the SAR; specifically, (1) there is no increase in the probability of, or (2) no increase in the possible consequences of, or (3) the creation of a credible probability of an accident or malfunction different from, accidents previously evaluated in the SAR, and the margin of safety as defined in the basis for any technical specification is not reduced.

In addition to three signed originals, 19 copies of the proposed modification are also included.

Very truly yours,

Peter S. Van Nort

Peter S. Van Nort
Nuclear Licensing
Administrator

SUBSCRIBED and SWORN to
before me this 31st day
of December, 1969.

Patricia A. Nelson
Notary Public

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DATA PACKAGE

COBALT DEMONSTRATION CAPSULES

FOR

COMMONWEALTH EDISON DRESDEN II

NUCLEAR POWER STATION

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COBALT DEMONSTRATION CAPSULES FOR DRESDEN II

I. INTRODUCTION

To demonstrate the feasibility of irradiating cobalt in the water gaps of a commercial power reactor, a test program is proposed for Dresden Unit II. This program will use cobalt pellets encapsulated in nickel plating inside test capsules which are prototypical of those which could be used in production quantities in current-design BWR's such as Dresden II and III, and Quad Cities I and II. The program will provide operational confirmation of the mechanical, thermal-hydraulic, and nuclear characteristics of the capsule design, and demonstrate the capsule handling feasibility.

The proposed cobalt capsules will be axially assembled as sticks of three capsules captured between the top grid guide assembly and core plate in the water gaps between fuel channels at the corners of four contiguous core cells. The BWR core cell consists of a cruciform control blade surrounded by four fuel channels. The outer four corners of a core cell form interstices with adjacent core cells; this space permits insertion of cobalt capsules without any change in reactor component geometry. The capsules will be attached between the upper grid structure and core support by a spring loaded latch and support device; the fuel channels themselves provide lateral restraint to the capsules, and the top grid guide assembly and lower core plate provide lateral and axial restraint.

With the cobalt capsules in interstitial spaces like the neutron sources and instrumentation guide tubes, the water velocity past the capsules will be nominally one foot per second or less. This provides adequate cooling for the low operational heat flux of approximately 3000 BTU/hr/sq.ft.; even stagnant water conditions with or without net steam generation provides sufficient cooling for the low rate of heat generation in the cobalt capsules. This low water velocity region of the core is additionally valuable in minimizing any flow-induced vibrations.

Because Dresden II provides the prototypical BWR environment, and because the proposed irradiation has progressed from the test reactor stage, this test program is proposed.

II. CAPSULE DESCRIPTION AND QUALITY CONTROL PROVISIONS

The irradiation target material is Cobalt-59, greater than 99.4% pure, in the form of cylindrical pellets with overall nominal dimensions of 1 mm in diameter by 1 mm long. Each pellet is plated with nickel to a

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plate thickness of .0003" to .0006" (nominally .0005"). These target pellets are encapsulated in an annular target volume formed by concentrically assembling two 304 stainless tubes into a capsule. The size of the annulus is precisely controlled to provide the desired linear loading of cobalt-59 in the capsule. The Dresden II demonstration capsules have a target cobalt annulus 36 inches long with a 0.562 inch inside diameter and 0.694 inch outside diameter which provides a linear cobalt loading of 4.1 grams per centimeter. Three of these demonstration capsules containing about 385 grams of target cobalt are assembled on a common axis into a stick so that the total amount of cobalt is 1.16 kg per stick.

The capsule stick structure (see Figure 1) is fabricated entirely from certified type 304 stainless steel. Each capsule chamber is a pressure tight vessel designed with guidance for stress allowance from the ASME Pressure Vessel Code, ~~Section~~ III, Class A. Each capsule inner tube is made up of 9/16" O.D. X .028" wall tubing swaged on one end to allow end-to-end slip assembly of inner tubes. The capsule outer tubes are 3/4" O.D. X .028" wall tubing swaged first on one end to fit snugly over the inner tube. The outer tube is fusion welded to the inner tube to produce a pressure and leak-tight seal; these welds are X-rayed to check weld penetration. An 11/16" O.D. X .049" wall X 1/8" long ring is positioned internally at the end of the outer tube and the annulus is filled by vibration with cobalt pellets. The amount of cobalt loaded is carefully weighed and recorded to assure uniform loading. A second 1/8" long ring is positioned in the annulus and the outer tube end is swaged to snugly fit the inner tube. This closure is then fusion welded to produce a mechanically strong pressure-tight seal. A weep hole is provided in the outer tube. The void space between encapsulated pellets is then pumped down to vacuum and back-filled with helium, and the weep hole is welded closed. A leak test is performed and the capsule is then X-rayed to ascertain good weld penetration on all welds and uniform void-free loading of cobalt. Three capsules are then assembled end-to-end with fusion welded joints to form an overall length of 117 inches. These welds are X-rayed for adequate penetration. Fully annealed tubing is used as raw stock. The cold work of swaged sections is in the range of 0 - 20%, resulting in improved mechanical properties in the swaged region.

The capsule stick is attached in the reactor grid in the same manner as the neutron sources. The same tools used for handling sources are used for handling the cobalt sticks. To accomplish this, each test stick is fitted with a locating device on the lower end and a spring-loaded latch handle on the upper end similar to those used with the neutron source. The locating device centers the stick in the interstice between four fuel support castings. The spring loaded latch engages a notch in the underside of the top guide grid. When installed thus in the reactor, upward and downward and sideward movement is prevented by the upper and lower core supporting structures just as it is with the neutron sources. Sideward movement is further precluded when the surrounding fuel elements are in place, providing a nominal diagonal gap between elements of .892 inches and nominal adjacent elements gap of only 3/8 inches. This physical arrangement allows insertion or removal of the capsule stick after removal of only one of the adjacent fuel elements from the core.

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III. OPERATIONAL CONSIDERATIONS

A. Storage and Handling

After irradiation, the capsule sticks will be transferred from the reactor to spent fuel storage area in a transfer basket. To minimize the potential for damage to the capsules during handling, procedures are recommended that require that the transfer basket be placed in a vacant fuel position near the capsules and that the capsule stick be loaded directly into the basket. The irradiated capsules will be prepared for shipment in the spent fuel storage area by parting the sticks into the three separate capsules and loading into a shipping cask. At discharge, the curie content of each capsule stick will be approximately 30,000 Ci, none of which is volatile. This is approximately 1% of the curie content of the non-volatile portion of fission product activity within any of the individual fuel bundles within the reactor core. The radiation exposure levels are thus expected to be much less than those encountered during normal refueling steps and should cause no operational difficulties.

B. Core Nuclear Effects

1. Reactivity Effects:

The reactivity effect of each capsule stick is extremely small. Taking into account the possible peaking factors, the maximum effect of a single capsule stick is less than 0.03% Δk. As already discussed, this very small amount of reactivity is quite tightly restrained within the corner water hole so that inadvertent movement is not possible. A gross rupture of the cladding of a single central capsule on a stick could allow relocation of the contained cobalt but would result in a positive reactivity addition of less than 0.02% Δk.

Local perturbation of the power distribution was calculated using initial core fuel with zero burnup and poison curtains at 38% void. Relative to operation without the cobalt capsules, a local depression of 12% is seen in the fuel rods immediately adjacent to the target. A maximum relative power increase in any rod is 1.5%. This power skewing is equivalent to that caused by the neutron sources and in-core instrumentation guide tubes, and does not affect reactor performance.

2. Instrument Effects:

Since the cobalt will be placed in those core cell corner positions in a current-design BWR which are not occupied by either startup sources or in-core instrumentation, it is appropriate to consider the effects that this placement has on the operation of that in-core instrumentation. Of interest is the potential shadow that the cobalt may throw on a monitor which could affect the process computer programming and the potential effect of local boiling at the cobalt capsule on the monitor response and noise level. The magnitude of any of these effects is expected to be extremely small (in order

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of a few percent at most) relative to the effects already present as a result of the initial core poison curtains. This is brought into focus by recognizing that even in a full core loading of cobalt sticks in a current-design BWR, the reactivity tied up in cobalt is less than .5% Δk, or less than 5% of the reactivity initially held by poison curtains (which are also interstitially located). Placement of the four demonstration capsules in Dresden II is being chosen to provide the best possible evaluation of these effects. The four cobalt test capsule locations are given in Figure 2.

C. Thermal-Hydraulic Effects

The maximum heat flux which must be removed from the cobalt capsules under overpower conditions will not exceed 2500 BTU/sq.ft./hr. This amount of heat released is extremely small. Once again it can be related to the heat release from the existing poison curtains, being approximately 5% of that total value. Small amounts of local boiling may occur, particularly in the upper regions of the core as sub-cooling is lost, but no net generation of steam is calculated to occur.

This low heat flux presents a very mild cooling requirement. In fact, local convection currents in stagnant saturated water will quite adequately provide cooling with some net generation of steam. Under full power the maximum cobalt temperature has been calculated to be no more than 14°F above the bulk fluid temperature.

The calculated velocity of bypass flow governed by seal leakage at fuel support castings is approximately one foot per second. This low flow rate, while providing adequate cooling, neither tends to lift nor vibrate the cobalt sticks in their position.

D. Mechanical Effects

The selection of 304 stainless steel for the capsule cladding was made to provide a highly reliable encasement for the cobalt pellets for the planned irradiation period of one year and potential irradiation periods of up to three years. The fabrication and quality control techniques used, coupled with the favorable operating conditions of very low heat flux and the near saturation temperatures, lead one to conclude that stress corrosion should not be a problem. The inner and outer tube are both made of 304 stainless which has a coefficient of thermal expansion, over the reactor operating and startup temperature range, essentially equal to that of cobalt so that mechanical stability during temperature cycling is expected. This has been demonstrated by autoclave tests. Fabrication techniques employed do not result in sensitization of the cladding since fully annealed material is used and only small amounts of cold work (less than 20% reduction in size) are employed.

Radiation-induced swelling of the cobalt target is not expected. Cobalt metal has been irradiated in over 2,000 similar capsules in the General Electric Test Reactor with lead capsules at an integrated flux exposure

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twenty times the exposure which will accrue in the Dresden II tests. No evidence of irradiation-induced swelling has been noted and interestingly, no evidence of in-service failures has been experienced at the reactor.

As already mentioned, in-service failure of the annular stainless cladding is highly unlikely.

- The heat transfer calculations show that mechanical stress due to differential thermal expansion is virtually non-existent.

- Racheting of the pellets relative to the cladding is not expected because of the low temperature differences and nearly identical clad/pellet coefficients of thermal expansion coupled with only a few thermal cycles over the capsule design life.

- Radiation swelling of the target material is nil under the planned test exposure.

- Fabrication quality control includes 100% weld inspection and completed capsule leak testing to assure weld and capsule body integrity.

- The clad thickness of 28 mils of stainless steel provides sufficient allowance for scratches and gouges which may occur during handling and for fretting corrosion or vibrational wear which may occur during the planned tests.

Thus, it is difficult to identify a mechanism which might cause loss of integrity of the cladding.

However, should integrity be lost, the most likely occurrence would be for a pin-hole or small crack to appear, allowing entry of water into the annulus. Under these conditions one would predict the atmosphere surrounding the pellets to range from saturated water in core regions of low heat generation and sub-cooled bypass flow to dry steam in the high heat generation regions. The nickel plating of the pellets as well as the cobalt pellets themselves would resist corrosion in the dry steam environment, but oxidation of the nickel is expected to occur in moist or saturated water conditions. The corrosion rate, of course, will be dependent upon replenishment of the oxygen by interchange of water through the clad defect and radiolytic dissociation of the water. Under completely replenished saturated water conditions with oxygen content up to 200 parts per million, complete oxidation of the nominal half mil nickel plate on a pellet could be expected to occur in a year to two years. After oxidation of this very low specific activity protective coat, oxidation of the higher specific activity cobalt base metal would occur but at a reduced corrosion rate. This oxidation of the pellet plate and base metal may cause some pellet swelling (in the order of .05 - .1% by volume) to occur but loss of pellets from the capsule is not predicted

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since a greater than 10% change in bulk volume at a longitudinal crack would be required in order to open the crack up sufficiently to allow passage of the pellets. A crack in the inner clad would, of course, tend to be closed by such swelling. Water logging will not result in pressure differentials that could cause failure of the cladding even with coincident rapid reactor depressurization. Similarly, pressures which could develop in the annulus are not sufficient to cause swelling of the capsule which might displace the fuel channels. Tests to demonstrate this show that the inner tube begins to collapse before the elastic limit of the outer tube is reached. Complete collapse of the inner tube did not produce bowing of the capsule nor did rupture result.

Complete loss of all of the pellets from a capsule under operating conditions cannot be mechanistically envisioned. Progression of a small crack to one which would allow passage of pellets is extremely remote and even then probably only a few pellets could be lost since movement of the vibratory-loaded pellets within the confines of the annulus is quite difficult. A complete opening of the annulus would require complete circumferential cracking and parting of both the inner and the outer tube, another highly unlikely event. However, should any of the pellets of a capsule be released, they would fall through the slowly rising water to the lower grid plate between the fuel support castings and be retained there. The one millimeter least dimension of the pellets precludes passage of the pellets through any of the core-plate-to-fuel support casting seals.

It is highly unlikely that the falling pellets could find their way into the control rod guide tubes since the opening into the guide tube through the fuel support casting is well shadowed from the cobalt capsule by the fuel elements. Cross-flow currents are well below the nominal one foot per second vertical velocity of the water, and vibrational amplitudes of the channels cannot be large so that significant scattering of the pellets as they fall should not occur.

The corrosion phenomena discussed above would take place with the pellets resting on the core support plate and, if left in the reactor long enough, the nickel plating would all go into solution allowing further corrosion of the base cobalt. (Of the 385 grams of target material, 370 grams are cobalt and approximately 15 grams are nickel.) Assuming a reactor operating cycle of one year, the removal of any failed capsule and its pellets could occur before significant corrosion of the base cobalt takes place. (Upon shutdown the cobalt pellets can be removed from their resting place on the lower core plate by magnetic means.) The amount of nickel that would be thus added to the recirculating water system would be small by comparison to that already added by normal corrosion of the stainless steel components of the primary system. It would mostly be removed in the cleanup system and would have the net effect of hastening the year at which equilibrium contamination from cobalt-58 is reached.

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IV. ACCIDENT ANALYSIS

A. Refueling and Handling Accident

There are no reactivity effects associated with the cobalt demonstration capsule which are significant enough for consideration in a refueling or handling accident situation. Exposure of personnel appears to be the only safety consideration in such an accident. Since no volatile radioactive materials are present either during or after irradiation, damage to the capsule or capsule cladding material during refueling or handling under water does not present a personnel hazard. Tests have demonstrated that the capsule design virtually precludes the loss of pellets from the capsule during any handling mishap. These tests included dropping the capsule in air on a sharp edge from heights up to 25 feet, attempting to puncture the capsule with a pointed object, flattening the welded end connections, and bending the capsule approximately 175°. Photographs of the results are shown in Figure 3, 4 and 5. In each test, the protection afforded by the annular cladding prevented release of pellets. Capsule design, procedures and practices should preclude such an accident, but should it occur, cobalt pellets released from the capsule can be retrieved magnetically.

B. Steam Line Break

The classic steam line break accident results in rapid depressurization of the reactor pressure vessel, and violent flashing of the coolant in and surrounding the capsules would be experienced. Physical movement of the capsules either axially or radially in the core is not possible because of its captured position between the four adjacent fuel channels and the upper grid and core plate. The heat flux which must be removed is a factor of 100 or more lower than that in the reactor fuel, consequently clad integrity greater than that of the fuel cladding is assured. Internal pressures developed, even if water logging is present, will not result in cladding rupture. Tests have demonstrated that an internal annulus pressure of 4800 psi above ambient pressure is required before damage to the clad occurs, and then clad damage is collapse of the inner tube without rupture. At this point in testing, measurements show that the outer clad diameter had increased by less than .015 inches (less than 2%) when the inner tube began to collapse, hence capsule swelling during the depressurization will not cause mechanical interference problems. Even if clad perforation were to occur, no volatile radioactive materials are present for release. The presence of cobalt capsules in the core does not add to the severity of the consequences of a steam line rupture accident.

C. Loss of Coolant Accident

During a loss of coolant accident, the decay power from the demonstration capsules is approximately three kilowatts. The core decay heat is approximately 25,000 kilowatts a few minutes after reactor scram. It seems valid to consider the decay heat contribution of the cobalt capsules to be insignificant.

D. Capsule Drop Accident

A model for this accident is one in which the cobalt from a capsule representing the highest reactivity effect is suddenly withdrawn from the core such as might occur in the coincident failure of both the inner and outer clad of a central capsule. The reactivity insertion associated with this accident is $< .02\% \Delta k/k$; a reactivity addition accident of a control rod drop of $2.5\% \Delta k/k$ in ~ 2.5 second was analyzed in the PSAR leading one to conclude that the capsule drop accident is much less severe than that for which complete analysis has already been made.

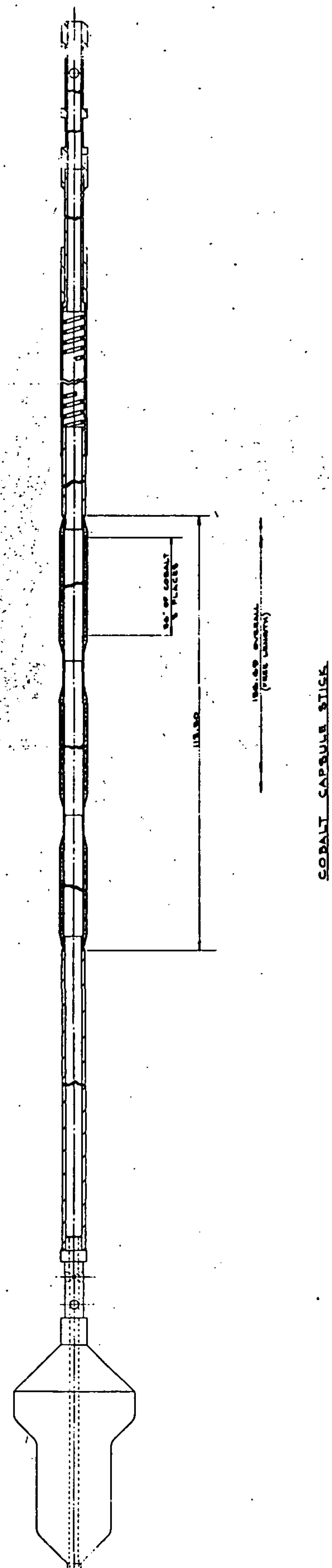

FIGURE 1

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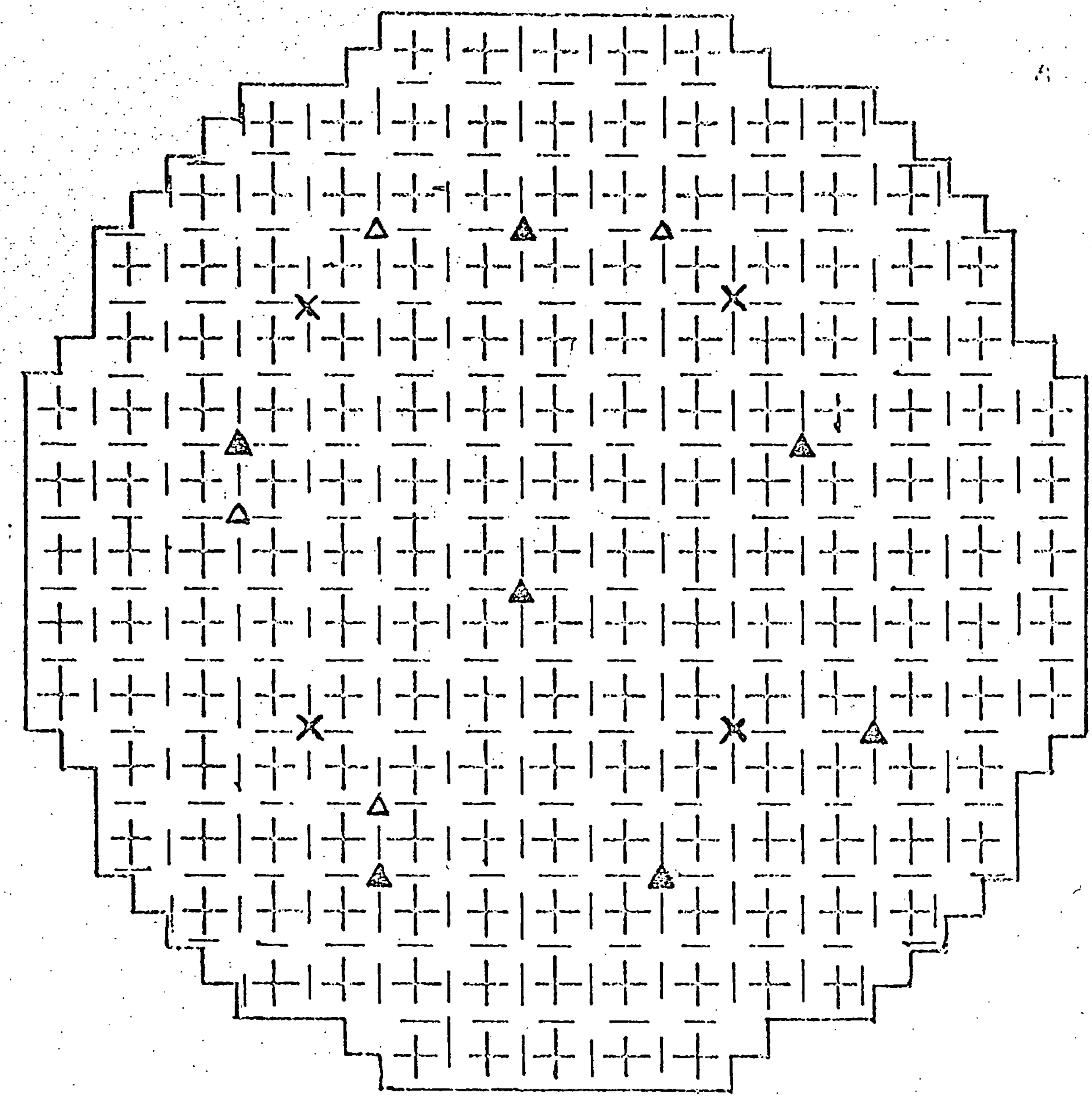

FIGURE 2 - SRM Detector, Source, and Cobalt Capsule Locations

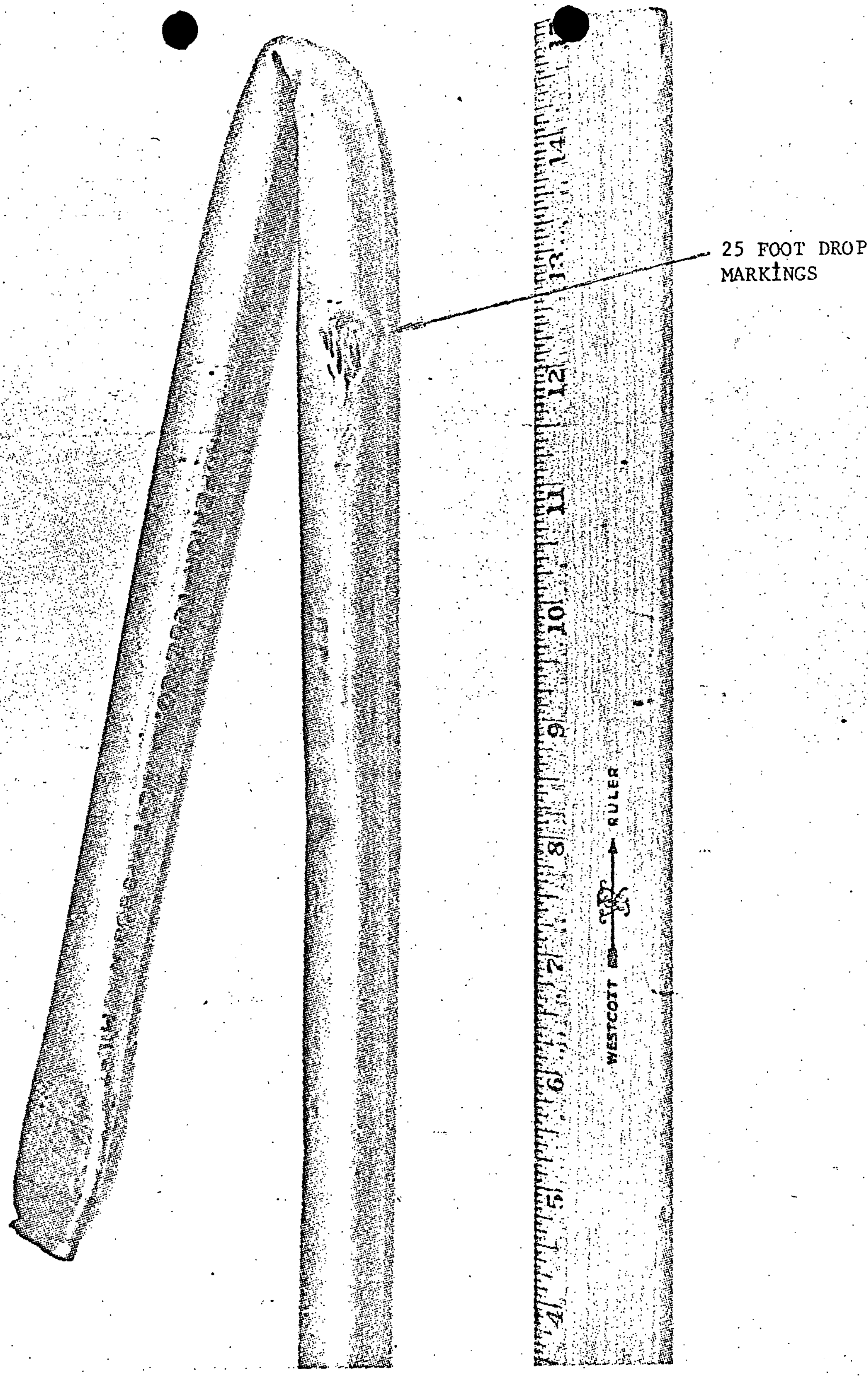

FIGURE 3 - BENT CAPSULE SHOWING MARKING FROM 25 FOOT DROP TEST

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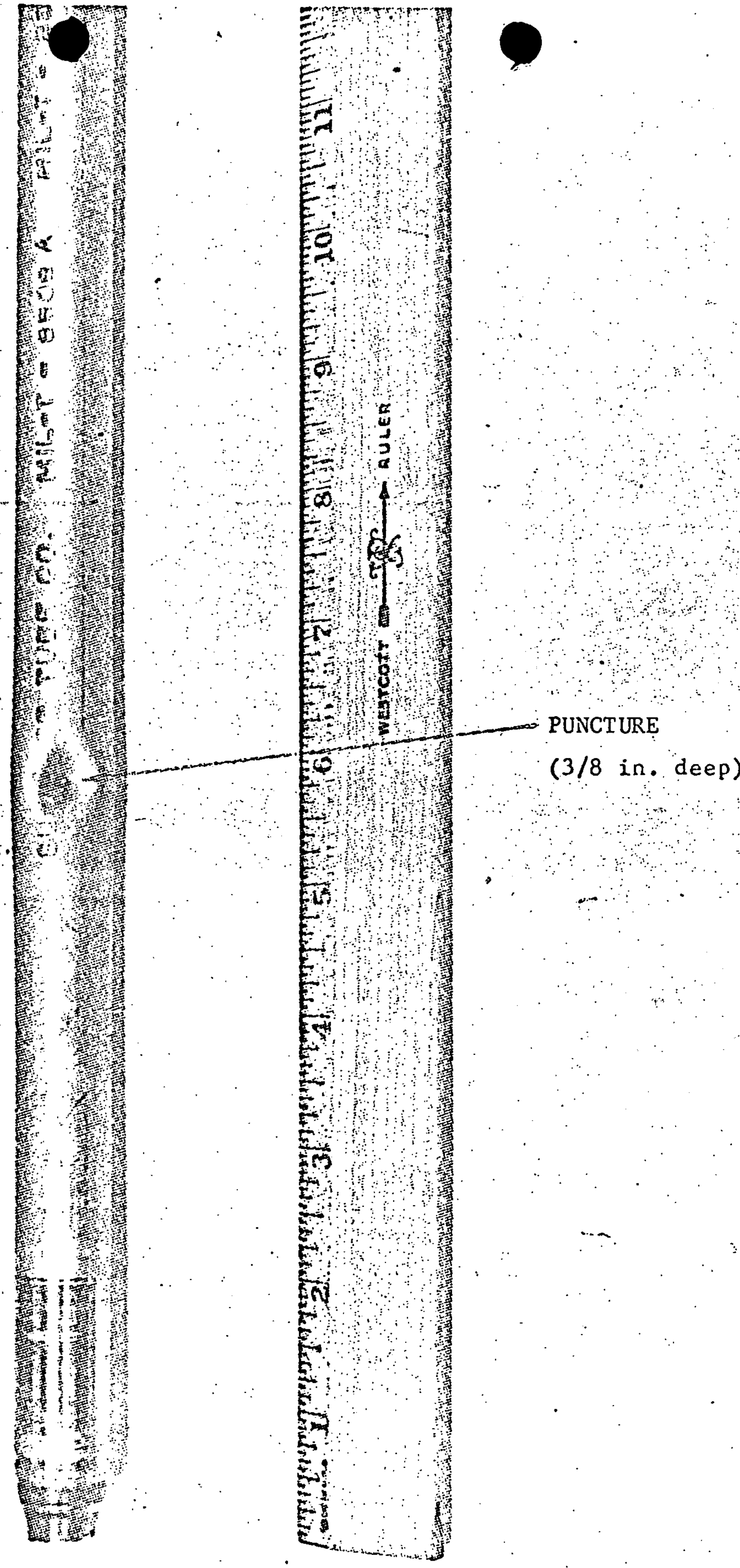

FIGURE 4 - PUNCTURE MARKING

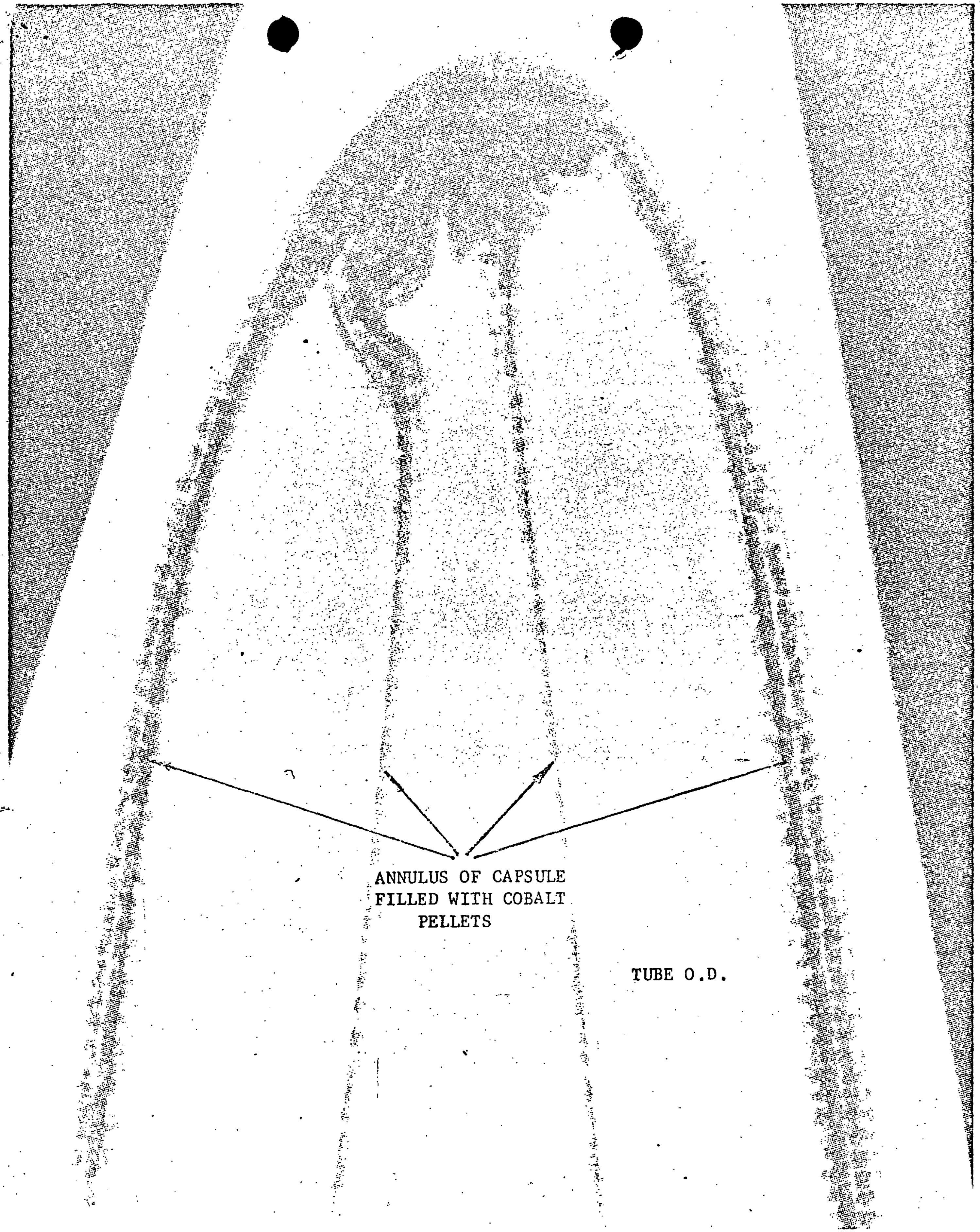

FIGURE 5 - RADIOGRAPH PRINT OF BENT SECTION OF CAPSULE; SHOWN THE CAPSULE DESIGN INTEGRITY