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# MODIFICATION OF THE LOS ALAMOS FAST PLUTONIUM REACTOR



Material Compiled by
and
Report Written by

Jane H. Hall



REACTORS

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## MODIFICATION OF THE LOS ALAMOS FAST PLUTONIUM REACTOR

### I. Reasons for Modification.

The fast reactor was shut down on March 27, 1950 in order to replace the control and safety rods, which had not been functioning properly and on several occasions had "frozen" in their channels, with rods which had:

i). more clearance in their channels,

ii). more clearance in the cans,

iii). thicker wall steel cans.

At this time a routine mercury sample was taken and the mercury was found to contain normal uranium and about 3 ppm of plutonium in the uranium. This indicated either a broken normal uranium slug or a broken plutonium slug since the plutonium can contains a 3/8" wafer of normal uranium between the top of the plutonium rod and the cap of the steel can. The plutonium present in the mercury could be accounted for by the amount of plutonium made be capture in $U^{238}$.* It was, therefore, decided to open the reactor. Calculations indicated that each plutonium slug would contain about 5 curies of fission product activity.

The reactor was opened in May, and all of the uranium and plutonium slugs were removed with the exception of two uranium and one plutonium slugs which were firmly wedged and could not be extracted. These slugs were finally removed by remotely taking apart the fuel cage.

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*For the reactor flux of $5 \times 10^8$ n/cm$^2$ sec watt, a total irradiation of about 19,000 KWH, and using a capture cross section of $U^{238}$ of 0.15 barns at these energies, a concentration of 5 ppm of plutonium in uranium is calculated.



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One of the uranium slugs (Slug 141), shown in Fig. 1, has a split in the 0.020" thick steel jacket. Fig. 2 is an X-ray of this slug showing the severe splitting and erosion of the uranium. A large number of blisters are visible on the sides of the uranium. The other wedged uranium slug (Slug 205) is shown in Figs. 3 and 4. Only one surface blister is visible. The plutonium slug was adjacent to Slug #141 and was wedged in by the uranium slug. The plutonium slug suffered no damage, however.

The uranium from which the slugs were made was mostly gamma-extruded material, the remainder of the material being stock from castings. According to developments in the study of the effects of thermal cycling uranium, gamma-extruded material is prone to develop blisters such as found here.

The reactor had been operated approximately a year. It is estimated that the fuel rods were thermally cycled about 500 to 800 times between 25°C and 150°C. The number of fissions which had occurred in each plutonium slug (450 gms.) is estimated at $7.5 \times 10^{19}$ each, in the uranium slug (580 gms.) about $1.4 \times 10^{19}$ (4% due to $U^{235}$).

II. Modifications Made.

It was decided to use only the plutonium rods in the reactor and to dispense with the normal uranium rods. Consequently, a new fuel cage containing 37 holes, instead of 55 as in the old fuel cage, was fabricated. The plutonium rods were X-rayed, cleaned, and tested for leaks using a mass spectrometer leak detector before reassembly.

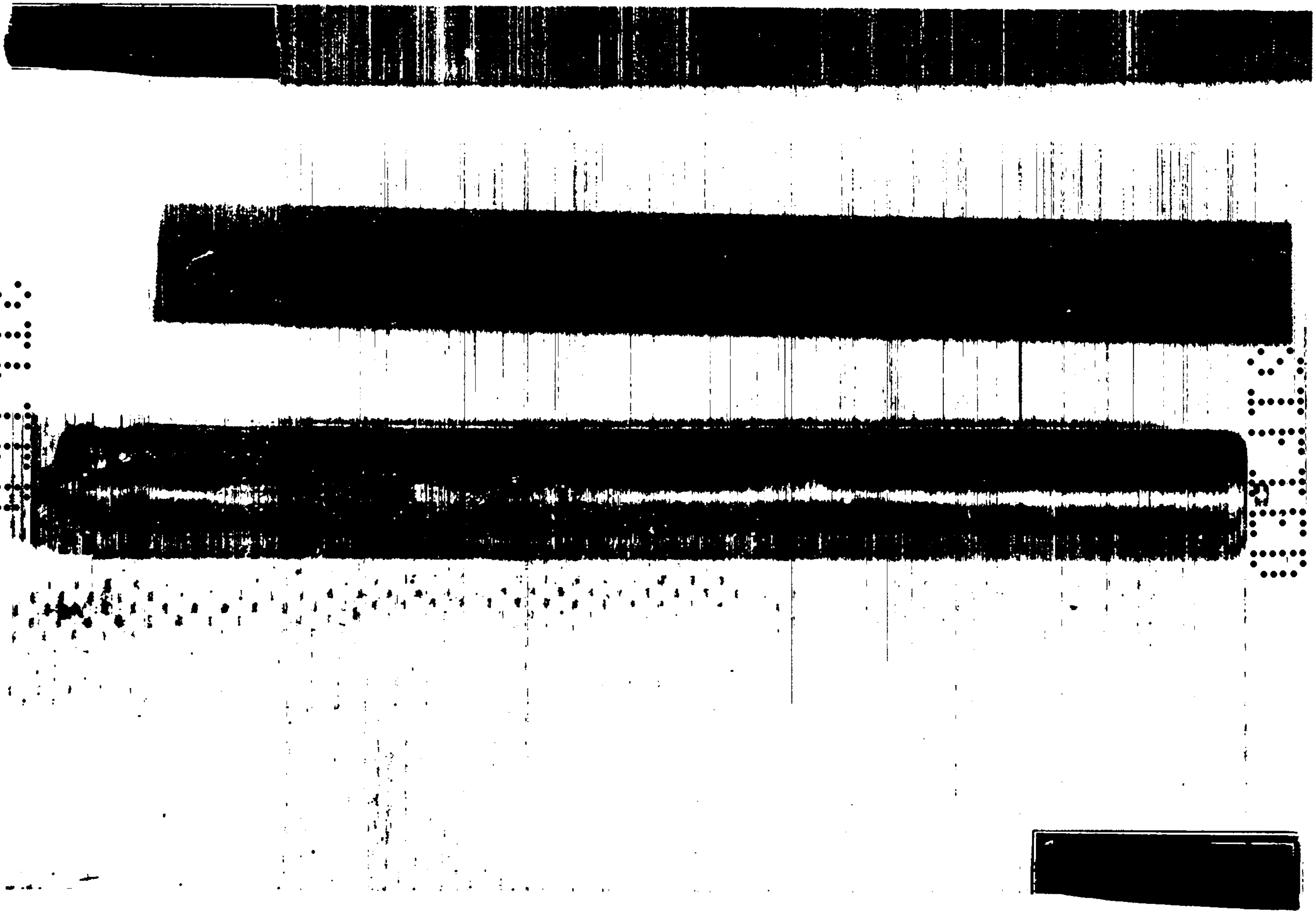

Fig. 1
Tu Rod #141

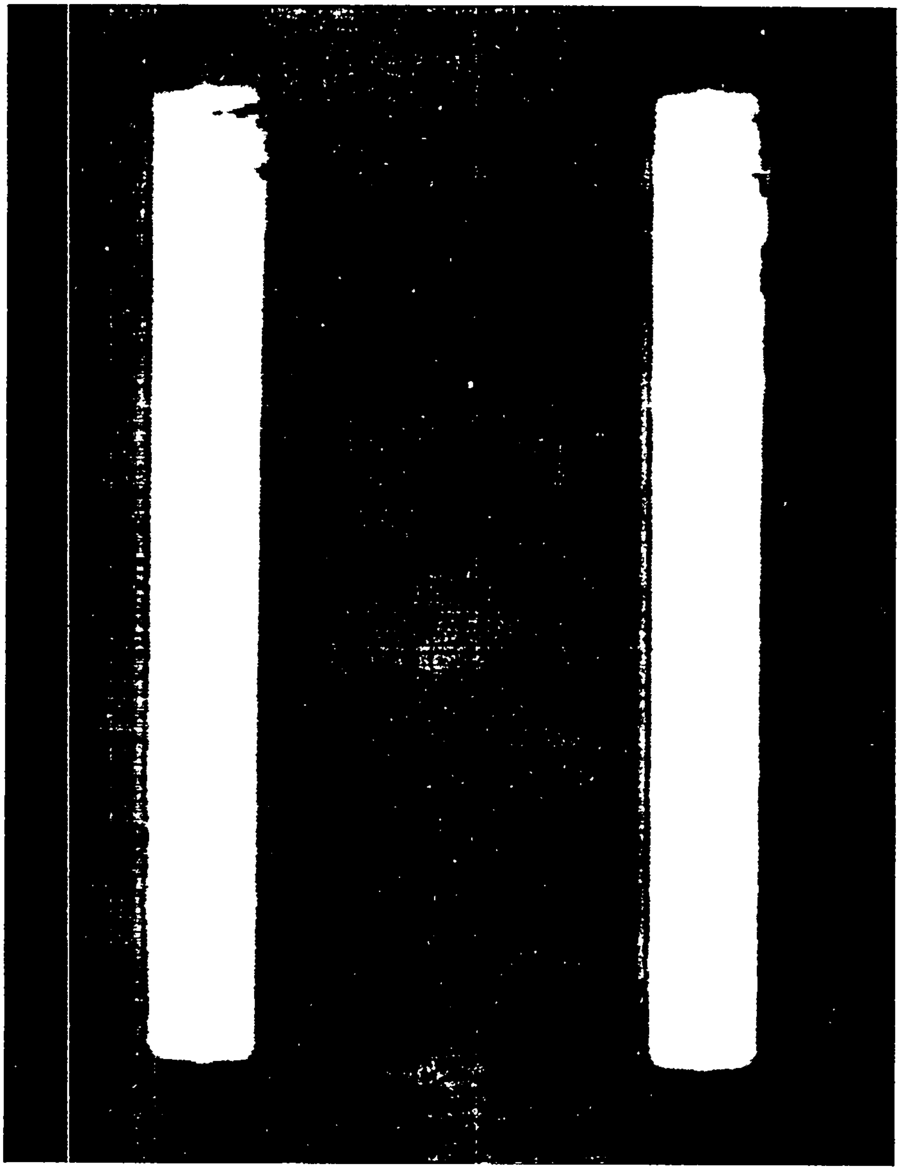

Fig. 2
X-ray of Tu Rod #141





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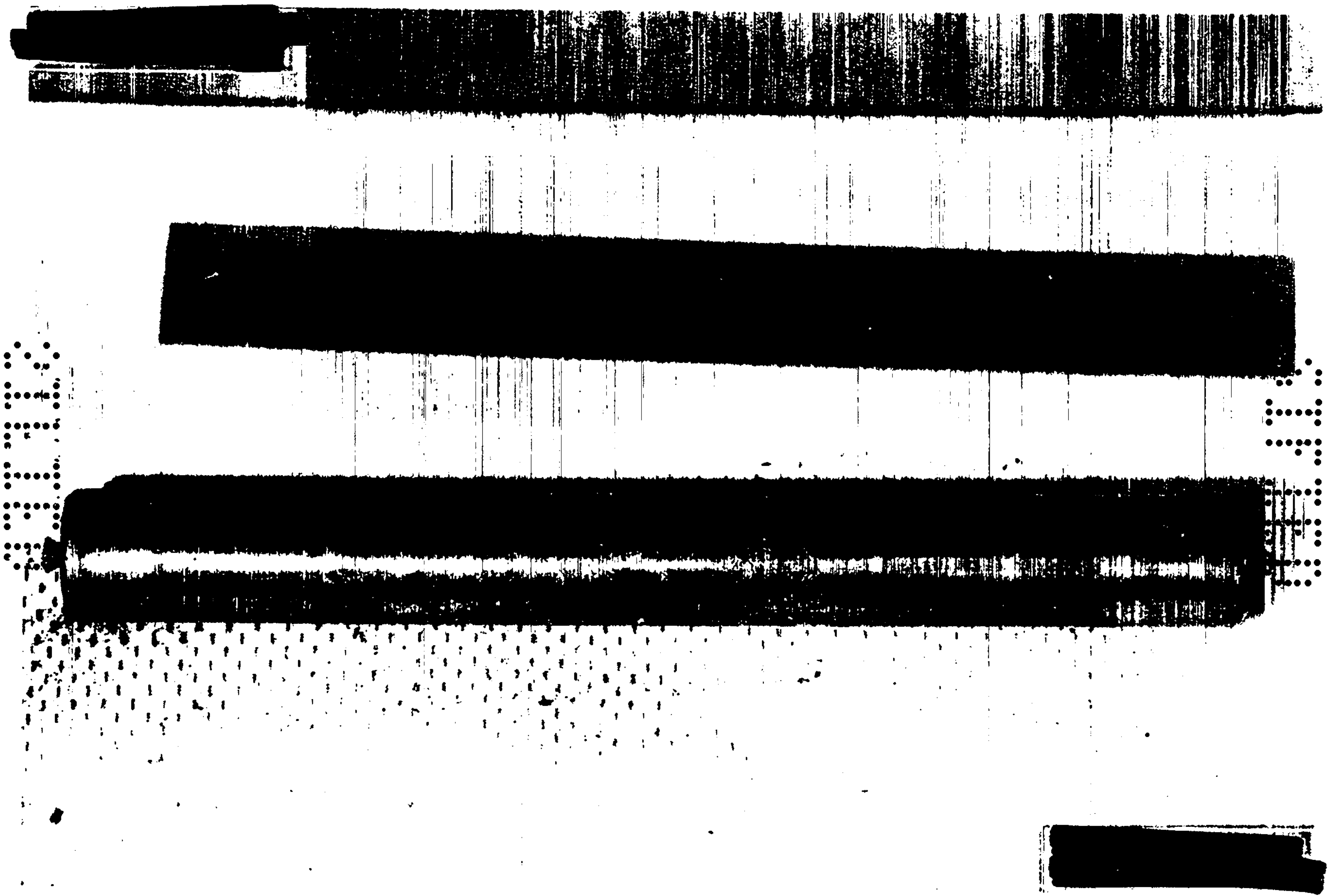

Fig. 3
Tu Rod #205



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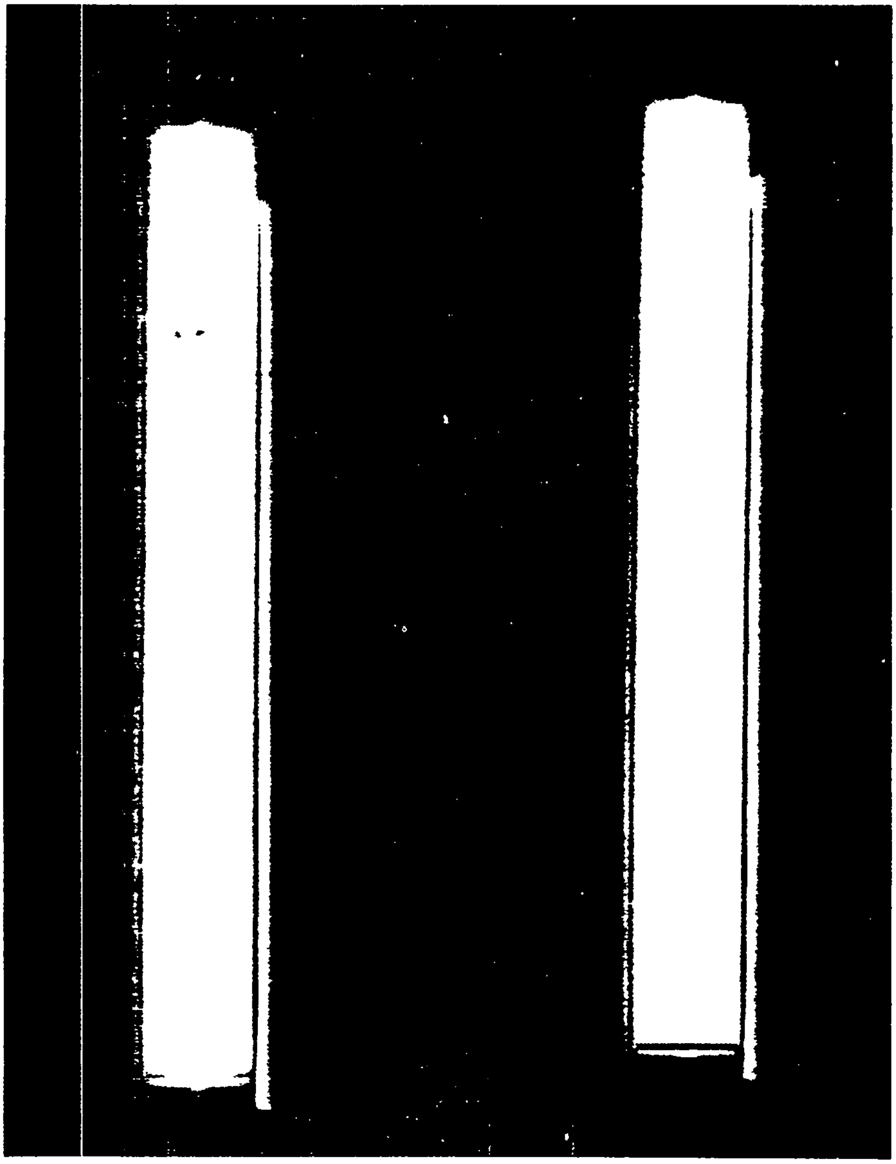

Fig. 4
X-ray of Tu Rod #205

The critical assembly was made on June 27, 1950 and the reactor welded closed on June 29. Thirty-two plutonium slugs were required. The five remaining holes were filled with steel cans having a small hole in the bottom and in the top so that the mercury can flow slowly through the cans and thereby not change the mercury flow pattern in the fuel cage.

III. Power Operation.

Power operation at 25 kw was resumed on July 17. The temperature of the central plutonium slug at 25 kw is now about 170°C as contrasted with a temperature of about 155° for the loading before. This increase is to be expected since there are now 32 slugs instead of 35 and the heat per slug is larger.

The temperature of a control rod during power operation has been measured by a thermocouple inserted in a specially designed control rod and found to be 190°C for 20 kw power. Since the rods are canned and welded, no trouble is anticipated because of the high temperature.

The reactor shows no changes in its behavior other than the slightly higher plutonium temperature.

IV. Changes in the Plutonium Rods.

Examination of the X-rays of the plutonium rods showed that in many cases a gap now exists between the plutonium rod and the uranium wafer. This gap was not observed on X-rays made (August 1947) before the reactor was operated.

As a result, measurements were made on the X-rays of many of the dimensions and compared with measurements made on the old X-rays and with caliper measurements before canning. No significant dimensional

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changes were found for the change in height of the Tu spacer. Changes in the total gap spacing were found and are compiled in Table I. Fig. 5 is a plot of the average total gap change versus original density of the plutonium rod. There is possibly some slight degree of correlation between the original density and the gap change. Since a shrinking of the plutonium rod would be evidenced by a gap change and shrinking of the plutonium rod could result from a density increase, such a relation is not impossible of explanation. If the original material were of high density in the delta stabilized phase, this might indicate that some of the original material was in the higher density alpha phase. Through heat cycling, and/or irradiation, more of the material might become unstabilized and revert to the higher density alpha phase.

Actual dimensional changes of the plutonium rods were impossible to obtain from X-ray measurements because the X-rays taken in 1947 were only of the ends where any gaps would be apparent.

In order to check the possibility of a plutonium shrinkage, Rod #66, which showed a gap change of 0.031" on the X-rays was decanned, calipered and its density measured. This operation was done by CMR-10 and is described in report CMR-10-125 by Philip Hammond.

The exterior of the steel can was not cracked or distorted but the plutonium slug had three longitudinal cracks in the nickel coating, one of which was about one inch long and 1/32" wide. When the nickel coat was removed, a large number of smaller cracks in the plutonium

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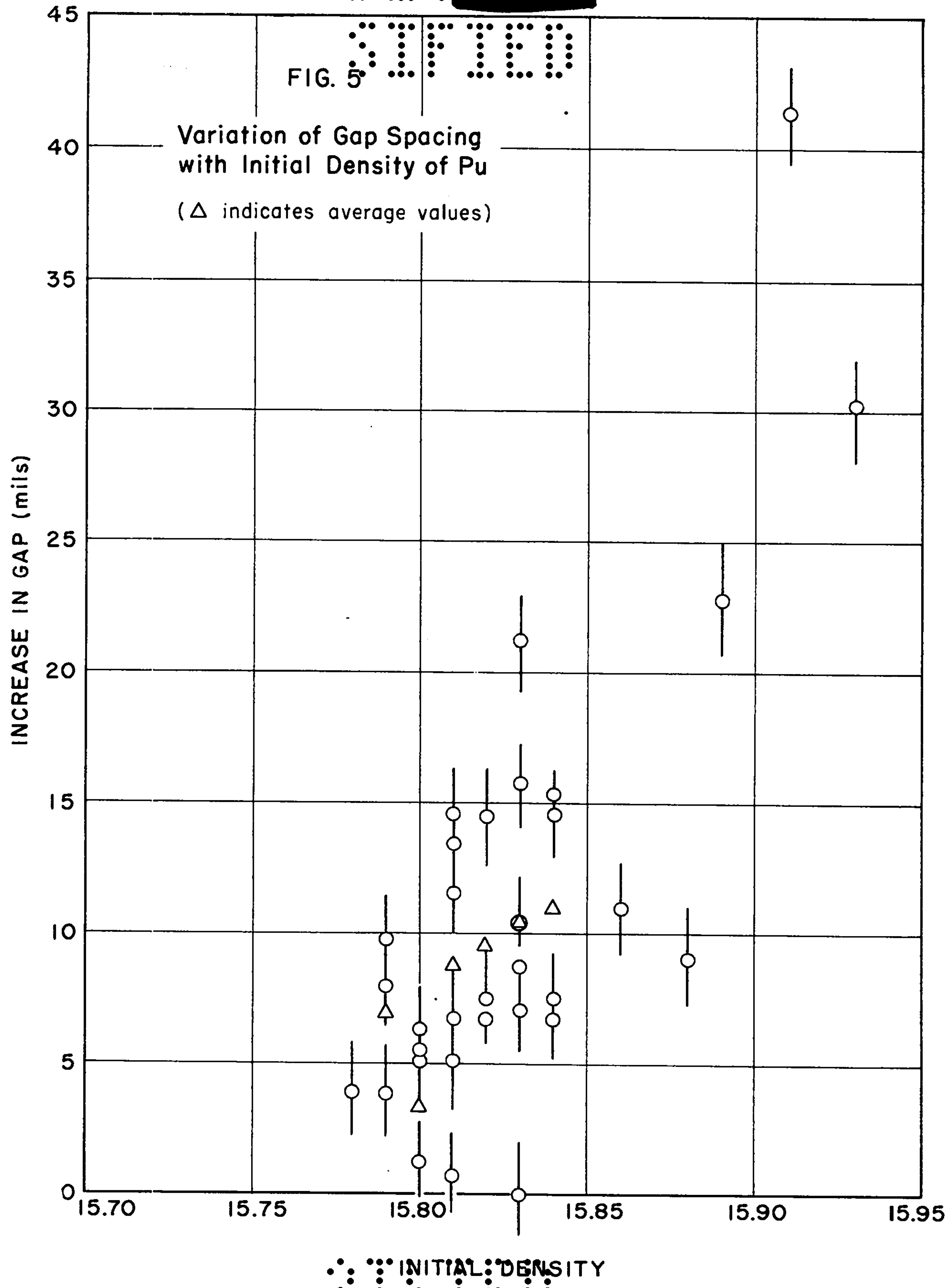


FIG. 5

Variation of Gap Spacing with Initial Density of Pu

(△ indicates average values)

# TABLE I.

## CHANGE IN TOTAL GAP SPACING OF PLUTONIUM ROD
(X-ray Measurements)

| Rod No. | ρ* (gms/cm³) | + Change in Gap (Mils)+ | Δ ¢ | Comments |
|---|---|---|---|---|
| 1 | ? | 12.6 | 0.7 | |
| 6 | 15.81 | 5.1 | 0.3 | |
| 7 | 15.80 | (-0.2) | -- | |
| 31 | 15.84 | 6.7 | 0.4 | |
| 33 | 15.82 | 7.5 | 0.4 | |
| 40 | 15.84 | 14.6 | 0.8 | |
| 44 | 15.80 | 5.1 | 0.3 | |
| 45 | 15.78 | 3.9 | 0.2 | |
| 46 | 15.81 | 14.6 | 0.8 | |
| 48 | 15.80 | 6.3 | 0.3 | |
| 51 | 15.88 | 9.1 | 0.5 | Not reloaded |
| 52 | ? | 0.4 | -- | |
| 53 | 15.84 | 7.5 | 0.4 | |
| 55 | 15.83 | 8.7 | 0.5 | |
| 56 | 15.86 | 11.0 | 0.6 | |
| 58 | 15.89 | 22.8 | 1.2 | |
| 62 | 15.79 | 9.8 | 0.5 | |
| 65 | 15.82 | 6.7 | 0.4 | |
| 66 | 15.93 | 30.3 | 1.6 | Not reloaded, decanned |
| 68 | 15.84 | 15.4 | 0.8 | |
| 76 | 15.83 | 21.2 | 1.1 | |
| 92 | 15.83 | 15.7 | 0.8 | |
| 106 | ? | 9.8 | 0.5 | |
| 201 | 15.83 | 10.6 | 0.5 | Not irradiated not loaded now |
| 202 | 15.81 | 6.7 | 0.4 | |
| 206 | 15.79 | 7.9 | 0.4 | |
| 208 | 15.83 | 0 | 0 | |
| 211 | 15.91 | 41.4 | 2.2 | Not reloaded |
| 212 | 15.81 | 0.8 | -- | |
| 214 | 15.80 | 1.2 | -- | Not loaded now Not irradiated |
| 220 | 15.81 | 13.4 | 0.7 | |
| 228 | 15.80 | 5.5 | 0.3 | |
| 230 | 15.82 | 14.6 | 0.8 | |
| 232 | 15.79 | 3.9 | 0.2 | |
| 233 | 15.83 | 7.1 | 0.4 | |
| 235 | 15.81 | 11.4 | 0.6 | |
| | | Σ = 19.6¢ | | |

*Density given is density as measured at DP when rods were fabricated in 1946.
+Total gap change includes change in gap between top of steel cap and uranium wafer, uranium wafer and plutonium rod, plutonium rod and bottom of steel can.

could be seen in addition to one large round spot which presented a shriveled and cracked appearance. Fig. 6 is a photograph of the plutonium rod, with the steel can and nickel coat removed, showing the spot mentioned above. The following measurements were made and are here compared with the original caliper measurements made at the time of fabrication and canning.

| | Aug. 1950 | 1947 | Change |
|---|---|---|---|
| Calipered over-all length of canned slug #66 | 6.035" | 6.027* | +0.008" |
| Calipered length of coated slug #66 | 5.461" | 5.498 | -0.037" |
| (X-ray gap change in canned slug) | | | +0.031" |
| Density | 16.27 | 15.93 | +0.34 ~2% |

These measurements indicate that the gap changes observed are due to shrinking of the plutonium rods which has occurred because of density increases of the rods.

V. Possible Reactivity Increase.

During the winter 1949-1950 a slow reactivity increase was observed which was correlated with the lower inlet water temperature and consequent lower mercury and plutonium temperatures. However, during March 1950 an increase of reactivity of about 17¢ was observed which

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*The over-all length of a canned slug is difficult to caliper because of the weld on the top surface which may vary in thickness by many mils. Hence, it is difficult to attach significance to variations in the over-all length of the canned slug. It is possible that some elongation of the steel has occurred due to thermal cycling and irradiation, but the inaccuracies in measuring are so large that conclusive evidence is not established.

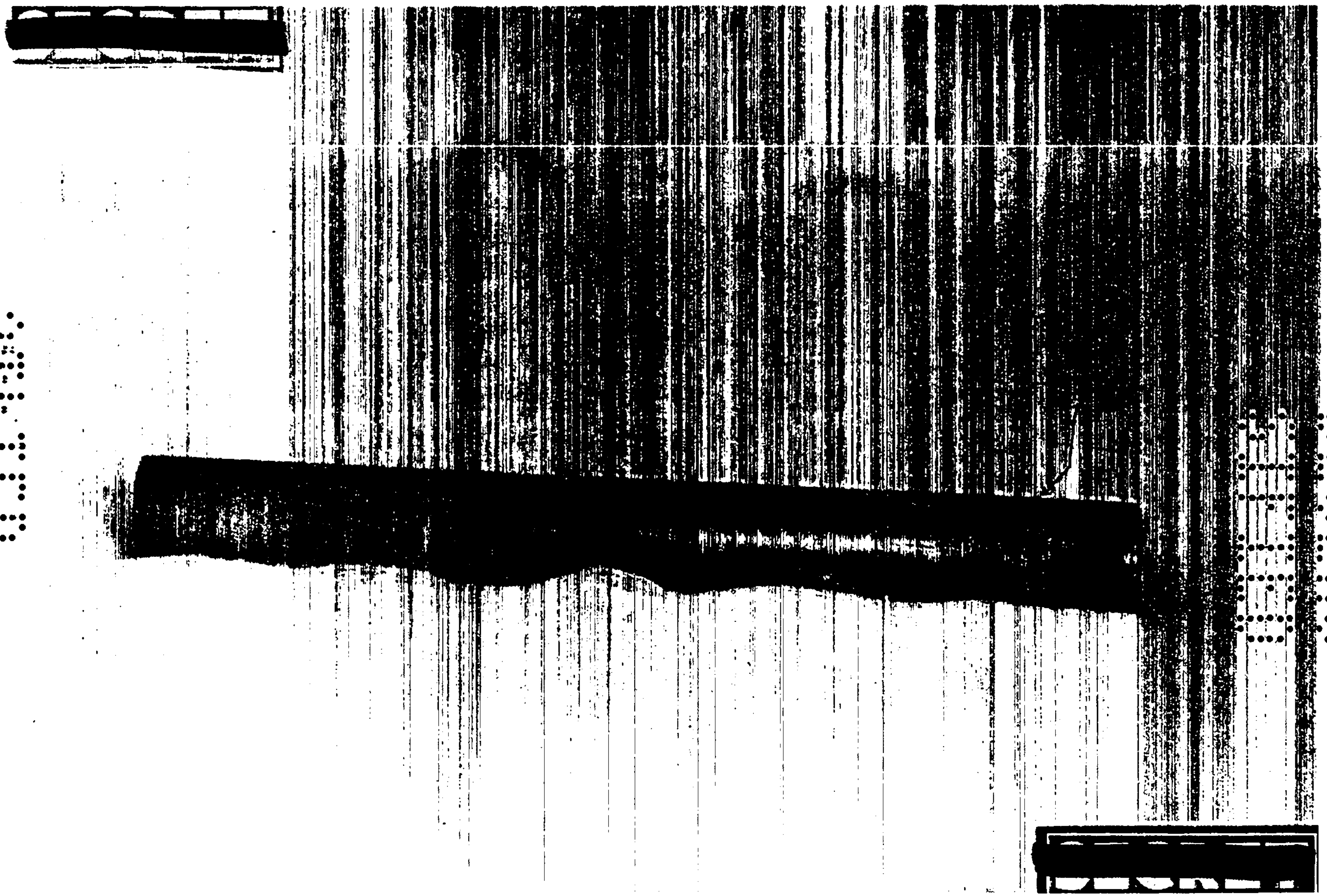

Fig. 6
Irradiated Pu Rod #66

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could not be accounted for by temperature considerations. It is not known if this reactivity increase was due to the density changes in the plutonium rod. One can estimate from the total gap spacing per slug and the measured density of slug #66 the new densities of each slug. Then, from old measurements which were made of the reactivity effect of an alpha phase slug of the same mass as a standard slug one can estimate the total reactivity change expected from the observed gap changes.

The approximate relation

$$\Delta \rho = -8.3 \Delta h$$

can be used where $\Delta \rho$ is the change in density to be expected from a uniform shrinkage of the slug in which the length change is $\Delta h$ in inches. Previous measurements indicated that a reactivity increase of 25¢ resulted from an increase of density of one rod from 15.8 to 19.8.

Hence,

$$\Delta R \sim K \frac{\Delta \rho}{\rho}$$

$$\Delta R = 25¢ = K \frac{4}{15.8}$$

$$K \approx 100$$

and

$$\Delta R \sim -\frac{830 \Delta h}{\rho} \sim -52 \Delta h$$

Table I shows the expected reactivity increase per slug expected from the length decrease of the slug as measured on the radiographs. The sum of the reactivity increase is 20¢, which is about the same as the reactivity increase observed and unaccounted for by the temperature changes.

[redacted]





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It may be concluded that evidence exists for varying degrees of plutonium shrinkage and density increase. The observed reactivity increase may be accounted for by this. The shrinkage will reduce the heat conductivity if the slug recedes appreciably from the can wall. If the slugs continue to increase in density, the reactivity may continue to increase. Since the control in reactivity is about $10.00 under present conditions, and since a phase change of all 32 slugs to alpha phase is equivalent to about $8.00, adequate control is present. The apparent reactivity increase was slow and any further changes would be expected to be slow also. Therefore, no hazard appears to exist.



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