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PLASTER OF PARIS REPLICAS OF REACTOR FUEL SLUGS

by

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PLASTER OF PARIS REPLICAS OF REACTOR FUEL SLUGS

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ABSTRACT

A method is described for preparing plaster of Paris replicas of irradiated fuel slugs. An impression mold is made by pouring the plaster about a fuel slug held in a specially designed holder. The slug is removed from the holder and the impression mold is used to cast a replica, also made of plaster of Paris. The replicas, including one end only, are accurate reproductions of the original slug for surface features down to about one-half mil and for dimensions within one or two mils. Two dental impression plasters were found to give satisfactory results.

Within the limits mentioned, the process will serve the purpose of preserving models of radioactive specimens for use as "museum pieces." However, the procedures are very exacting in achieving such results.

INTRODUCTION

Some work has been done at Hanford on reproduction of damaged slugs as plaster replicas.¹ Such a procedure makes available a three-dimensional model for general inspection by those who cannot visit the cave to which the subject slug is confined and study it there. Reproduction also preserves a tangible record of subject slug after it has been destroyed by examination processes and by disposal of the radioactive remnants.

There is no question of the suitability of plaster techniques for recording gross deformations, such as "blisters," large swellings and kinks. However, just what lower limit of resolution of fine details might be accomplished was unknown. Therefore, it was decided to experiment with replicas and to compare surface contours on them with the original slug by means of a profilometer. This work was done as part of a program of evaluation on irradiation damage to slugs being tested for the Savannah River Project. Surface relief on these subjects was known to be of the order of two mils and under.

¹Private communication from L. D. Turner reports development work, in which C. W. Botsford, R. G. Wheeler, R. C. Fields, C. L. Boyd, E. C. Watts and L. F. Miller have collaborated, still in progress. Studies have included dental materials and rubber molding compounds for "negatives," plaster of Paris and centrifugally cast low melting alloys for "positives." Topical report will be issued.

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EXPERIMENTAL PROCEDURES

The process was evolved by trial and error. The recommended procedures are described below:

A. Plaster - Dental impression plasters were thought to offer the best chance for producing good replicas with a limited amount of equipment. Of three plasters investigated, the two listed below were found satisfactory when the indicated proportions of plaster to water were used:

1. Kerr Snow White Plaster No. 1, manufactured by Kerr Manufacturing Co., Detroit, Michigan. (3 parts water to 4 parts plaster by weight.)
2. Castone, manufactured by Ranson and Randolph Co., Toledo, Ohio. (2 parts water to 5 parts plaster by weight.)

Distilled water was used at all times, because the high salt content of the laboratory domestic water made it unsatisfactory. These mixes contain more water than recommended by the manufacturers. The extra water was required to make the plaster more fluid for easy pouring inside the cave. The amount of extra water is not enough to produce unsound or porous molds. Some shrinkage or settling occurs during initial setting, but the plaster is still fluid, and as it settles it forms a concave top surface. During the final setting, the plaster expands slightly.

Both Kerr No. 1 and Castone plasters produced replicas of about equal quality. Castone is a stronger plaster, probably because of the smaller ratio of water required, but it is light brown in color, and the color is not quite uniform throughout. This tends to mask small surface irregularities. Kerr plaster, on the other hand, is snow white, and all surface characteristics are easily observed. For this reason Kerr No. 1 plaster is recommended.

B. Specimen Holder - After preliminary experiments indicated that a plaster replica could accurately reproduce a metal surface, a wood holder was designed to properly hold a CP-6 type slug and contain the fluid plaster until it could set.

The holder assembly is shown in Figure 1. It consists of two halves hinged together at the bottom. Two thin metal separator plates are fastened to the wood to enable one to easily split the plaster mold in two. The holder is clamped in the closed position by a screw clamp that is tightened with wing nuts.

The slug is held in the holder as shown in Figure 2. The beveled end is supported by the wooden end plug, and hence it is not reproduced. Four positioning screws hold the upper end of the slug properly centered in the holder.

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To pour the plaster impression mold, the holder is placed on end as in Figure 3, so the plaster can be poured into the hole at the top. The whole weight of the slug is now borne by the end plug.

After the plaster mold is made, the end plug and slug are removed, and the mold is inverted as shown in Figure 4. The plaster for the replica is poured into the hole formerly occupied by the end plug.

Figure 5 shows the position of the plaster mold and replica in the holder.

The choice of wood for the holder material was unfortunate. Water absorption from the plaster produced severe warping and distortion of the holder. This allowed the fluid plaster to leak out. It also prevented proper re-closing of the mold for pouring the replica, hence the diameter and warp of the slug were not accurately reproduced in the replica. It is recommended that, in any future work, the holder be made of metal, such as aluminum. Guide pins should be provided to insure correct registry of the two halves on closing the mold. The cross section size should be reduced for easier handling by the master-slave manipulator.

C. Details of Process. - The sequence of operations is described below. Some steps are illustrated in Figures 1 through 5.

1. Preparation of Holder: All parts of the wood holder and end plug which will be in contact with the plaster are coated with "Tincture of Green Soap" or other sizing material, so that the plaster may be easily removed. The four positioning screws are adjusted, using an unirradiated control slug. If the irradiated slug is badly warped or blistered, the screws must be adjusted by trial and error.
2. Preparation of Slug: The slug is thoroughly washed with soap and water and dried with CCl_4 or acetone. No other surface preparation is required. If the aluminum is clean and dry and the slug is not ruptured, the plaster will wet it completely and produce a good impression, yet the slug can be easily removed from the impression without damaging it and without leaving any significant radioactive contamination. The slug is placed beveled-end down on the wood plug. The four positioning screws hold the upper end properly centered in the holder. The holder is closed, the clamps tightened, and assembly is placed behind a radiation shield so the cave may be entered safely.
3. Pouring of Plaster Impression: A fluid plaster is mixed outside the cave using 3 parts distilled water to 4 parts Kerr No. 1 plaster (by weight). A satisfactory way to insure equal

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crystallization throughout the mix is to agitate the water with a stirrer and gradually add the plaster. Stir as rapidly as possible without beating air into the mix. Enter the cave and place the mix in suitable apparatus so it can be poured into the holder with the use of manipulators. Close the cave, and pour the plaster into the holder. For this particular holder, a mix of 280 ml of distilled water plus 375 grams of plaster just fills the holder. The plaster mix begins to stiffen in about 10 minutes and is fully hard in about an hour. The slug may be removed from the holder about an hour and a half after the plaster has been poured.

Attempts were made to avoid having to enter the cave by using a very slow setting plaster made by adding extra water or acetic acid to the mix, but this always produced weak and porous molds.

The mold is opened by wedging a screwdriver between the two separator plates at the space provided. This breaks the plaster away from one half of the slug and the mold can be opened. The slug will usually fall away from the other half of the mold under its own weight or with the aid of tapping the mold against the table. However, in this operation care must be taken to insure that the beveled end (top) of the slug and the wood plug come away first. If the weld end (bottom) of the slug comes out of the mold first, it will destroy the plaster impression of one half of the weld end. This happened to the mold used to cast the replica of slug AZ, shown at the left of Figure 9.

4. Preparation of Mold for Casting Replica: Remove the mold from the cave and dry thoroughly under heat lamps or in an oven. High temperatures may cause fine cracks in the plaster and hence should be avoided. The mold must be "sized" by rubbing a soap solution into the surface. This prevents the plaster replica from adhering to the plaster mold. Sizing the mold is the most difficult and unpredictable step in the process. Only by experience and practice can one learn to do it properly.

"Tincture of Green Soap" (Standard Drug Co., Newark, N. J., alcohol 28 - 32%) is a suitable sizing agent. It is desirable to thin this tincture a bit by adding one volume of alcohol to 3 volumes of the stock tincture. The soap is brushed on with a paint brush and allowed to dry. Then the mold is rubbed lightly with Kleenex or a soft cloth until nearly all the soap is removed, and the whole mold surface is evenly covered with a very thin soap film. The rubbing

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seems to have a polishing action that imparts a glaze to plaster. After sizing, the mold appears glossy and feels very smooth and somewhat slippery to the touch.

5. Pouring of Plaster Replica: After sizing the mold, the holder is again clamped shut. A 3 to 4 mixture of water and plaster is mixed as in step 3, except that 120 ml of distilled water and 160 grams of Kerr No. 1 plaster is sufficient for the replica. The round wood plug is left out of the holder and plaster poured through this hole. Again allow about 1-1/2 hours before attempting to remove the replica.

DISCUSSION OF RESULTS

Figure 6 shows two surface profile traces taken on control slug BT and on a plaster replica of this slug made using this procedure. It is seen that the general contours are reproduced with good fidelity, while the finer details suffer somewhat in duplicability. Some of this discrepancy may be due to a real difference in location of the paths traced on the slug and its replica. The practical limit of resolving contour heights seems to be in the vicinity of 0.0005 inch.

Figure 7 is a photograph of a plaster replica of irradiated slug AZ. The circumferential bumps are made visible by using oblique lighting. These bumps were also shown by photographs of the irradiated slugs themselves (Figure 8).

Replicas of the welded ends of slugs AZ and BP are shown in Figure 9. Half of the end of the mold of slug AZ was damaged when the slug was removed. The ridge in the center of the slug is the parting line flash, where plaster penetrated between the two halves of the mold.

Measurements of diameter and warp indicate that these dimensions are not reproduced accurately enough with the present mold to warrant making these measurements on the replica. The fault lies primarily with the wood holder. When the holder is clamped shut to cast the replica, the two halves may not come together exactly. Then the two half-cylinders of the replica will not be concentric. Warp measurements taken in the usual manner (by rotating the slug about its axis and measuring high and low points at the center) will be inaccurate. The replica diameter is usually several mils larger than the slug diameter because the wooden holder had not closed completely. The parting line flash prevents diameter measurements in the perpendicular direction. A mold could be designed that would eliminate these faults. Then warp and diameter should be reproduced to within, say, 0.001 inch. However, these dimensions can be easily and accurately measured on the irradiated slug itself, using remote methods, so there is nothing to be gained by attempting to use replicas for this purpose.

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CONCLUSIONS

The process described in this report will produce plaster of Paris replicas of irradiated specimens on which surface conditions that are visible to the naked eye, or can be felt with the fingers, are usually reproduced. The "limit of resolution" of surface contours seems to be about 0.0005 inch.

Uniformly good replicas are not obtained one hundred per cent of the time, due primarily to the difficulty in "sizing" the mold correctly. As the operator masters this art, the number of unsatisfactory replicas should become small. It is easy to pick the "good" replicas from the "bad" ones by visual examination, however, so false conclusions based on study of the replicas can be avoided. "Good" replicas have a uniformly glossy surface, while "bad" replicas have dull appearing spots, where the plaster either has not wet the mold or has adhered to the mold and broken away from the replica when the holder was opened.

Physical measurements of warp, diameter, and profiles on the replica were not reliable with the present equipment. It is felt that, with an improved holder, these dimensions could be reproduced to within about 0.001 inch.

The replicas can be used to preserve models of interesting specimens, i.e., they can serve as "museum pieces." It is recommended that plaster of Paris replicas be used only for this purpose.

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Figure 1. Wooden Holder Assembly. One Separator Plate is Removed to Show Interior of Holder.

Separator Plate

Clamp

End Plug

Macro #13,522

1/3X

Figure 2. Wooden Holder With Fuel Slug and End Plug in Place.

Macro #13,521

1/3X

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Figure 3. Holder in Position for Pouring of Plaster Impression.

Macro #13,519

1/3X

Figure 4. Holder in Position for Pouring of Plaster Replica.

Macro #13,520

1/3X

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Figure 5. View of Holder Showing Plaster Impression at Left, (Separator Plate Removed for Illustrative Purpose only) and Plaster Replica at Right.

Macro #13,518

1/3X

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Figure 7. Plaster Replica of Irradiated Slug AZ. Circumferential Bumps are Made Visible by Oblique Lighting.

ANL Neg. No. 106-803

1X

Figure 8. Photograph Through Cave Window of Irradiated CP-6 Fuel Slugs. Circumferential Bumps are Made Visible by Oblique Lighting.

ANL Neg. No. 106-305

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Figure 9. Plaster Replicas of Irradiated Fuel Slugs AZ and BP, Showing Welded End. (Mold of Slug AZ was damaged; only half of this weld end is reproduced). The circular grooves are from machining marks on the slugs.

ANL Neg. No. 106-803

Slug AZ

Slug BP

3X

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