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For The Atomic Energy Commission

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Chief, Declassification Branch

PROCESSING OF SPECIAL METAL

FOR HANFORD

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MALLINCKRODT CHEMICAL WORKS
William A. Oppold

March 10, 1947

AEC RESEARCH AND DEVELOPMENT REPORT

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PROCESSING OF SPECIAL METAL

FOR HANFORD

Object

To reduce the impurities and raise the density of rejected slugs and briquetted turnings from these slugs by recasting the material.

Discussion

Experience has shown that metal high in nitrogen could be greatly decreased in nitrogen content by recasting. As high nitrogen metal is low in density because of the nitrogen content, the recast metal being very low nitrogen is also improved in density. Impurities such as iron cannot be reduced by recasting, but they are not increased in that operation, so the overall quality is greatly improved. Some impurities like carbon and silica are probably increased slightly by recasting.

With the above facts in mind, the Hanford Engineer Works requested that M.C.W. recast some low quality slugs and some briquetted turnings made from the scrap left when these slugs were machined. A program was outlined by the Hanford people, and Mr. E. A. Smith and Mr. T. Jones of Hanford visited our plant to watch the processing of the material. The original program was changed somewhat after several runs had been made and not all the metal was recast for reasons which will be stated later.

We started out by recasting the slugs. The metal acted very peculiarly in that it did not boil at all in the crucible and left a very heavy film on top of the melt. When the material was poured, it appeared to be very viscous and gave very poor yields when only heated to the pouring temperature of virgin metal biscuits. After the pour was completed, metal kept running out of the crucible which pointed to the fact that there was a large "heel" in the crucible which was honeycombed with molten metal slowly working its way down to the pouring hole. It was quite evident that the metal would have to be heated much hotter than virgin metal to make it fluid enough for a good yield.

The history of the runs made is tabulated in Table I. Column one gives the run number, column two the type of material, and column three the total weight of the charge. Columns four and five give the heating procedure and the heating time required to get the metal ready to pour. Column six gives the yield of recast metal obtained from the charge and column seven lists the observations from each run.

The following conclusions have been drawn from a study of Table I:

1. Slugs run by themselves should be heated to 2500°F, cooled to 2400°F and poured. This procedure makes the metal fluid enough to give good yields and by cooling down before pouring it gives the impurities time to float out. Slugs run at a lower temperature than this give metal which is too viscous to flow freely with resulting low yields.
2. Mixing virgin metal with slugs does not materially increase the yield but helps the impurities like iron by virtue of dilution. The density of the material and the nitrogen content are no better than when slugs are run alone. The mixture of biscuits and slugs need not be heated to 2500°F because there is enough virgin metal present to make the other material fluid. There is also some boiling off of impurities in the virgin metal, causing agitation in the melt which is beneficial. Virgin metal cast with good slugs gives a slightly better yield than running virgin metal alone.
3. Briquettes run by themselves give poor yields, probably because of their high oxide content. This oxide greatly decreases the fluidity of the material and gives a poor yield. The briquettes also contained a large amount of added magnesium which does not help the yield or the quality. We are not aware of the reasons for adding this magnesium. This material boiled out of the melt and collected on the water cooled lid, and a good share of it got into the vacuum system. This is dangerous because the magnesium burns spontaneously when exposed to air and in some instances ignites so rapidly it causes an explosion. This occurs both on the lids and in the vacuum lines, where it is doubly dangerous, as an explosion in the vacuum pipes blows the material out any opening with quite a bit of force. It is our opinion that the magnesium should not be added to the briquettes at all.
4. Slugs and briquettes give a slightly lower yield than is obtained by mixing briquettes with virgin metal. The physical placing of the material in the crucible has no effect on yield or purity of the metal. This has been further substantiated in our own plant with sawdust and croppings or virgin metal. A long program would prove which was the best method of recasting the briquettes, that is, whether they should be cast alone or with slugs to get the best overall yield.

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5. Briquettes and/or slugs will be very hard on graphite crucibles. Out of thirteen runs, nine crucibles were broken. In the processing of virgin material, seven to eight heats per crucible can be expected. The large heel formed by the residual material from the low yields broke five of the crucibles in the furnace and the other four broke on the fire while burning out. This is the process where the residual material in the crucible is burned out by a gas flame. Again, a long program might point the way to better graphite usage.
6. The program was stopped when all the slugs were recast and enough of the briquettes had been used to give an indication of what could be done with them. The rest of the briquettes were not recast because of the difficulties stated above, namely:
 - 1) The briquettes contained too much magnesium.
 - 2) The yields were so low from the briquettes that the residual material in the crucible caused the crucible to break.

Three billets were made in all the heats where there was enough metal to do so. In each case, these billets were stamped with the heat number and the billet position in the pour. A billet stamped "3B", for instance, would mean that this billet was from the third heat made and was the second billet poured in that heat. An additional egg was poured in all heats regardless of the number of billets poured and was designated the heat number and the letter "D". These eggs, being low in density, were very difficult to cut to 1900 ± 60 grams and consequently, a number of the eggs are outside these tolerances. These eggs were also very hard and consequently were tough to saw. As high as three sawblades were used in making a cut through an egg. This situation made it impossible to cut samples from these last eggs, as the blades run out on thin cuts of very hard material. (That is, the blade cuts through the side of the slice instead of going straight through the cut.)

Some of the billets are shorter than 10 inches, but it was decided that some benefit could be derived by sending these billets on rather than putting them in scrap.

Analytical Data

The Hanford people requested that, in addition to regular analyses, our laboratory should run chromium, copper, lead, tin, aluminum and oxygen, if the program did not seriously interfere with the normal functions of the laboratory. The laboratory was not set up to run oxygen or chromium and therefore did not do so because of the time involved in setting up the tests.

Three sample slices were cut from each egg and a set of these slices will be sent to Hanford to get checks on the analyses run by our laboratory.

The analytical results are listed in Table II. All the analyses are shown with the exception of carbon and hydrogen, which will be reported at a later date. The data sent to us by Hanford listed the density of the metal to be recast as 18.1 to 18.62 with an average density of 18.47 (weighted calculation). The first column of Table II shows the analytical results from a slug or rod picked at random and tested. As can be seen, the nitrogen is very high in this material, but all the rest of the impurities seem to be quite low. This slug was probably not too representative of all the metal, as later analyses show some impurities to be higher and these elements are not usually increased by recasting.

It is evident that the samples from heat number one got switched, as the results show billet 1A to be lower density and higher in impurities than billet 1C, which experience has shown is impossible.

As can be seen from the table, the metal was considerably improved in density and nitrogen content by recasting, and the other impurities are low enough to not cause any trouble. Iron in the metal cannot be removed by recasting, but, as can be seen from heats five, eleven and twelve, it can be improved by dilution with virgin metal, as this material runs between 30 and 40 ppm iron. In some instances, the quality of the third billet in the heat was low, but this could be expected, as the bad metal floats to the top of the melt and would be poured out in the last billet.

Summary and Conclusions

1. Slugs and briquettes made from turnings produced when these slugs were machined can be recast with great improvement in quality.

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2. Casting this material is quite hard on graphite crucibles, but a long-range program might point the way to better graphite usage.
3. This metal run alone gives fair yields (88.8% to 94.8%) if heated to 2500°F and then cooled to 2400° before pouring. Mixing with virgin metal improves the final quality, but does not materially increase the yield.
4. Briquettes should not be mixed with magnesium before recasting.

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TABLE I

Run Number	Type Material	Charge	Heating Procedure	Heating Time	Yield	Remarks
1*	Can 1 and 2. Complete 128. 3 lbs. Can 3. Slugs.	422.38	Heat to 2400°F. Cool to 2350 and Pour.	2 hr. 1 min.	81.6%	No. 1 mold boiled, No. 2 mold filled evenly, 3rd mold 1/2 full --metal very viscous. Metal kept running out after pour was completed. Xble broke in furnace. 4th egg extra hard.
2*	Cans 4 and 5. Slugs.	420.73	Heat to 2400. Pour. Heel in xble quenched in H ₂ O-red hot. Strong NH ₃ smell given off.	2 hr. 1 min.	86.8	No. 1 mold boiled hard, No. 2 mold boiled hard, No. 3 mold 1/2 full. Very viscous metal. Ran out after pour. Xble broke in furnace.
3*	Cans 6 and 7 and 7.52 lbs. Can 3. Slugs.	420.36	Heat to 2400, cool to 2350, hold 5 min. and pour.	2 hr. 5 min.	86.5	No. 1 mold boiled hard. No. 2 mold filled evenly. No. 3 mold 1/2 full. Evidence of sublimate on molds in bottom of furnace. Xble broke on fire.
4*	Cans 8 and 9, 15.2 lbs. Can 3 and 15.5 lbs. Can 18. Slugs.	423.24	Heat to 2500, cool to 2400, pour.	2 hr. 6 min.	88.8	All molds boiled, no evidence of sublimate. Two full molds and 3rd mold 2/3 full. Xble broke in furnace. Metal very fluid.

* No boiling in crucible.

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TABLE I (cont'd)

Run Number	Type Material	Charge	Heating Procedure	Heating Time	Yield	Remarks
5	2 virgin biscuits, Can 10 and 54.3 lbs. Can 11. Slugs.	454.35	Heat to 2400, cool to 2350, pour.	1 hr. 49 min.	95.7	Three full molds, all molds boiled, good caps, metal very fluid. Metal boiled in xble. Xble did not break.
6	Can 28 and 84.7 lbs., Can 30. Briquettes.	300.7	Heat to 2400, pour. Boiled during melting.	1 hr. 32 min.	77.4	No. 1 boiled, 2nd mold 1/2 full. Metal very viscous, xble broke in furnace. Large deposits of Mg on lid of furnace.
7	139.3 lbs. Can 11, 133.3 lbs. Can 30, 31.2 lbs. Can 18. Slugs and briquettes	303.8	Heat to 2400, Cool to 2350, pour.	1 hr. 31 min.	85.9	Boiled in melting. Poured with- out boiling. No. 1 mold full, 2/3 of 2nd mold full. Xble broke on fire. Mg on lid.
8	Can 14 and Can 15 and 46.7 lbs. Can 18. Slugs.	418.86	Heat to 2500, Cool to 2450, pour.	2 hr. 21 min.	94.0	Semi-smooth pour, 3 full molds, metal quite fluid. Metal did not boil during melting. Xble did not break.
9	Can 16, 23.4 lbs. Can 18 and 200.4 lbs. Can 27. Slugs. Briquettes.	409.92	Heat to 2400, cool to 2350, pour. Furnace had to be rebuilt	2 hr. 10 min.	79.2	Stopper rod stuck, had to be broken thru bottom of xble. Bad pour. Large quantities of Mg on furnace lid and walls.

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TABLE I (cont'd)

Run Number	Type Material	Charge	Heating Procedure	Heating Time	Yield	Remarks
10	Can 17, 190.7 lbs. Can 29, 23.4 lbs. Can 18. Slugs. Briquettes. 10 grams MgF_2	400.39	Heat to 2400, cool to 2350, pour.	1 hr. 57 min.	85.5	Poured O.K., molds 1 and 2 full, 1/2 3rd mold. Flux ineffective. Mg deposited on walls and fur- nace lid. Porous 3rd billet. Xble broke on fire.
11	2 virgin biscuits and 134.0 lbs. Can 24. Biscuits and briquettes.	337.8	Heat to 2400, cool to 2350, pour.	1 hr. 43 min.	89.0	No. 1 and 2 boiled. Large Mg deposits on lid and furnace wall. Large heel in xble. Xble broke on fire.
12	2 virgin biscuits and 175.3 lbs. Can 23. Biscuits and briquettes.	378.4	Heat to 2400, cool to 2350, pour.	1 hr. 37 min.	88.5	Smooth pour. Mg partially ex- ploded on opening furnace. De- posit very heavy. Xble did not break on burn out. Metal boiled during melting.
13	Cans 12 and 13, 46.6 lbs. Can 18. Slugs.	434.69	Heat to 2500, cool to 2400 and pour.	2 hr. 18 min.	94.8	Fairly smooth pour. 3 billets. Xble had arch over void where metal ran out. Xble did not break. Arch was 1/8" thick.