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Quality Control of Castings on S. Site

The following memorandum contains a number of thoughts and ideas on the subject of quality control of castings on S Site.

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(1) I understand that you plan to install viscosimeters for use on the kettles, as is the customary procedure in many ordnance plants. It seems to me that this procedure suffers from the disadvantage that, unless the measurements are made in a highly controlled fashion and very carefully by experienced personnel, they may give misleading results. For instance, withdrawing a sample near the edge of the kettle rather than the center will give a slightly different temperature and hence different viscosity. Simply because of different working conditions, the withdrawal of a sample from a nearly empty kettle may give you a different reading than a sample taken from a full kettle, even though the viscosity of the material in the kettle is actually the same. This is hard to correct unless the viscosimeters are provided with very elaborate devices to keep the temperature constant from the moment of withdrawal to the time of measurement. I would like to propose, therefore, a method which will simplify the operations in the casting house and, at the same time, probably give a better control of viscosity. The method is as follows:

When the first lot of Comp. B has been scheduled for use, a representative sample will be taken and its viscosity determined in the laboratory under easily controlled conditions. In view of the availability of viscosity data on Comp. B from Bruceton, it will be necessary only to determine the viscosity at two temperatures; for instance, 100° and 85° C. These two points, together with the Bruceton data, will make it possible to draw the entire viscosity-temperature curve.

The casting house should be provided with accurate thermometers (probably either a meter attached to the present fixed thermocouples or a portable unit, such, for instance, as the Leeds & Northrup portable thermocouple potentiometer, which will read the temperature easily to 1/10th of one degree). Substantially by the method of trial and error, the casting house, with the aid of the Control Laboratory staff, determines the temperature, as read on the above thermocouple, at which the best quality of casting with a given mold is obtained. Having already obtained in the laboratory, as mentioned before, the viscosity temperature chart, one then reads off the viscosity of the melt corresponding to the temperature of the best casting. Now, when a new lot of Comp. B is delivered, the laboratory determines its viscosity at two temperatures and obtains,

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in general, different values than with the previous lot. These points are used to construct a new viscosity temperature curve on the plot on which the standard lot data have been recorded. One then reads off the temperature of the new lot at which it has the same viscosity as the one which was found best for casting previously. The casting house is then simply instructed that pouring should be made when the thermocouple reads a specified temperature. By this general procedure we transfer the more delicate viscosity measurements from the casting house to the laboratory where they can be made considerably more accurately, and introduce instead into the casting house the much more simpler technique of temperature measurements. Naturally, instructions will have to be issued as to where in the kettle to put the thermocouple, how long to keep it there, etc., so that the temperature measurements are reliable.

(2) The three major sources of imperfect castings in Comp. B are: (a) porosity; (b) segregation; and (c) cavitation. In addition, there is the less serious matter of getting TNT crystallized in very coarse crystals, a phenomenon which is of no great importance for ordinary shell and bomb charges, but may be objectionable in our case.

(3) These three main sources of poor castings require procedures which are somewhat contradictory and one will have to find by the method of trial and error compromise conditions for best results. To eliminate porosity as far as possible, one has got to get rid of the small air bubbles, which are present in every freshly melted batch. Since we are not pressed for time, I wonder whether it may not be advantageous to stop stirring the kettle for definite intervals of time after the material has been all melted, so as to give the small air bubbles a better chance to rise to the surface. If that is impracticable because of too much segregation, it may be that slowing down the stirring to an absolute minimum would accomplish this better than vigorous stirring, which prevents the bubbles from reaching the surface so long as they are small and rise slowly in the liquid. Of course, the reduction of viscosity of the melt is very favorable to the elimination of air bubbles and, in that connection, I would like to mention that Holston Ordnance Works and Bruceton Laboratory have both found that Comp. B can be kept at a temperature as high as 110° C. for long intervals of time (tests have been continued for two weeks at Bruceton) without decomposition. Such a high temperature will give a melt of quite low viscosity, and should be very effective in clearing the material from air bubbles. It will have the further advantage

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that it will dry the material well. Comp. B, as it comes here, contains about .2 - .4 per cent of water. While this is not harmful for experimental charges, I would much rather see the water content of the charges used for the real thing reduced quite considerably because the explosive will be in contact with delicate parts which may be damaged by moisture.

(4) I assume that you will shortly start work on two essentially independent programs. One to make charges for immediate experimental use, mainly by E-5 group, and these will be made according to procedures which are considered best at the time of casting. The other program, in which I am particularly concerned at the moment, is research and development of a process for making the best possible castings which will eventually be used in the real thing. The results of this work, naturally, you will apply to the making of experimental charges mentioned above. Since we are not certain exactly what size and shape of charge segments will be wanted eventually, I believe that the experimental part of the work should be made with two types of molds, in view of the fact that the pouring conditions and cooling conditions, to give the best results, depend on the size and shape of the casting. If the design of proper molds is delayed, you could accomplish the development program by using simple square molds, one of which might be in the form of a cube to give a charge weighing about 80 lbs.; the other, also of square cross section, but, for instance, only 3" on the side and, say, 12" tall. I believe that such two molds will represent adequately the most extreme variations in the actual molds, which we may want later. Several units of each mold size should be made.

(5) The actual tests could be executed as follows: Upon selecting a certain temperature of pouring and allowing adequate time for the air to escape from the melt, the explosive is poured into a series of identical molds, and is allowed to cool under controlled and varied conditions. For instance, two molds of each size may be pre-heated and one allowed to cool fast, the other slowly (this being accomplished, for instance, by wrapping the mold in a blanket). Several molds will be left cold to start with and again allowed to cool fast or slow or very fast as by immersion in cold water. Also we may try increment pouring, in which case it may be desirable not only to puddle the charge but actually to prevent a crust formation on the surface by putting heat insulated pad over the molten explosive, so that the charge cools mainly from the bottom and the sides. The next increment would then be poured before the

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preceding one has solidified 100%, so as to avoid boundaries and planes of mechanical weaknesses between the increments. Identical tests of this type will have to be made with the melt poured at different temperatures, so that we shall eventually have a complete set of data on the effect upon the quality of the casts of such variables as viscosity (temperature) of the melt, duration of heating preliminary to pouring, hot or cold molds, rate of cooling of the melt, and direction of cooling of the melt. If we have these data for the two types of molds mentioned above, it will be possible to predict fairly accurately what are the best conditions to use for a new mold.

(6) I suppose that after the castings have cooled, they will be taken from the molds and given to the Test Laboratory for inspection and evaluation. As it occurs to me at present, the following tests may be useful in the program:

(a) Inspection of the appearance of the surface of the casting to see whether the explosive filled out the corners in the molds, which it may not do if it was too viscous, or if the mold chilled the melt too quickly.

(b) Determination of over-all density by weighing the casting and measuring its dimensions.

(c) Determination of the density of the casting at various points by coring samples (I believe that Mr. MacDougall has already discussed with you the need for making coring tools).

(d) Using the same cored out samples to determine the composition in order to find whether any segregation has taken place. For this purpose, only two samples need be used, one taken from the bottom, and the other from the top of the cast. For the density determination, however, samples taken also near the center and near the side surface of the cast ought to be measured.

(e) The cast should be sectioned to determine whether any cavitation has taken place.

(f) It may be possible that we will develop successfully a physical method (supersonic, X-ray, or ultra short radio wave) for determining rapidly the inhomogeneousness in the material. When and if this method is developed, it should also be used in the development program and, of course, it will be practically the only method possible to use for the casts intended for the use in the real thing.

(g) If the physical methods turn out to be impracticable, then we shall have to limit our studies of charges intended for the real thing essentially to two operations. One of them is the determination of the over-all density by the displacement method, it being probably more accurate than the one involving the measurement of dimensions. The other is the determination of the center of gravity of the charge, such deter-

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mination giving us a good indication of whether the casting is uniform and homogeneous or not. There are several relatively simple methods by which the center of gravity can be determined with adequate accuracy.

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