Mr. Busbee

8 June 1944

Captain Ackerman

Experimental Work at S-Site.

1. This memorandum confirms our several discussions on this subject. It is an attempt to outline the problems now expected to be encountered in casting work at "S" together with a brief summary of experimental work which may yield some information on the more critical factors affecting future work. It is not intended to be a final exposition of the subject but should be considered as the first series of work which will serve as a guide for further work tending to assist in the development of a technique for casting work and for the design of molds, risers, etc.

2. Work to be performed at S-site is unquestionably more complex than than encountered in an industrial plant in that you will be required to pour many experimental castings which will vary in size, shape, and requirements as to density, crystal structure, etc. It will probably be impossible to pour such varied castings satisfactorily unless a systematic attempt is made to learn in advance the effect of each factor affecting mold design and casting procedure so that the design and technique for each pour can be laid out in advance with some expectation of success.

3. The contents of this memorandum are laid out with the purpose of holding the number of specimens and total volume of castings to a minimum. I am sure that your study and application of it will lead to a somewhat more comprehensive series of tests.

4. Good results and indications of future problems have been determined from the excellent experimental work which has been conducted to date. These tests have, however, served largely as indications of future problems and for the development of some technique by the personnel which has been assigned to this work. Consideration of the future work of the site indicates that a systematic collection of experimental data on the following is imperative:

a. Temperature-viscosity curves for all lots of Composition B now on hand.

b. Adequate procedures for casting density determinations. Over-all casting density as well as spot densities are necessary.

c. Procedures for chemical tests of Composition B.

d. Temperature distribution in casting room kettles and accuracy of temperature control. Loss in temperature between kettle and mold must be determined. All temperatures must be correlated with viscosity.

e. Removal of air and dispersion of RDX by long-time stirring in the melting kettle.

f. Highest viscosity (lowest temperature) at which molds of different shapes, materials, and surface structures can be poured.

g. Effect of viscosity (or temperature) on casting density.

h. Linear shrinkage coefficient.

i. Effect of size, shape and insulation of risers.

j. Effect of chill cooling of metal molds subsequent to casting.

k. Optimum insulation of tops of metal molds.

l. Study of RDX and TNT crystal sizes and dispersion.

m. Effect of cooling time on crystal growth.

n. Procedure for incremental pouring and effect of incremental pouring in reducing internal temperatures, large crystal growths, and segregation.

o. Effect of pelleting.

p. Suitability of the Blast front mold as an apparatus for studying many of the above effects.

q. Problems attendant on bonding new pours of Composition B to previously cast material.

5. It is obvious from the above that the program for experimental work is certain to be rather pretentious. As a result, the tests must be conducted in a systematic and progressive order planned to produce specific information limited to the effects of one of the variable factors. Care must be exercised to be sure that two factors are not varied simultaneously in any one test. Tests which yield inconclusive results must be repeated or conducted in another manner which will yield the desired information. Because of the large volume of tests indicated, I believe it desirable to conduct as much of the work as possible with laboratory size molds, progressing of course to casting room size to determine the effect of larger molds and to develop the final casting technique. I carry no torch for the laboratory other than it permits faster and easier collection of information on certain variables. In all cases, results of laboratory tests must be confirmed by full-scale tests in the casting room.

6. A proposed schedule for testing in accordance with the above list of items is presented below. The laboratory phases of the testing are listed first but should not necessarily be conducted first. A number of items for casting room tests should be begun immediately.

LABORATORY TESTS

a. Temperature-Viscosity Curve.

1. Since it is your intention to cast at optimum viscosities, temperature-viscosity curve should be run as soon as possible on material now on hand and on new material as soon as received.

2. For the present, at least, tests should be made with the Bruceton-type viscosimeter.

3. These tests should be correlated with casting room procedure if possible by conducting supplementary tests in the casting room during a casting operation.

b. Chemical Tests.

1. Chemical tests will be necessary not only for the purpose of checking quality of new shipments of Composition B but also for study of uniformity of castings by spot tests. The procedures available to the laboratory to date do not appear to be satisfactory. I am under the impression that Sgt. Carlson will secure more adequate procedures when at Bruceton next week.

c. Density Determination.

1. Density determinations are intended to be the key control method for determining uniformity and adequacy of castings. Over-all densities should be taken for every cast after the removal of risers.

2. Spot determinations will be made for those portions of test and control castings that necessitate the additional work.

3. Laboratory equipment suitable for density tests by immersion in water or Mercury, where the latter is desirable, should be set up immediately. Record forms for data should be furnished to the laboratory personnel at once.

d. Effect of Viscosity (or Temperature) on Density.

1. The density of the cast as well as its crystal structure appear to be dependent on the temperature and viscosity at which the pour is made. A series of tests should be made in the laboratory to determine this effect. Information on several other effects can be collected from the same specimens as will be noted below:

(a) Pour two small cylinders or rectangular molds at each of the following temperatures: 200, 195, 190, 185, 180, 175, and 170° F. The lot of material used for this test should be tested for viscosity prior to the pour. The same molds should be used throughout and should be at the same initial room temperature at the start of each pour. Molds should be poured with insulated tops and insulated risers. Castings should remain in the mold same length of time. Pouring from one batch, starting at highest temperature, letting the mass cool gradually is suggested. If inconsistent results are secured, tests should be repeated starting with the lowest temperature and pouring at successive higher temperatures. If possible, heat and stir the melt for at least one hour before pouring specimens to avoid viscosity problems resulting from lack of dispersion of RDX.

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2. The failure to secure filling of the mold at right angle corner or sharper corners should be observed. When the temperature and viscosity which do not yield a full mold with sharp corners is determined, additional pours should be made at this temperature and five and ten degrees lower. In these cases, however, the mold should be heated, prior to pouring, to the temperature of the melt at the time of pouring to determine whether filling of the mold corners can be secured at the lower temperature and higher viscosity.

3. After removal of risers, castings should be checked for over-all density. Specimens will then be sectioned to determine extent of cavitation and spot densities. Specimens used for spot densities will also be used for chemical tests. (Extension of present system for sectioning to include a core from upper one-third of cast is suggested). Other portions of casting should be kept for crystal studies described later in this memorandum.

e. Puddling.

1. A pair of molds should be poured under conditions identical to those for paragraph 6d, above, with the pour puddled throughout the casting period. The mold should be poured with insulated top and riser. Packing of the central crystal cavity should be attempted.

2. Investigation of densities etc. should follow same pattern as for paragraph 6d.

f. Linear Shrinkage.

1. Shrinkage on castings will be of significance in design of molds for precision casts. It will be desirable, therefore, to determine the coefficient of the linear expansion for the material at an early date.

2. For the present, I believe that sufficient data can be obtained by accurately calipering interiors of molds prior to casting and measuring the outside diameters of the fully cooled cast. Special tests of coefficient of expansion may be necessary later but can be deferred for the present.

3. To eliminate casting special molds for this purpose, the data may be collected from specimens cast under paragraph 6d above.

g. Optimum Insulation of Mold Tops.

1. Tests to date have indicated almost conclusively that with the use of metal molds, a tendency to pinch off the flow of molten metal to the interior of the casting occurs due to dispersion of heat by the mold at the upper corners of the casting. Some results have been secured by insulating this part of the mold.

2. Specimens should be poured with the upper one-fifth, one-third, and one-half of the mold insulated with a reasonably thick layer of insulating material. If possible, the test series should include specimens cast in cardboard, sheet metal, and thick metal molds to determine effect of variable conduction beneath insulation. The tests should be combined with the tests of riser shape listed below, to the extent possible.

3. Records should be kept of insulation thickness of mold and the ratio of mold weight to casting weight. Specimens should be sectioned to determine extent of cavitation.

h. Effect of Size, Shape and Insulation of Riser.

1. The small number of tests made to date indicates that a riser will be effective in minimizing cavitation. A series of cylinders or prisms should be cast with varying riser size, shape and insulation. The sketch attached hereto is a suggested layout for the test. Indications to date are that insulation of the riser, both sides, and junctions with the mold, as well as the top of the riser after completion of pour, can appreciably reduce the size of riser necessary to provide the liquid material necessary to feed the interior of the mold during crystallization. Since reduction in the size of the riser will reduce the amount of work necessary to dress the finished casting, these tests should be conducted in such a manner that ratios of size of riser to top surface area of casting and volume of casting can be established for each shape and condition of insulation.

2. Preliminary tests in the laboratory using the rectangular mold are recommended. This series of tests must be run independently of other tests except paragraph 6g, and will probably involve as a checking method, only the sawing open or breaking of the finished mold to see whether the riser eliminated cavitation. The use of insulite or other thick materials of considerable insulating value is recommended for the test.

i. Study of RDX and TNT Crystal Sizes and Distribution.

1. The use of chemical analysis as the sole method of determining the equitable distribution of RDX probably will be too laborious for ordinary control methods. Consequently, an attempt should be made to develop a more rapid physical test procedure. The following two procedures are suggestions.

2. Break open cast specimens, particularly those involving more porous cores and examine them under directional light to determine whether the following can be observed quantitatively:

(a) Distribution of RDX.
(b) Relative size of TNT crystals.

3. Another suggested procedure is to mill the face of a broken specimen to secure a plane surface. Following this, the finished surface of the specimen should be immersed in heated Benzene (saturated with RDX at the given temperature) to dissolve TNT, leaving the RDX in relief. This specimen should be examined under a microscope or suitable glass with side elimination to determine whether the distribution of the RDX can be observed.

4. It would be particularly desirable to make the above tests on fragments from a casting room mold of large dimensions and slow cooling time so that the maximum effect of the rate of cooling on crystal dispersion can be observed.

j. Effective Cooling Time on Crystal Growth.

1. This effect can probably not be determined until specimens of large molds from the casting room are available. For the immediate present, however, a rough check should be made as indicated below.

2. Cast one specimen in a small cylinder or rectangular mold with top of mold and riser insulated and allow to cool rapidly in the air.

3. Cast second specimen in same mold with riser, but in this case, completely insulate the mold: side, bottom and top of riser, with the equivalent of at least two inches of insulite and allow to remain insulated for several hours until fully cooled to room temperature.

4. Examine crystal growths in the interior of the two specimens by the method indicated in paragraph 6i above. Also make chemical analyses of core and side sections.

k. Cooling of Metal Molds.

1. The effect of cooling time on the size of TNT crystal growth is recognized as one of the factors leading to the lack of uniformity throughout large molds. It is suggested that an attempt be made to determine whether the cooling time and consequently the size of crystal growths can be reduced by artificial cooling of metal molds after completion of the pouring.

2. Cast one specimen in large rectangular mold with insulated top and riser permitting specimen to cool in air.

3. Cast second specimen exactly same temperature in same mold with insulated top and riser. Immediately following completion of pour, cool the bottom half of the mold by means of wet rags or by immersion in water.

4. If practical, make above test on molds of two different thicknesses: sheet metal and thicker.

5. Check over-all densities and spot densities. Break specimens open at center to determine whether cavitation is observable and whether the difference in crystalline size can be observed by methods outlined elsewhere. This effect should be determined more fully at a later date in the casting room.

l. Pelleting.

1. Conduct if possible a test of pelleting in the large size rectangular mold in the laboratory using insulated top and riser. Pour a prism cast in the same mold with same insulation and riser.

2. Cut density specimens at normal locations as well as determine over-all density of the mold portion of the casting.

3. If this cannot be advantageously done in the laboratory, defer the test to full scale operation in the casting room. However, if the work is done in the casting room, it should be done on a mold with insulated top and riser.

m. Effect of Incremental Pouring in Reducing Internal Temperatures and Segregation.

1. In pouring large molds the quality of the central portion of the casting is definitely reduced by the lengthy cooling time which permits the development of large crystals. Little can be done to accelerate the rate of cooling other than to pour in increments. Past attempts at incremental pouring have not been very satisfactory because of the tendency for the formation of planes in the casting where liquid material is poured against material which has previously hardened. Since this type of procedure may be necessary to improve the quality of the casting, the following tests are suggested for the laboratory.

2. Using a large rectangular mold, pour the mold in four increments of equal depth. During the process of pouring the outside of the mold should be insulated to a depth of one inch below the liquid level and at least one inch above that level. The purpose of this insulation is to reduce the rate of cooling at the surface of the liquid adjacent to the mold. The surface of the liquid inside the mold should be insulated with a floating material such as insulite. It is probable that a hold should be cut out of the center of the floating insulator so that solidified level in the mold can be located and the second increment poured before the surface hardens.

3. Pour in increments same as before except that instead of insulating the surface, insulate the entire sides of the mold above and at least one inch below the current liquid level. The top opening of the mold should

also be covered with insulating material. At the completion of the incremental pouring, attach a riser and pour the riser.

4. Since the procedure for incremental pouring is a doubtful one, additional molds should be cast with different procedures developed from above two to see if maximum cooling can be secured with adequate bond between increments.

5. If difficulty is encountered in the laboratory, move this test to the casting room.

n. Glass Front Mold.

1. The glass front mold has been found to be unsatisfactory unless it is adapted so that the space between the two glasses can be filled with hot water to prevent initial chilling of the liquid by the glass. Reconstruct the glass frame of mold to permit use of hot water. Then conduct tests to study the effects of methods outlined above such as incremental pouring and riser size by means of the glass front mold, as this may give the benefits of visual observation to density tests in determining the effects of the various methods.

7. The following tests should be made at full scale in the casting room. Many of these, especially those near the top of the list, should be performed as soon as possible. As in laboratory work, careful records should be kept of all work performed.

CASTING ROOM TESTS

a. Temperature Distribution in Kettles.

1. The casting room kettles unquestionably permit differences in temperature between the outside and the center of the kettle. Temperature surveys should be made to determine this temperature distribution. If standard thermometers are not effective, attempt to secure from elsewhere in the Technical Area, a Leeds and Northrup portable thermocouple potentiometer.

2. While conducting the above test, determine the accuracy of the present temperature control devices now installed on the kettles.

3. At time of next pour, determine the temperature loss between the kettle, the bucket, and the mold and correlate with viscosity results on same material. The pouring procedure used at the time of tests should be that which will normally be used on the casting floor.

b. Viscosity.

1. Correlate laboratory viscosity-temperature relationships with those

in the casting floor by viscosity tests in the casting room if this is practical. This should be done as a possible forerunner of installing such equipment in the casting room.

c. Density Determinations.

1. Since over-all and spot densities will be the key to control of casting room specimens, equipment should be set up as soon as possible for immersion tests of all specimens poured in the casting room. In cases where the finished casting will incorporate a cylinder or other metal item, the air and immersed weights of these metal items should be secured before the pour and shown on the data sheet used in the final density tests.

2. Where possible for each pour, a full sized specimen of the shape and type poured during the day should be cast solely for control tests. This specimen will be cut up for porosity and density tests.

d. Effects of Viscosity.

1. The laboratory work outlined under paragraph 6d should be expanded to show the effect of viscosity on density secured in molds of different sizes, shapes, and materials. At least two molds such as a cylinder and a cube should be poured at three different viscosities including the extremes found satisfactory in the laboratory tests.

2. Full density and chemical analyses should be made on these specimens.

e. Effect of Melting Time.

1. Laboratory tests of viscosities conducted at Bruceton show a gradual decrease in viscosity on continued tests over a two-hour period. The decrease in viscosity probably results from removal of air and dispersion of RDX.

2. The specimen should be cast immediately upon heating to the given temperature and correlated with exactly similar specimens cast at the same temperature after a continued period of two hours of stirring.

3. Specimens from the two conditions should be compared on the basis of over-all and spot densities as well as chemical tests to determine whether segregation has occurred.

f. Effect of Viscosity (and Temperature) on Density.

1. Laboratory tests under paragraph 6d should be repeated and if possible extended to lower viscosities in the casting room to determine optimum densities for larger molds. Series should include molds varying in size and shape from small sharp angle molds to large ones with few corners or angles. Comparable number of specimens of same type and same

conditions of risers should be used.

g. Linear Shrinkage Coefficient.

1. Laboratory results should be supplemented by comparable specimens in accurately measured molds poured in the casting room.

h. Optimum Insulation of Tops of Metal Molds.

1. Based on results secured from laboratory tests, verification tests and extensions of testing to the more complicated casting room molds should be made. Metal molds of several thicknesses should be tested. Comparable number of specimens will be necessary.

i. Effect of Size, Shape and Insulation of Risers.

1. Same as paragraph 7h above.

j. Effect of Cooling Time on Crystal Growth.

1. Same as paragraph 7h above.

k. Study of RDX and TNT Crystal Sizes and Distribution.

1. Same as paragraph 7h above.

l. Cooling of Metal Molds.

1. Same a paragraph 7h above.

m. Effects of Incremental Pouring.

1. Same as paragraph 7h above.

n. Casting of Kosky's Cylinders and Segmental Cylinder and Segmental Sphere.

1. Attempt should be made to apply data collected above in the design of molds, risers, and insulation for these molds which are complicated because of the unusual cooling surfaces and complicated shapes. On the basis of known results, tests should be conducted to determine the most effective locations, sizes, and types of risers and locations at which insulation or cooling of molds yields most satisfactory results. The warping of specimens should be measured.

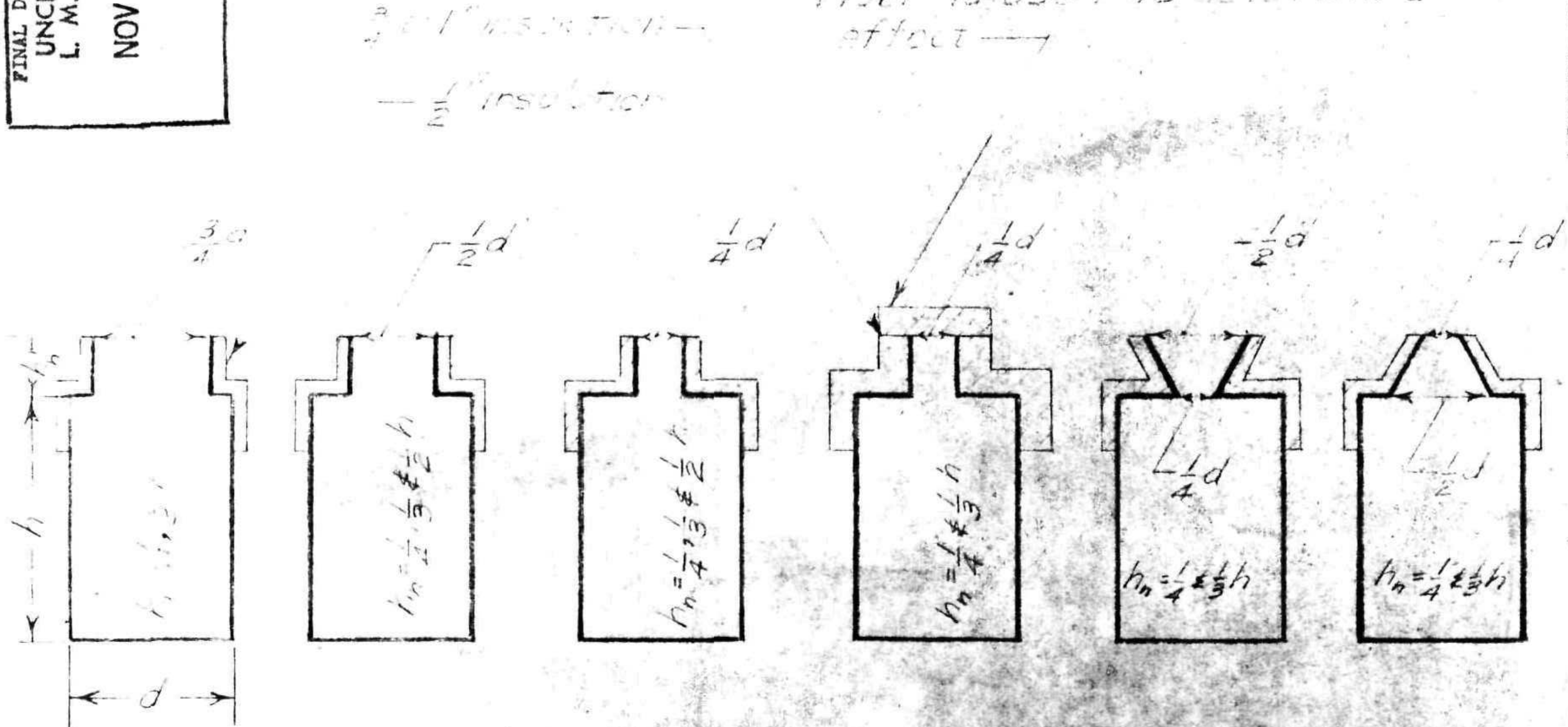
o. Measurements of Temperatures Within Castings.

1. Thermocouple and potentiometer equipment should be located for use in measuring temperatures inside of castings during cooling period. Schedule of tests can be set up later.

8. Procedure for keeping systematic records for the above tests should be developed. All specimens should be properly numbered and stored in a vacant magazine until the completion of the tests. If particularly useful results are secured, photographs of specimens showing effects should be made. All data should be recorded in a systematic manner.

9. I shall appreciate any comments you may have on the above together with an indication of the order in which you can conduct the tests both in the laboratory and the casting room. This experimental work should progress with as few interuptions as the schedule for work in S-4 will permit.

J. O. ACKERMAN,
Capt., CE.



NOTE: Walls to be of metal.
Increase thickness of insulation where necessary.

SCHEMATIC DIAGRAM
FOR EXPERIMENTAL
HE CASTING AT "S"
9 JUNE, 1944 J. WEIL