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Progress Report on

The Causes of Porosity and Leakage in Non-Ferrous Castings

(Foundry Details for Fuel Booster Pump)

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ABSTRACT

Five fuel booster pumps of Hydraulic Bronze were cast by various foundry techniques. Although required to pass a pressure test of 200 lbs. per sq. in., three of the castings withstood 1000 lbs. per sq. in. for fifteen minutes without evidence of any leakage whatever. Complete details of the foundry procedures and hydrostatic testing are given.

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AUTHORIZATION

1. The investigation of non-ferrous castings was authorized under Bureau of Ships Project Order BP/6R dated 22 June 1943 entitled "Non-Ferrous Castings Research".

STATEMENT OF PROBLEM

2. Although many bronze pressure castings may appear sound by visual inspection, they often leak as a result of micro-porosity which is an inherent property of many casting alloys. This intercrystalline shrinkage becomes more severe when complicated castings are made under conditions of inadequate feeding.

3. Pressure tightness is closely related to adequate feeding and often may be secured by applying the principle of directional solidification. According to this technique, the freezing zone progresses toward the risers so that final solidification takes place within the risers. By this means the shrinkage of the bronze is provided for by the reservoir of molten metal and the shrinkage porosity instead of being dispersed in critical sections is concentrated in the risers. The proper location of the gates and risers coupled with the use of external chills, thus will lead to controlled directional solidification and greater pressure tightness.

KNOWN FACTS BEARING ON THE PROBLEM

4. The casting selected for this investigation was a fuel pump for PC boats made by the Oberdorfer Foundries of the American Locomotive Corporation in Syracuse, New York, under Navy Contract NObs-174. Although the hydrostatic test specified is 200 lbs. per sq. in., the rejection of these castings often amounted to fifty per cent. Much of the leakage occurred after machining, especially within the bolt holes which were adjacent to the pressure chambers. The material specified for the production of this casting was Hydraulic Bronze (ounce metal) Navy Specification 46B23c.

EXPERIMENTAL PROCEDURE

(a) Introduction

5. Five castings of the same nominal composition were cast with different melting and foundry techniques. The first two castings (see Appendix) were unsound, showing large shrink cavities above the compression cylinder. However, the subsequent three castings passed radiographic inspection after complete machining and were subjected to a hydrostatic test of 1000 lbs. per sq. in. The specimens for mechanical tests and samples for chemical analysis (Table I) were taken from a separately cast coupon which was poured with each casting.

(b) Foundry Procedure - Heat P7A

Molding

6. Albany sand, Nos. 00 and $1\frac{1}{2}$, were mixed in proportion of 3 to 1 respectively for the molding sand with a moisture content of 8.50 per cent. Green permeability measured 22 and the compressive strength was 4.92 lbs. per sq. in. Plate I shows the core boxes and patterns and Plate 2, Figure A, the locations of risers and gates. Chills (hot rolled steel) of 1/2" diameter and $1\frac{1}{2}$" long were inserted in the drag portion of the mold and placed at each end of the cylinder and also on the end of the hub. The faces of the suction and discharge flanges were chilled by bars, 1" in diameter and 1" long. These bars were molded into the core sand. The core mixture consisted of 56 per cent No. 00 Albany sand, 37 per cent sharp silica sand, 2 per cent bentonite, 2 per cent linseed oil and 3 per cent water. The cores were painted with a mixture of wet graphite and one tablespoon of molasses per pint of water after baking for 10 hours at 400°F. A 7/8" D core was inserted in the impeller hub and a 5/8" D stock core was used for the cylinder.

7. A mixture of kerosene and #10 lubricating oil (1 to 1) to which flaked graphite had been added to form a light paste was painted on the surface of the chills after the mold was rammed. The sizes of the risers and gates are given in Plate 3, Figure A. Dry graphite followed by a mixture of molasses and water was sprayed over the surface of the mold cavity. The mold was air dried for one day and vented liberally.

Casting and Melting

8. The charge consisted of 45 per cent scrap from a previous heat (P6) and the remainder was of virgin metal. The desired chemical composition was 85 per cent copper, 5 per cent tin, 5 per cent zinc and 5 per cent lead. To compensate for oxidation losses, 10 per cent excess of the total zinc present was added. The scrap and copper were charged with some charcoal into a clay-graphite crucible and melted in the lift coil induction furnace. When the metal was molten, it was deoxidized with one ounce of 15% phosphor-copper per hundred pounds followed by the alloying elements: tin, zinc and lead. A maximum temperature of 1180°C (2156°F) was attained within the furnace. One more ounce of phosphor-copper was added before casting.

9. The metal was skimmed and a tensile mold was poured at a temperature of 1130°C(2066°F). Immediately following thereafter, the fuel pump mold was poured with a steady stream of metal flowing into the pouring basin. The oxides and the remaining charcoal were held back by a skimming paddle. When the risers were filled to within 7 inches from the top, the metal was poured directly into the risers. Carbon dust was then sprinkled over the surface of each riser and normal shrinkage occurred in both risers.

10. The casting was allowed to remain in the sand for 3 hours before shaking out. No external defects were observed after sand blasting, the casting was photographed (Plates 3 and 4) and sent to the machine shop.

11. A complete machining operation (exclusive of bolt holes) was made before the hydrostatic test. It was necessary to mill out part of the impeller chamber in order to insert pipe plugs to seal off the valve and discharge chambers. After machining, the casting was again inspected for defects but none were observed.

(c) Foundry Heats P10 and P12

Molding and Casting

12. These two heats were molded and poured in the same manner as heat P7A. Because of the difficulty in removing the hard cores, a change of sand compositions was made. The mixture consisted of 92.5 per cent washed silica sand, 0.5 per cent Bentonite, 0.5 per cent Mogul, 1.5 per cent linseed oil and 5 per cent water. The charges consisted of 40 per cent scrap and 60 per cent virgin material. Two ounces of 15 per cent phosphor-copper served as the deoxidant. The pouring temperature was 1125°C (2039°F).

13. After sandblasting and removal of gates and risers, no defects were observable. The castings were subsequently machined completely including the bolt holes. A radiograph (Plate 6) was made of the casting produced from heat P10.

(d) Hydrostatic Tests

14. All outlets of the fuel pumps were sealed with pipe plugs except the suction and discharge flanges to which a water gage and hydraulic pump were connected. Residual air was forced out of the chambers of the casting by displacement of the water before the valve was closed.

15. The required test pressure was 200 lbs. per sq. in. No leakage occurred in any of the three castings tested (Heats P7A, P10 and P12). The maximum pressure applied was the limit of the gage (1000 lbs. per sq. in.). This pressure was maintained for more than 15 minutes.

CONCLUSIONS AND RECOMMENDATIONS

16. The fuel booster pump can be cast to withstand the hydrostatic test by the procedure outlined herein.

17. The indiscrimate positioning of risers and gates does not always insure complete feeding within the casting. The application of external chills with the proper placement of

risers assists directional solidification.

18. A pouring temperature of 1125°C (2039°F) is recommended for this casting.

APPENDIX

(a) Foundry Procedure   Heats P6 and P7

Molding

19. Albany sand of the same composition as that of Heat P7A was used as the molding material as well as the same core sand mixture was employed for these heats. Plate 2, Figures B and C show the location of the risers for these castings. On one heat the impeller hub was molded in the drag while on heat P7 the pattern was inverted so that the hub was in the cope portion of the flask. There was no core inserted in this hub but a riser placed above as shown. The system of gating was altered.

Casting

20. The charge for heat P6 consisted entirely of 100 pounds of virgin stock and was melted in the induction furnace. Charcoal was added as a cover and one ounce of 15 per cent phosphor-copper added when copper was molten. The zinc, tin and lead additions were made in the order named. A temperature of 1180°C (2156°F) was attained in the furnace before removal. One ounce of phosphor-copper was added before skimming and pouring. The temperature of pouring was 1150°C(2102°F).

21. When the mold cavity was filled, the risers were poured directly. Good normal shrinkage occurred on all risers and at no time during the melting and pouring operation was there evidence of gassy metal.

22. After removing the casting from the mold, it was noticed that extremely small globules of lead had formed on the cope surface of the casting. When the risers were removed, shrink holes beneath the center riser (Plate 2, Figure B) were found to have penetrated to the cylinder chamber so that no further work on the casting was deemed necessary.

23. The charge for Heat P7 consisted of 45 per cent scrap metal and 55 per cent virgin material. The scrap and copper were melted with some charcoal in the induction furnace. One ounce of phosphor copper, tin, zinc and lead were added in the order named. Just prior to pouring, another ounce of phosphor-copper was added. The metal was poured at 1150°C (2102°F) and all risers were filled directly. The surface of each riser was thinly covered with fine carbon dust.

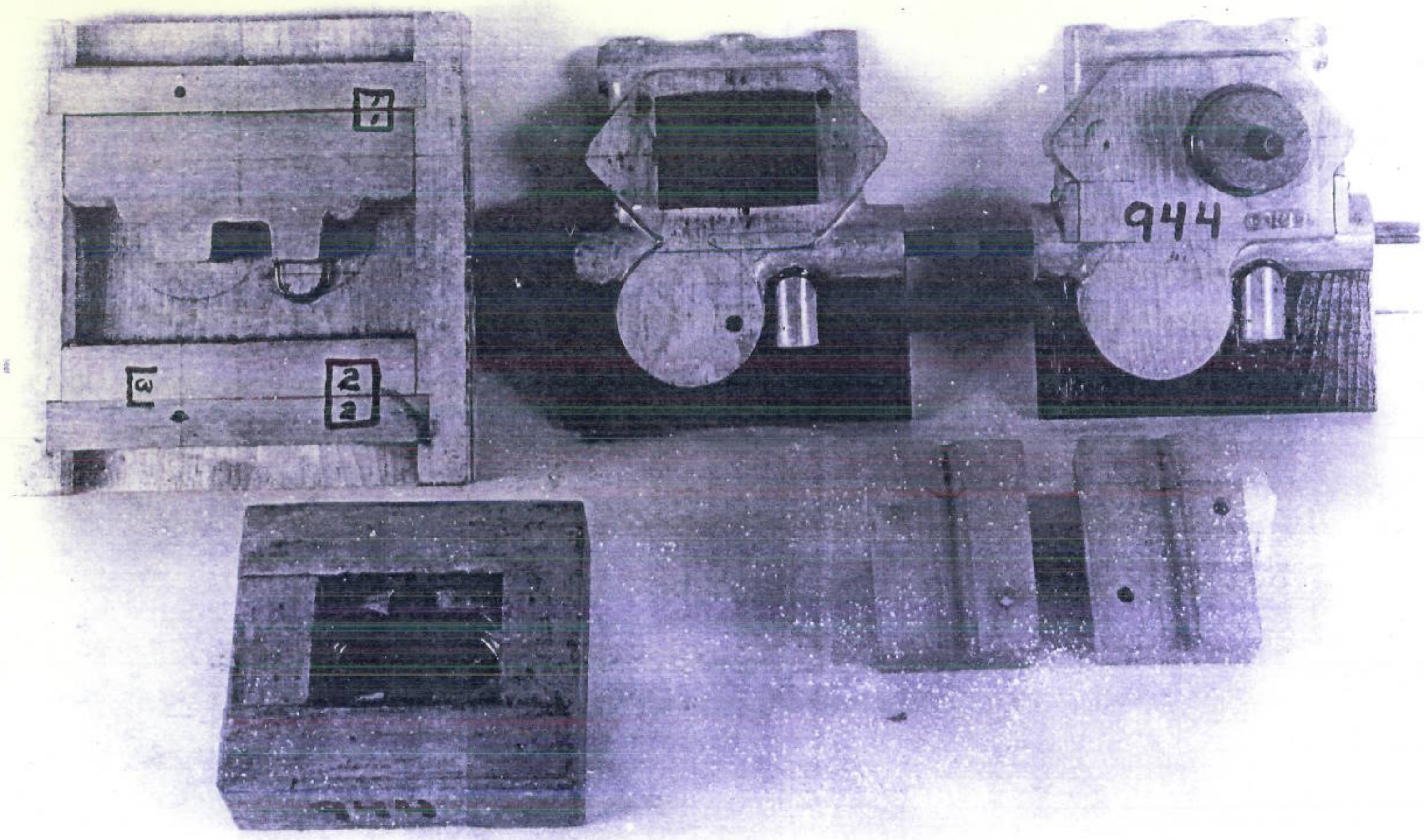
24. The casting had no serious defects except a slight segregation of lead on several scattered areas at the surface. A large shrink hole was observed above the cylinder near the hub. It was considered unnecessary to do more work on this casting.

TABLE I

Chemical Composition and Physical Properties

Heat No.	Chemical Composition Cu	Sn	Zn*	Pb	T.S. psi	Elongation Per Cent in 2 inches
P7A	85.38	5.03	4.57	5.02	36,500	37.3
P10	86.03	4.92	4.64	4.31	33,700	30.5
P12	87.31	5.04	2.72	4.93	31,300	26.7

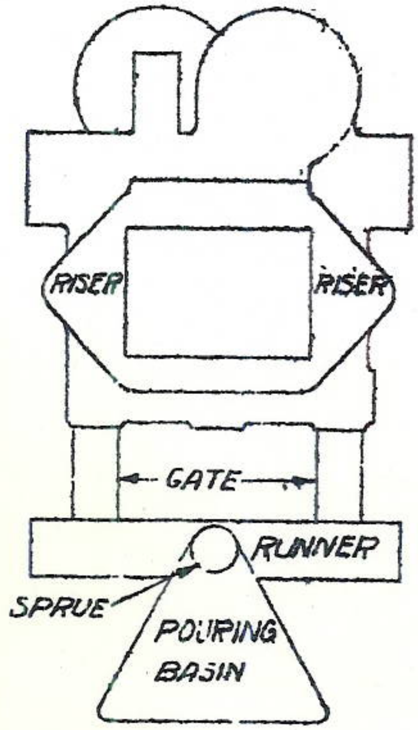
* By difference



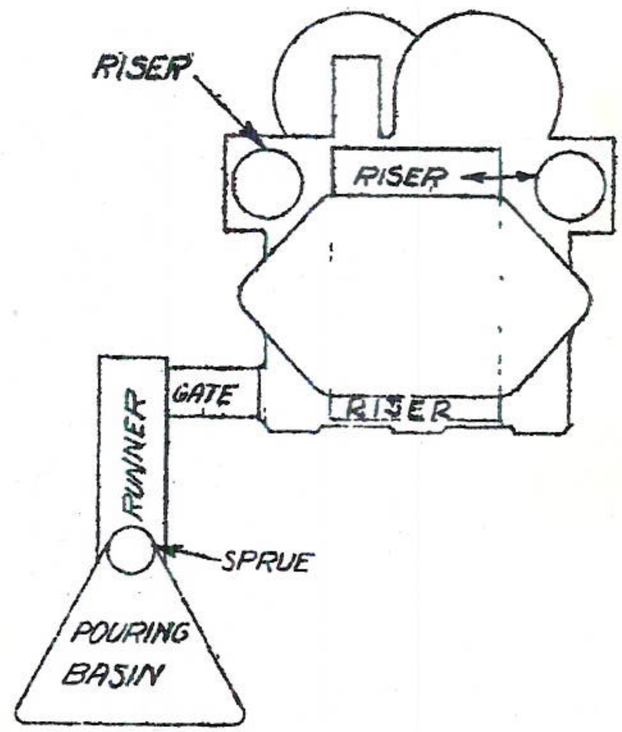
CORE BOXES AND PATTERN

PLATE I

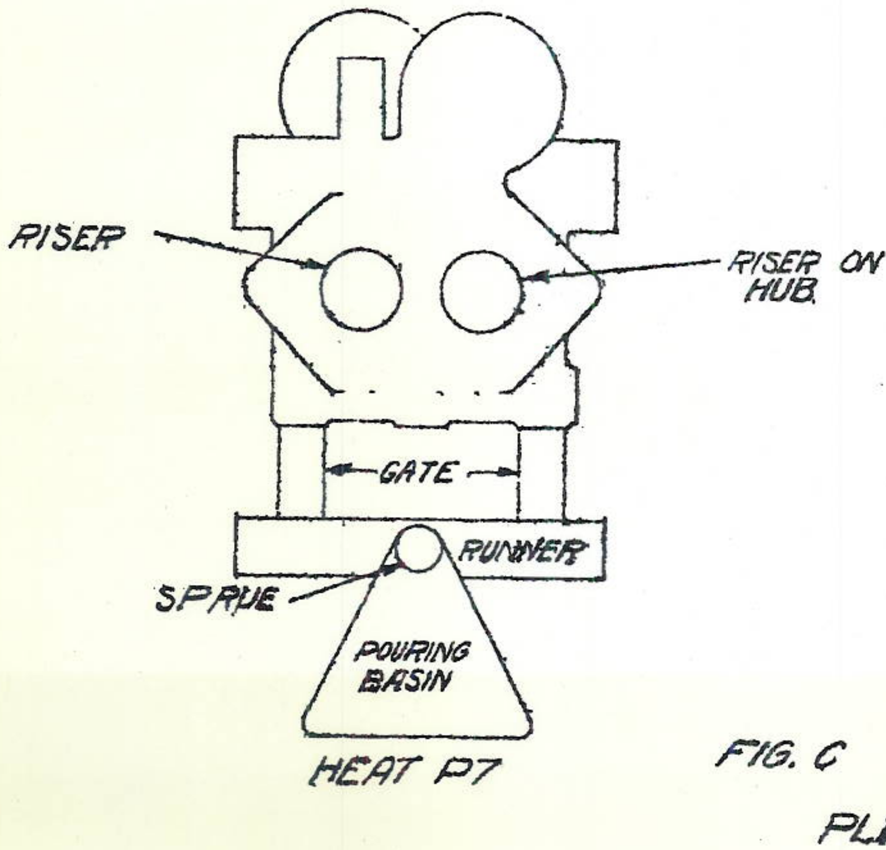
LOCATION OF GATES AND RISERS



HEAT P7A
FIG. A

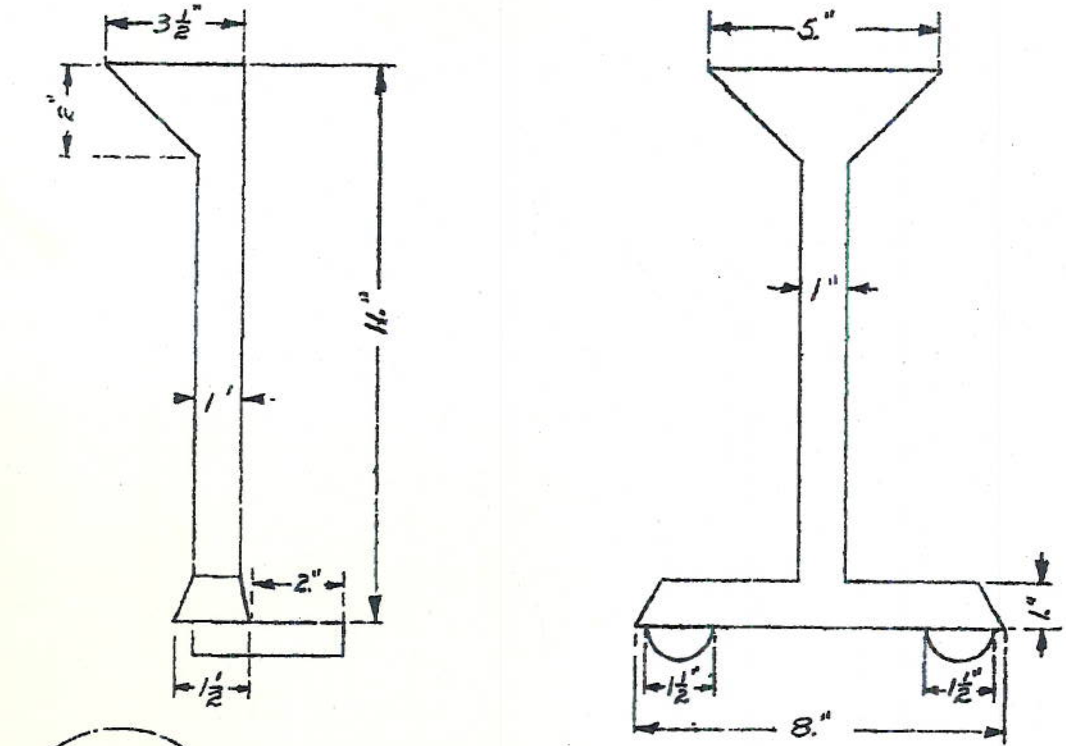


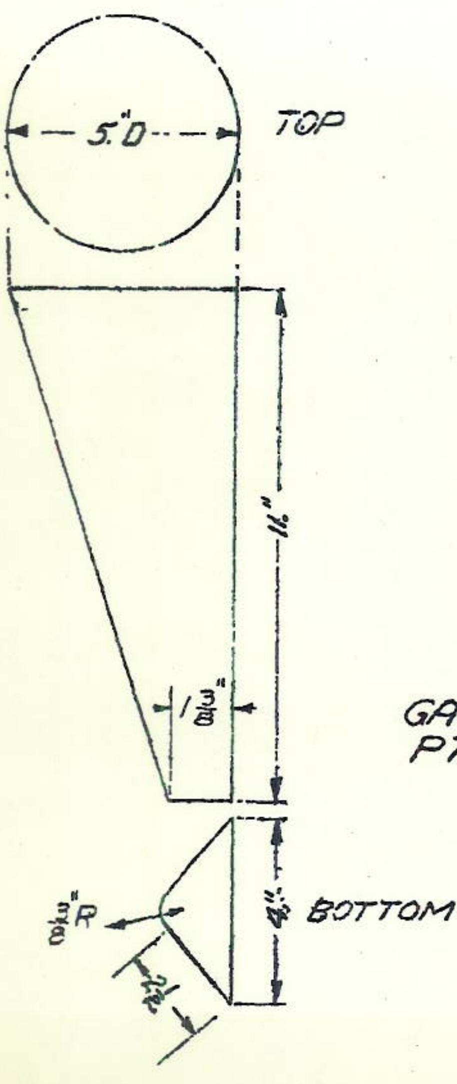
HEAT P6
FIG. B



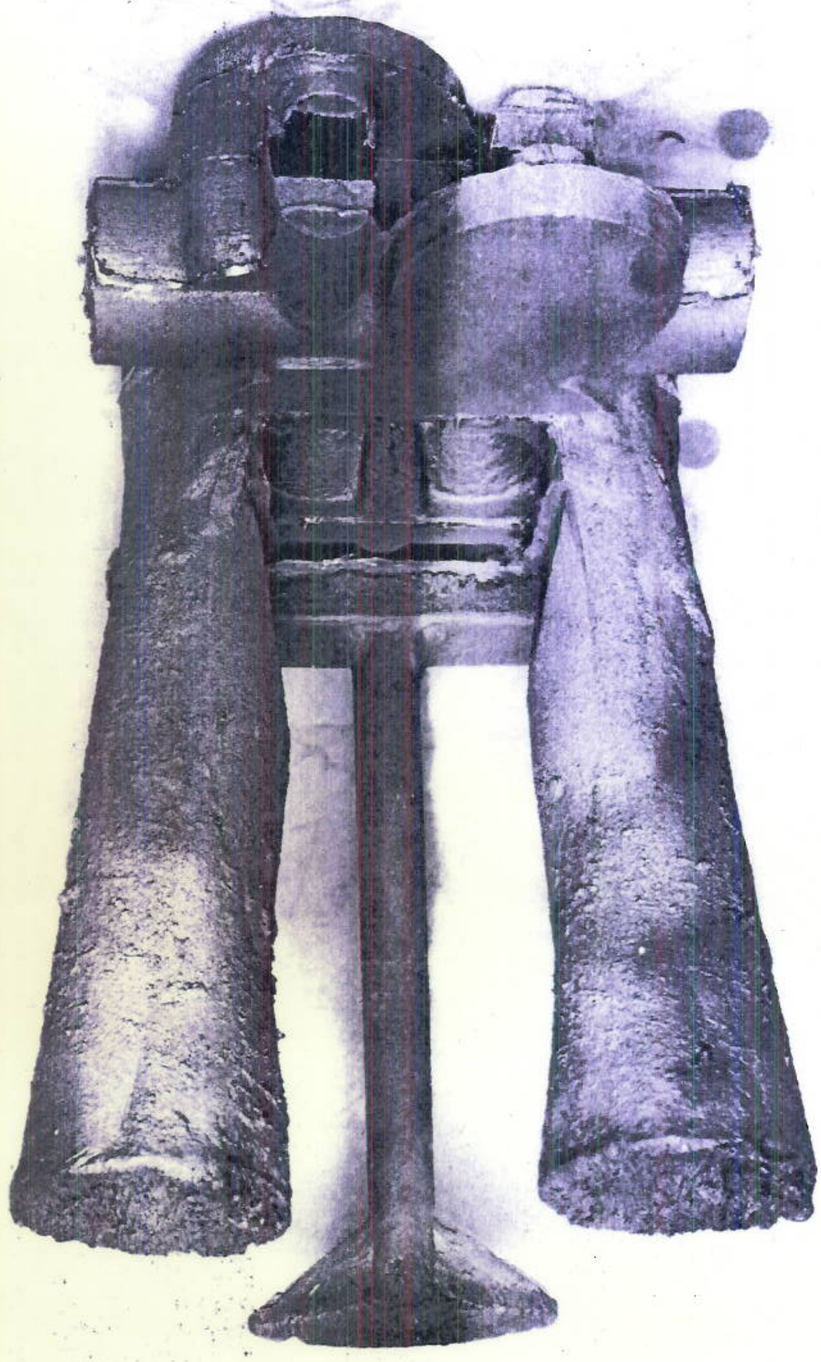
HEAT P7
FIG. C

PLATE 2





GATES AND RISERS FOR HEATS
P7A, P10 & P12.



ROUGH CASTING

PLATE 4