

ort No. M-1443  
Report on Studies of Grid Alloys  
Submarine Storage Batteries

REPORT NO. M-1443

FR-1443

DATE 6 June 1938

DECLASSIFIED by NRL Contract

Declassification Team

Date: 4 MAY 2016

SUBJECT:

Reviewer's name(s): A. THOMPSON,  
P. HANNA

Declassification authority: NAVY DECLASS  
MANUAL, 11 DEC 2012, 05-038

Partial Report on  
Studies of Grid Alloys  
for  
Submarine Storage Batteries



DECLASSIFIED: By authority of  
5000A Dated: 8 Jan 1958

Entered By: E. Bliss Code 2027

BY

NAVAL RESEARCH LABORATORY

BELLEVUE, D. C.

DISTRIBUTION STATEMENT A APPLIES

Further distribution authorized by  
UNLIMITED only.

DECLASSIFIED

APPROVED FOR PUBLIC  
RELEASE - DISTRIBUTION  
UNLIMITED

DECLASSIFIED

6 June 1938

NRL Report No. M-1443

FR-1443

NAVY DEPARTMENT  
BUREAU OF ENGINEERING

Classification changed from \_\_\_\_\_  
to \_\_\_\_\_  
By authority of 2000-155/49  
File No. \_\_\_\_\_ Date 9/9/49

Partial Report  
on  
Studies of Grid Alloys  
for  
Submarine Storage Batteries

NAVAL RESEARCH LABORATORY  
ANACOSTIA STATION  
WASHINGTON, D.C.

Number of Pages: Text - 11 Tables - 1 Plates - 6  
Authorization: BuEng. let. C-SS/S62(2-15-Ds) of 21 February 1933.  
Date of Test: 15 August 1937 to 31 May 1938.  
Reported by: Howard F. Taylor, Contract Metallurgist  
Reviewed by: C. W. Briggs, Acting Superintendent, Metallurgy Division.  
Approved by: H. M. Cooley, Captain, U.S.N., Director.

Distribution: BuEng.(5)

bms

DECLASSIFIED

### ABSTRACT

This report presents in summary form all pertinent facts drawn from previous work on special lead alloys for submarine storage batteries. The effect of various alloying constituents on the operational characteristics of pasted plates is discussed in detail and reasons given for the choice of alloys used in the current series.

The method used in casting the grids is discussed and plans for facilitating future research are included, this report covering only such details as were involved in the manufacture of the grid; the results of physical and life testing will be the subject of another report. This is necessary since the results of life tests at the Bureau of Standards are not yet available.

DECLASSIFIED



TABLE OF CONTENTS

	Page
ABSTRACT	
AUTHORIZATION . . . . .	1
STATEMENT OF PROBLEM . . . . .	1
FACTS ESTABLISHED BY PAST RESEARCH . . . . .	1
MATERIALS . . . . .	3
COMPOSITIONS . . . . .	3
MANUFACTURE OF GRIDS . . . . .	5
CONCLUSIONS . . . . .	9
RECOMMENDED CHANGES IN TECHNIQUE . . . . .	10

APPENDICES

Theoretical Composition of Grids . . . . .	Table 1
Complete Melting and Casting Assembly . . . . .	Plate 1
Complete Melting Pot and Insulation Detail . . . . .	Plate 2
Grid Mold Assembly and Accessories . . . . .	Plate 3
Cast Grid Ready for Pasting . . . . .	Plate 4
Sketch of Recommended Melting Assembly . . . . .	Plate 5
Sketch of Recommended Special Pouring Ladle . . . . .	Plate 6

## AUTHORIZATION

1. This problem was authorized by Bureau of Engineering confidential letter C-SS/S62(2-15-Ds) of 21 February 1933. Other pertinent references are listed as (a) to (g) inclusive.

### References:

- (a) Preliminary Report on Studies of Grid Alloys for Submarine Storage Batteries of 27 July 1933.
- (b) NRL let. SS/19 of 20 April 1934 to Bureau of Engineering.
- (c) NRL Report No. M-1052 of 17 May 1934.
- (d) NRL Report No. M-1121 of 30 January 1935.
- (e) BuEng. let. C-SS/S62(7-31-Y1) of 7 August 1935.
- (f) Bureau of Standards Report on Storage Battery Grids Cast from Navy Type Experimental Alloys of 7 December 1936.
- (g) NRL let. C-SS/19 of 16 September 1937 to BuEng.

## STATEMENT OF PROBLEM

2. The object of this work was to prepare storage battery grids of such alloys that strength in the finished plate would be a maximum and sulfation and intergranular corrosion would be a minimum. In practice this means elimination of antimony from the positive grids, or reducing the amount of that element to below 4-1/2%.

3. The experimental work leading up to the present status of the problem and influencing the current trend of research has been carried on at this Laboratory, with life tests conducted at the National Bureau of Standards. The results have been presented in Naval Research Laboratory Reports No. M-1052, M-1121, and by formal report from the Bureau of Standards.

4. Pertinent facts established by the foregoing researches will again be presented below for the sake of clarity.

## FACTS ESTABLISHED BY PAST RESEARCH

5. (a) Antimony below 4%, especially at 2-1/2%, reduces sulfation to a low level and aids in reducing the tendencies toward the formation of moss and trees. At the same time, antimony at even so low a concentration as 2-1/2% aids materially in giving the positive grid resistance to oxidation or "forming," which is the chief cause of positive plate failure. At this concentration the antimony is largely in solid solution in the lead. Grids containing 4-1/2% antimony with no other alloying element are, however, lacking in strength, at least for service in submarine cells.

(b) Strontium plus 2-1/2% antimony was found to prolong the life of grids as compared to the plain strontium type, and at the

same time caused no more self-discharge than grids containing strontium alone.

(c) A large number of life tests on grids containing varying percentages of strontium plus tin showed that such positives soon failed due to intercrystalline attack of nascent oxygen. This seemed to contradict the conclusion, from numerous laboratory tests of solid unpasted plates of the same compositions, that some of them were more resistant than antimony alloys. Tin promotes the growth of large columnar grains, which may be the cause of the trouble.

(d) Sodium has been used as a preferential oxidizer to protect the strontium from oxidation but apparently does not serve the purpose. The probable accumulation of the sodium or some of its oxides at the grain boundaries was thought to augment corrosion activity both generally and locally.

(e) Strontium-tin alloys of lead, if properly cast, are superior to lead-antimony alloys in strength, electrical conductivity, and resistance to corrosion, except as noted under (c) above.

(f) Alloys containing no antimony are prone to form trees during operation.

(g) Silver has a protective effect against corrosion.

(h) Impure lead causes much of the spurious corrosion often laid to other causes.

(i) The Navy type alloys #1 and #2 of the composition -

I - .4% Strontium + .3% Tin  
II - .4% Strontium + 1.0% Tin

when used as positive plates, disintegrate more rapidly than the standard antimony alloy. They were superior to the plain lead type, however. Loss of capacity on open circuit was much less in the strontium alloys, but the antimony plates regained their lost capacity after re-cycling for a few cycles and were once more superior.

(j) When cells were constructed using both positives and negatives of each of Navy alloys I and II, it was found that they maintained their capacity longer than when used as positives against negatives of standard alloys.

(k) Charging voltages for the Navy type alloys I and II were higher than for pure lead or lead-antimony alloys.

(l) The Navy type alloys I and II were subject to moss and trees but this fault was easily remedied by a slight change in design of the cells.

(m) Rate of sulfation for negatives of Navy type alloys is

much smaller than lead-antimony plates and little, if any, greater than the pure lead type.

(n) Pure lead positives and those containing less than 2% antimony corrode badly and crack, while at 3% or more antimony these properties are very good.

(o) Antimony content does not affect the capacity of cells.

(p) Cadmium alloys, when used as positives, caused excess treeing on the negative, these redissolving on open circuit. These alloys are also expensive, deficient in strength, and have nothing to recommend them.

(q) Age hardening alloys appeared to withstand corrosion better than solid solution alloys. Their ductility and hardness are also superior.

(r) Plain calcium and barium alloys showed great internal corrosion in electrolytic oxidation tests and became extremely brittle, while the plain strontium type remained tough, ductile, and lacked pronounced corrosion. (Results of laboratory tests on solid plates.)

(s) The strontium content of a series of grids cast from one melt varied from .4% for the first few grids cast to nothing in the last, getting poorer and poorer in this element throughout the process.

#### MATERIALS

7. Since it was shown that accidental impurities were responsible for much of the inefficiency of pasted plates used in storage batteries, only elements of the purest composition obtainable were used in the present work and much care taken throughout the procedure to eliminate this doubtful variable. The lead was the purest commercial type available, being 99.99% pure.

#### COMPOSITIONS

8. Grids were produced of the following compositions, these analyses being chosen by Dr. R. H. Canfield after a careful consideration of established facts.

Table 1

## Theoretical Compositions of Grids

	% Sb	% Sr	% Sn	% Ag	% Te
A	4½	- -	- -	- -	- -
B	2½	- -	- -	.05	- -
C	2½	- -	- -	.10	- -
D	2½	.07	- -	.05	- -
E	2½	.07	.20	- -	- -
F	2½	.07	- -	.10	- -
G	2½	.15	- -	.05	- -
H	2½	.15	.20	- -	- -
I	2½	.15	- -	.10	- -
J	2½	.15	.15	.05	- -
K	2½	.15	- -	- -	.02
L	2½	.15	.20	- -	.02
M	2½	.15	.40	- -	- -
X	2½	.07	.15	.05	- -

9. Having found that positive grids containing less than 4% antimony reduced sulfation to a very low level, and since unrelated research has proven 2-1/2% to be the limit of solid solubility of antimony in lead, this was selected as the basic composition of the entire series. It was decided, in the light of substantial evidence, that perhaps the precipitated phase known to be present in alloys containing more than 4% Sb might be the cause of accelerated sulfation as the proportion of this element is raised. A plain 4.5% antimony-lead series was made to be used as a reference standard for comparison of operational characteristics. This composition is superior to any other plain lead-antimony alloy in prolonging cell life.

10. The age-hardening effect present in the usual antimony-load grids of 8 - 14% antimony was necessarily eliminated with the choice of the low limit of 2-1/2%. As a consequence some agent had to be used which would impart the necessary hardness characteristics to the finished plate and at the same time not show any tendency toward

promotion of sulfation. Strontium was selected on the basis of its past good showing in decreasing self-discharge, prolonging the life of the grid, promoting hardness, and decreasing formation of trees. In certain cases such as the Navy type alloys I and II, it is safe to say that the results obtained were greatly influenced by such unfortunate circumstances as a gradual loss of strontium through oxidation in the melting pot and the presence of large columnar grains as a result of the presence of tin as well as adverse temperature gradient in the mold with corresponding directional solidification in the finished product. This series could hardly be taken as a criterion of the true action of strontium.

11. Alloys of lead containing Sr and Sn in small percentages, when properly cast, were found to be superior to plain lead-antimony types in several respects especially in the form of solid plates, and as a result such alloys are repeated in the current series with the hope that perhaps more purity and homogeneity may be realized under the revised procedure and the results be more conclusive. The tin seems to be a dominant factor in the resistance to electrolytic corrosion, at least in solid unpasted plates.

12. Since cadmium caused excess treeing when used as a constituent of positive grids, and redissolving on open circuit, it was concluded that this element had no beneficial effects.

13. Likewise, calcium and barium alloys showed up very poorly in operational tests and were discarded in favor of strontium.

14. Tellurium was found to inhibit corrosion, but it also served to make the grid soft. As a result it was decided to incorporate the possible anti-corrosion properties of tellurium with the hardening property of strontium in a certain number of grids to see if such a double duty combination might not facilitate better and longer cell performance.

15. Silver was added in several cases because of its beneficial effect in protecting the structure from intercrystalline corrosion. Whether it accomplishes this as a result of alloying with the other elements or by forming a protective coating at the grain boundaries is not clearly understood at present.

16. Certain other unaccountable phenomena have manifested themselves throughout the research on this project which may be clarified by future research. Such research will be resumed when results are available from the current life test being conducted at the U. S. Bureau of Standards on the above series to see if further work in the present direction is justified.

#### MANUFACTURE OF GRIDS

17. As mentioned before the loss of strontium during the casting process was probably responsible in large part for the poor operation of many of the grids. After a resume of available literature,

it was decided that perhaps the rapid disappearance of the strontium through oxidation could be controlled by the maintenance of an atmosphere of  $\text{CO}_2$  and  $\text{CO}$  over the surface of the molten alloy. Such a method had been successfully used by the Bell Laboratories in the manufacture of calcium grid alloys. Pulverized charcoal was spread over the surface of the molten alloy and kept there during casting. This showed from analysis of grids taken at the beginning, middle, and end of the series, that the rapid and constant loss of strontium took place in spite of these precautions. Also small particles of charcoal were occluded in the metal of the grid and resulted in a product of poor quality. The small holes caused by the charcoal would undoubtedly promote localized and increased corrosion during operation in the cell.

18. Owing to the fact that helium is available, and on account of its unreactive and non-explosive properties, it seemed that perhaps this sort of atmosphere, if maintained over the metal, might solve the oxidation problem and at the same time be economical. Thus, the unit pictured in Plate 1 was designed and built at the Laboratory. The purification train for removal of moisture and any small amount of oxygen that might be present in the helium consisted of (1)  $\text{CaCl}_2$  drying tube, (2) fused quartz chamber containing a coil of very fine mesh copper screen for removal of the oxygen, (3) a  $\text{H}_2\text{SO}_4$  (c.p.) drying bottle, (4) a mineral oil flow indicator also serving to keep any  $\text{H}_2\text{SO}_4$  vapor from passing over into (5) the final  $\text{CaCl}_2$  drying tube. An electrical heating element was placed around the portion of the quartz tube containing the wire screen and kept at approximately  $1500^\circ\text{F}$  to promote the separation of the oxygen which, if present at all, is in very small amounts. The slight blackening of the copper indicated that some oxygen was being removed. It was not thought necessary to further purify the helium as any other gases that might be present would probably not affect the strontium.

19. The pot was made fairly gas tight by use of a copper gasket and strong machine bolts. The small amount of leakage through the hole in the large pipe cap and other places was allowed as an escape for the helium which was constantly forced through the unit. Also it allowed an escape for initial air as it was forced out by the helium. The pot was heated electrically by means of nichrome wire elements bent to the shape of the pot and mounted in "thermolith" cement. The unit was made so it could be easily disassembled in detail for cleaning after each melt of a certain series to insure the absence of any contaminating compounds. The current for heating was controlled by the special transformer, also shown in Plate 1. The space around the cemented elements was lagged with ground diatomaceous earth and shredded asbestos.

20. The pot used was already on hand at the Laboratory and was made of cast iron found to be suitable from previous tests.

21. The extension unit and valve were constructed of a special high cobalt alloy. This material was found to have a very low coefficient of expansion and to have unusually good characteristics when

operated at elevated temperatures. High temperature at the valve and through the extension unit was necessary since at any temperature below the melting point of the lead alloy the valve would freeze up. An electrical heating element, fitted closely around the extension and kept at approximately 1300° F. was used most of the time. This is not shown in the picture. A bunsen burner kept under the valve constantly maintained it at the right temperature and was also used to preheat the pouring ladle. The very low coefficient of expansion of the cobalt alloy permitted the valve to operate satisfactorily without seizing and sticking and was yet constructed with close enough tolerances to prevent leakage of the lead.

22. The pot was charged with molten pure lead through the small pipe seen projecting from the lid. Helium was forced rapidly through the heated, empty pot to remove the ordinary atmosphere present. Keeping up the rapid flow of helium, the pipe cap was removed and previously melted lead introduced by means of a ladle. The lead was melted in a second electrically heated pot and ladled out as rapidly as possible. The temperature of the pot was measured by means of an iron-constantan thermocouple maintained in a 3/8" tube leading to the bottom of the pot and sealed into the cover. This gave a constant control of the temperature of the lead, being measured directly in degrees Fahrenheit on a Leeds & Northrup potentiometer. A voltmeter was also kept across the circuit to give a constant insurance that all electrical connections were intact and that the proper taps were being used on the transformer.

23. Pot temperatures as low as 1150° F were used for the first few heats but it was found that the strontium was not being alloyed with the lead. As a result the bath was maintained at 1450° F and much better results were obtained. The addition of strontium, silver, antimony, tin, and tellurium as desired and in proper quantities, was made by first introducing these elements into the larger of the pipes at the top of the assembly. The handle, as shown in Plates 1 and 2, was raised to its highest level and held there by hand. Next, the pipe cap was removed, the alloying agents introduced, and the cap replaced. These additions were held in the pipe by means of a cone-shaped plunger on the end of the stirring rod and any air present could be swept out with the helium. This plunger when raised as high as possible, fitted tightly into a seat at the bottom of the pipe and kept even the finely divided elements from falling into the bath until the proper time. When released and dashed up and down it also served to thoroughly agitate the molten metal, this precaution being adhered to before pouring each grid as a precaution against possible segregation.

24. Analyses made from grids at the beginning, middle, and end of a melt proved beyond any doubt that no loss of strontium was being suffered, and that the percentage was remaining very constant. This was proof that one of the greatest obstacles in the manufacture of this type of alloy was surmounted.

25. Another very difficult step was the production of satisfactory grids from the metal. As mentioned before some trouble was experienced with previous plates due to the presence of large columnar grains with their consequent increased rate of deterioration through accelerated oxidation. In an effort to eliminate, or at least reduce, this trend the grid mold was heated from the bottom by means of an air blast burner. The arrangement is shown in Plate 3. From microscopic examination the structure of the final grids was of a fine grained variety and very uniform. Since the mold was kept at approximately 350° C., the cooling gradient from 1450° F. was much steeper than that usually employed and might account in large part for the fine grains. The mold was operated at as low a temperature as possible consistent with good handling technique.

26. A very important item in making good clean grids seems to be the choice and manipulation of a proper spray for coating the surface of the mold. This spray must be fine enough to give a smooth surface even in the small ribs as any roughness in the finished grid tends towards increased oxidation, be heat resistant and tough enough to stand repeated use, and satisfactorily prevent sticking of the grid in the mold. The type, developed by B. H. Schubert of the National Lead Company, and known as "Molspray", was found to be satisfactory for this work and was used throughout.

27. The grid mold surface should be thoroughly cleaned with a wire brush and heated externally, no flame to be applied directly to the mold face. The temperature should be slightly above casting heat at the time the spray is applied to compensate for the thermal loss in vaporizing the Molspray. An instantaneous evaporation is a good indication of proper temperature. The Molspray, diluted half and half with water should be atomized upon the grid surface by means of an air gun. An ordinary Atlas nasal atomizer attached to an air line was found satisfactory. The nozzle should be kept about 5 inches from the mold surface while spraying. Starting at the top corners of the mold, the sprayer should be moved horizontally across the mold surface at the same time working down. Next the sprayer should be operated in like manner with a vertical motion and moving across the face. The proper technique can be obtained only from experience and it should always be borne in mind that the ultimate aim is a thorough covering of the surface only deep enough to prevent sticking of the grid. It was found best to apply a light layer, cast a couple of grids and apply a second layer, this being kept up until a proper coating was obtained. "Fins", or extraneous metal around the grid, often result from a piling up of the spray in certain regions around the mold face. A leather strike was used to dress down the face of the mold and clean the air vents. The mold used in this work was of the ordinary, manually operated variety and is clearly pictured in Plate 3. The small dots noticed in the rear mold face are air vents leading entirely through the metal. It was found very important that these air passages be kept clear as they served as outlets for the air forced ahead of the molten metal. If these become plugged, a back pressure builds up which favors the production of cold shuts.

Once the required mold temperature and thickness of coating is attained, the unit can be operated for a complete series without further attention to this factor. Excessive roughness on grids is evidence of too thick coatings of this spray. Outwardly the composition of this product seems to be a suspension of ultra-finely divided graphite in water but it may be more complex.

28. The technique of pouring the grids appeared to come from experience as it was impossible to get good results at first. However, after a certain amount of practice this difficulty was eliminated. The entire procedure of pouring the grid was as follows:

The valve and pouring ladle were kept hot by means of the burner shown in Plates 1 and 3. After raising the mold temperature to 4000 C., as measured by small chromel-alumel thermocouples placed in holes drilled in the mold, the heat was turned off and the surface sprayed as outlined above. The valve was operated by means of an extension handle as shown and a ladle full of the molten alloy quickly drawn. This was immediately transferred to the mold and after a predetermined time necessary for the grid to solidify, the mold was opened and the grid removed. This was trimmed free from the heavy lug and fins with an ordinary paper cutter and stamped with the proper label.

29. The strontium content was the only control variable chemically checked throughout as it was assumed from past experience that all the other elements would remain constant and in their proper proportions.

30. Certain grids were selected for final chemical analysis from each series. Others were reserved for such tests as were necessary, and 30 grids of each of 14 series submitted to the National Bureau of Standards for life tests. These tests and others are now under way and the results will appear in future reports, not being in any definite order of completion at the present time.

#### CONCLUSIONS

31. The problem of satisfactorily casting a series of strontium-lead alloy grids without experiencing a constant and often complete loss of strontium was solved.

32. This method could be used on a large scale by the Navy for production of submarine batteries and with certain modifications, by commercial concerns. It would only be necessary to find a suitable atmosphere as a substitute for helium to make the procedure generally acceptable. This, however, would not concern the Navy. The amount of helium used in the preparation of approximately 750 grids was in the order of 30 cu.ft.

33. The use of a controlled atmosphere over the surface of the metal, and the practice of taking the cleanest metal from the bottom of the melt gave castings of a much better quality than would

otherwise be the case since contaminating oxides were a minimum and occluded particles of charcoal were eliminated.

34. The high temperature of 1450° F. was necessary in order to alloy the strontium completely with the lead since the melting point of strontium is approximately 1400° F. This was definitely established by chemical analysis of grids poured at lower temperatures.

35. Heretofore commercial attempts to use a valving technique with molten lead were in vain. However, the use of a special cobalt alloy, prepared at this Laboratory, served to solve the problem very efficiently. The low coefficient of expansion of this metal, together with its good operational characteristics at elevated temperatures permitted the unit to operate without seizure or leakage at temperatures as high as 1450° F. After repeated use at this temperature the outlet plugged with oxide and it was decided to operate it at a lower degree of heat. At about 1000° F. the valve operated with perfect ease and efficiency for the duration of the casting work. The type and general features of the valve are shown in disassembled condition in Plate 2. The other parts of the melting assembly are also disassembled to show their general form.

#### RECOMMENDED CHANGES IN TECHNIQUE

36. Since the cast iron pot used in the past was far too cumbersome for convenience, it would be best if one could be made of 1/8" sheet steel rolled and welded in the form of a cylinder. A suitable flange for the attachment of the lid and necessary articles could also be welded on and holes drilled for fastening the two parts. This would facilitate cleaning after successive heats. The bottom of the pot could be made eccentrically conical and the outlet welded at the lowest point. This would completely drain the molten alloy. This bottom would be welded securely to the cylindrical sides. Heating elements of nichrome could be molded in "Thermolith" cement around the pot and the whole encased in a metal shield as used in the current practice. The lagging between the heating elements and the casing would be ground diatomaceous earth. The illustration of Plate 5 will serve to show how the altered assembly would look.

37. To eliminate the high personal equation in the pouring of the grids it might be well if some sort of modified ladle could be utilized. Certain of the alloying constituents seem to change the fluidity of the molten metal and make it either more or less easy to cast. Some of the compositions proved difficult to cast into good grids, and the manner of handling the ladle seemed to be very important. If the entire surface of the mold opening were not covered with the melt at the same time a great number of "cold shuts", or unfilled ribs, were obtained. The unit pictured in Plate 6 would perhaps eliminate this variable, to be used only when found

necessary. The time loss of heat in the hand operated ladle would be lessened as the time of manipulation could be somewhat decreased. A certain amount of metal loss due to splashing would also be eliminated.

38. The mold would no doubt operate far more efficiently if it were heated by electricity, using elements especially adapted to the purpose. A steady flow of heat into the mold would thus result and no loss of time for intermittent heatings would be necessary. Also the effect on the mold would be far less drastic than the use of burners since excess heating at spots where the flame impinges is bound to result in a warping of the individual plates. This was noticed in the current mold and caused considerable "finning" around the grid. This was removed from the finished casting with a knife or, with a certain amount of care, could possibly be prevented by using an extra amount of mold spray in the loosely fitting places. The trouble with this procedure is that mold spray is also deposited where it is not needed, causing unnecessarily heavy castings.



Purification Train

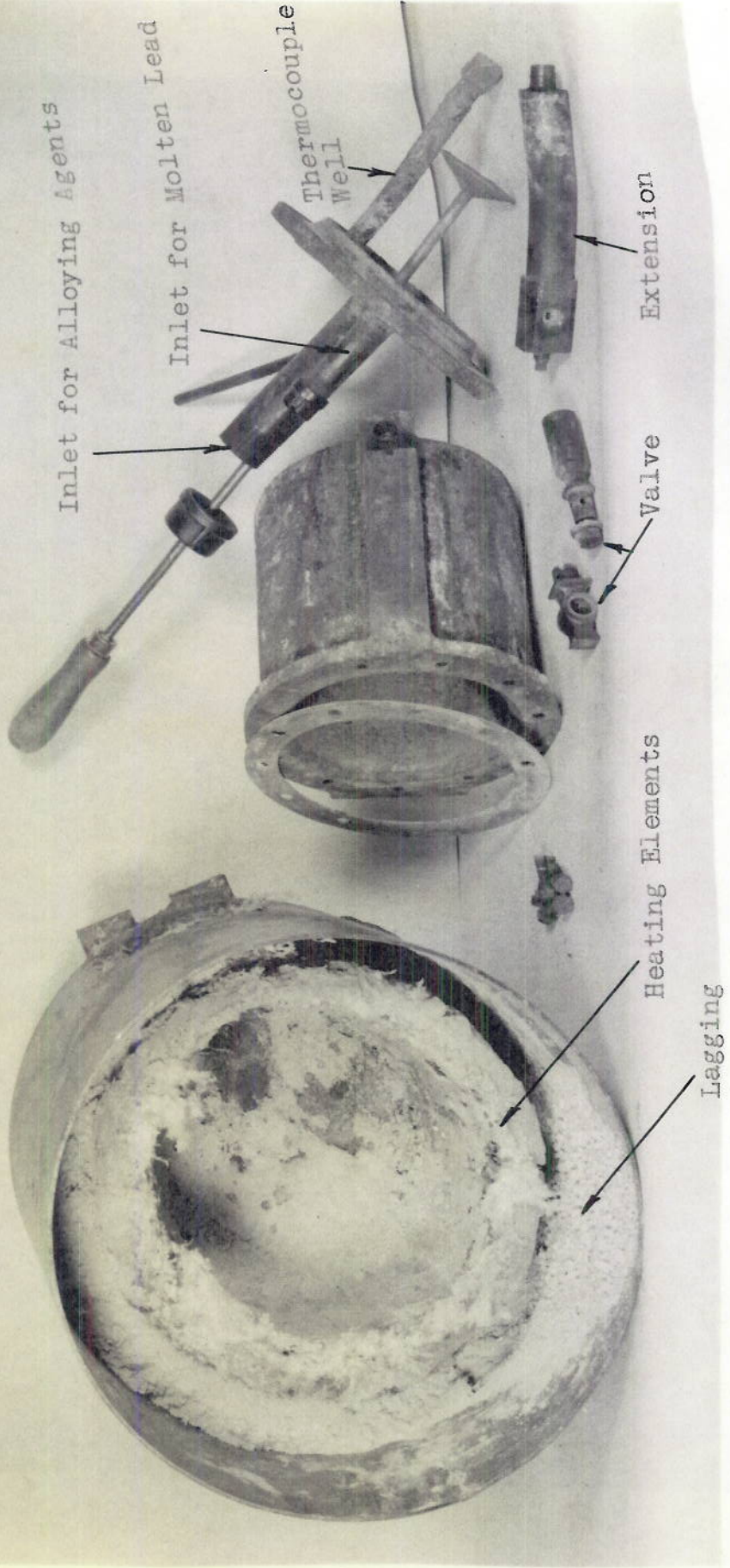
Melting Pot  
Assembly

Helium Line  
- In

Transformer

DECLASSIFIED

Plate 1



Inlet for Alloying Agents

Inlet for Molten Lead

Thermocouple Well

Extension

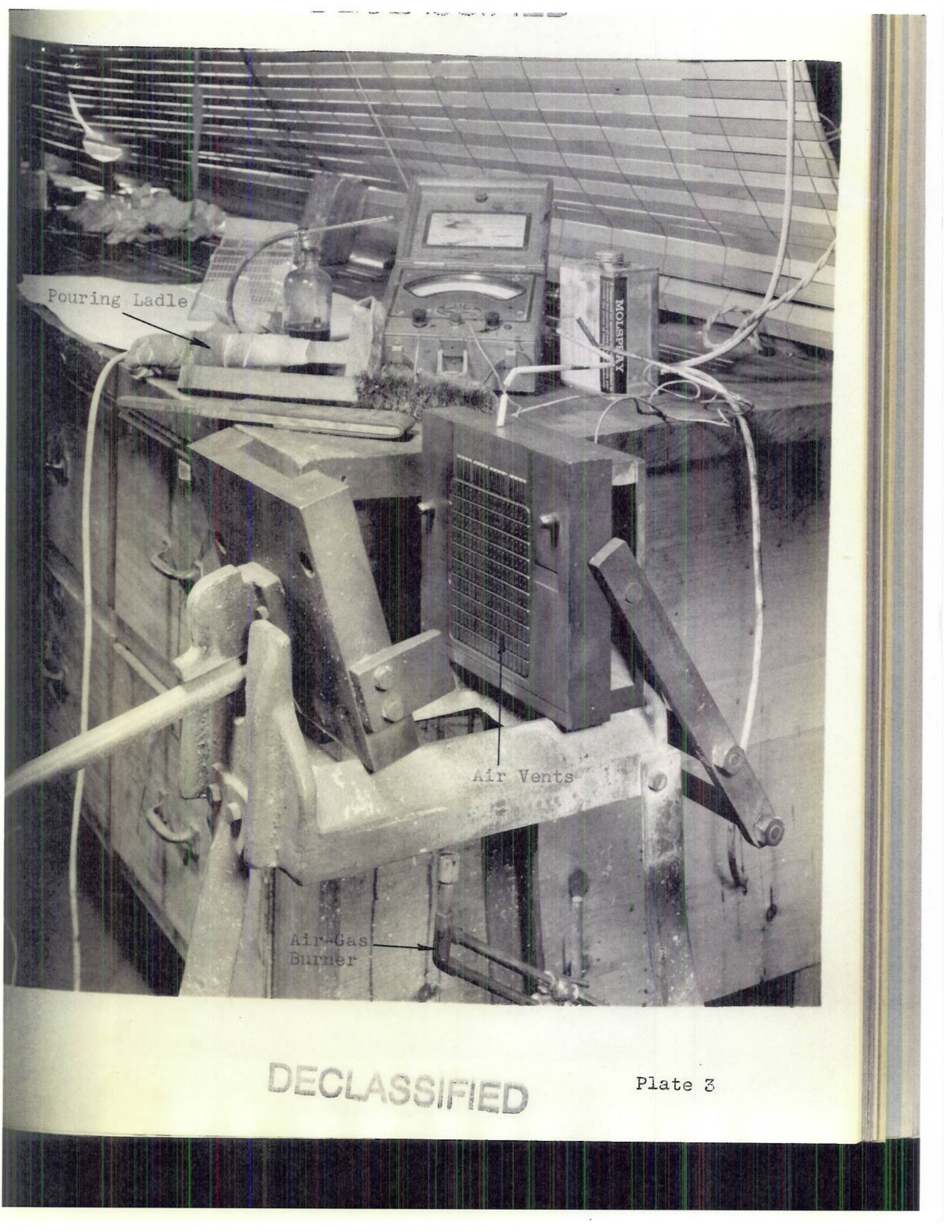
Valve

Heating Elements

Lagging

DECLASSIFIED

Plate 2



Pouring Ladle

Air Vents

Air-Gas  
Burner

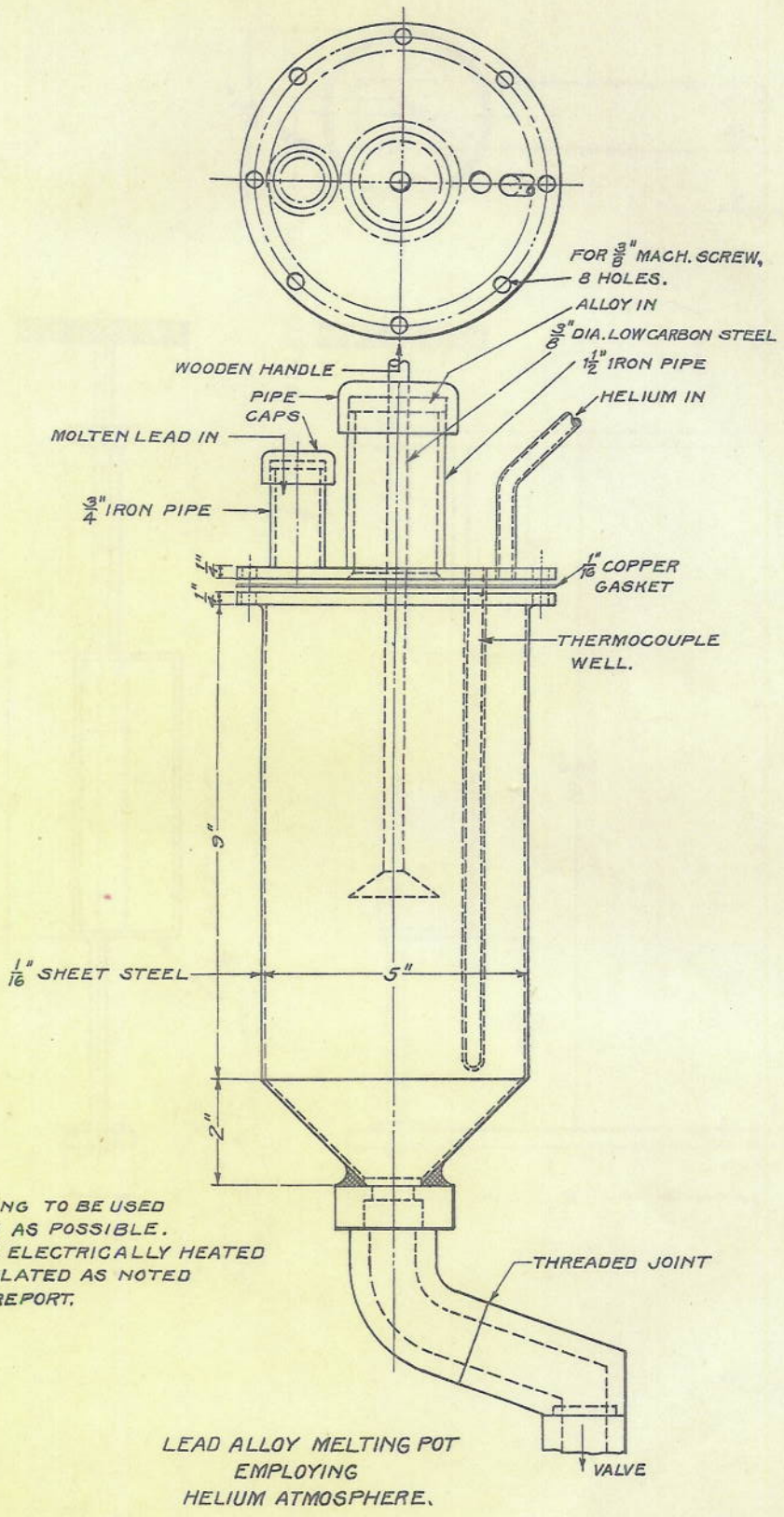
DECLASSIFIED

Plate 3



DECLASSIFIED

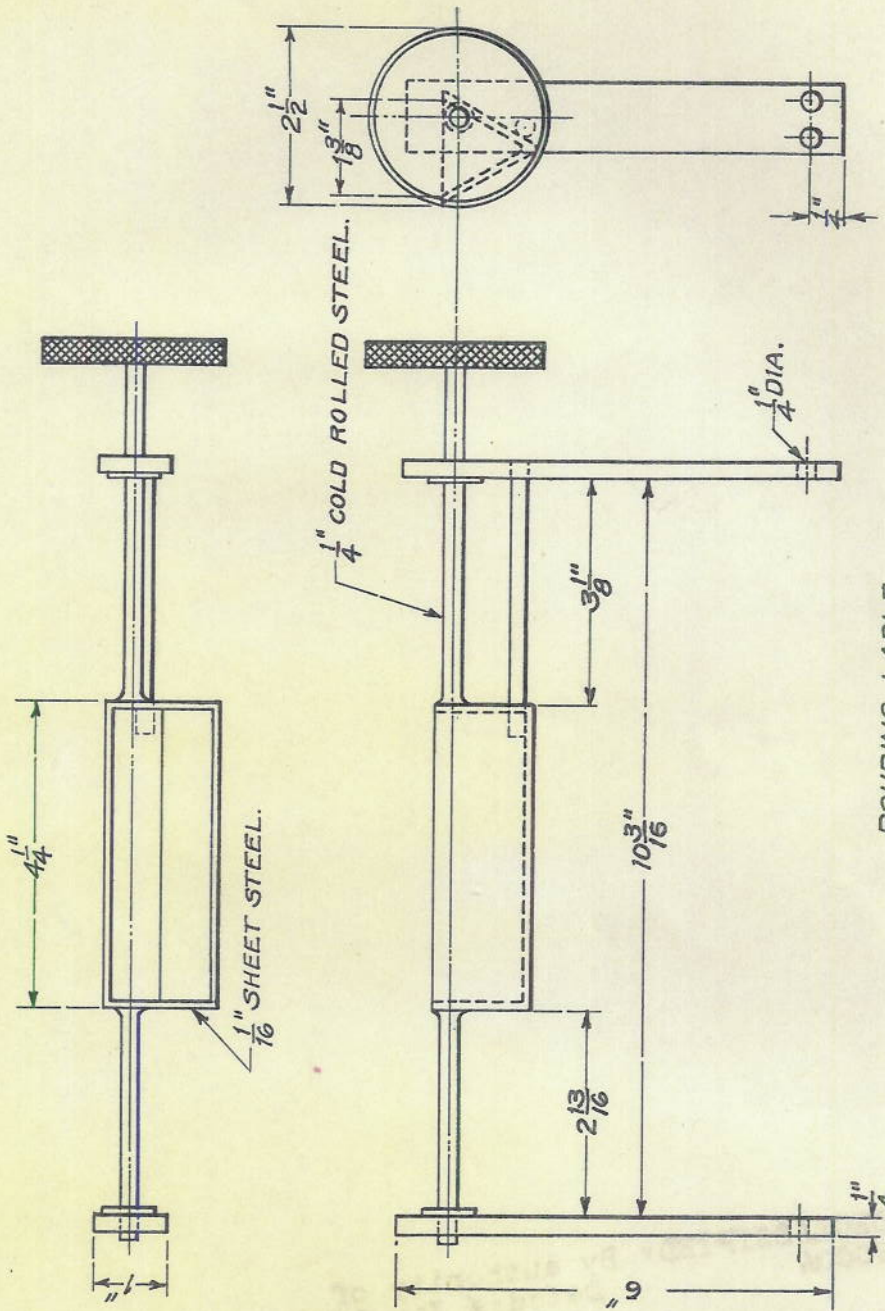
Plate 4



NOTES:  
 1- WELDING TO BE USED AS MUCH AS POSSIBLE.  
 2- TO BE ELECTRICALLY HEATED AND INSULATED AS NOTED IN THE REPORT.

DECLASSIFIED

PLATE 5



POURING LADLE  
FOR  
LEAD ALLOY GRIDS

PLATE 6

DECLASSIFIED