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High Pressure Reducing Valves.

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON DC

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Prepared by:

D.L. Hay, Physicist, Superintendent of
Division of Mechanics & Electricity

Approved by:

H.M. Cooley, Captain, U.S. Navy,
Director.

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ABSTRACT

The troubles experienced with reducing valves in the past are briefly discussed and the basic principles, incorporated in the Naval Research Laboratory valves to eliminate them, are described. This is followed by a brief description of the Mark I and Mark II valves, and a more extended description and discussion of the Mark III valve. The fouled condition of submarine air systems is also discussed, and recommendations given relative to the further improvement of reducing valves.

AUTHORIZATION

1. This problem was authorized by Bureau of Construction and Repair letter, reference (a).

Reference (a) Bu.C&R ltr. SS/S48(24)(DS) SS/L9-7 of 29 January 1929.

GENERAL DISCUSSION OF PROBLEM

2. For many years high pressure air reducing valves for reducing from pressures of 3,000 lbs./sq.in. to 100 lbs./sq.in. or 200 lbs./sq.in. have been very unsatisfactory in operation, due primarily to the following troubles:

(a) Leakage.
(b) Sticking or sluggishness.
(c) Diaphragm and spring breakage.
(d) Chatter and vibration.
(e) Freezing during heavy air delivery.

3. The above (a), (c) and (d) appear to have been due in large measure to the use of large diameter valve seats to obtain sufficient capacity, combined with a floating control by means of which the attempt was made to control the lift of the valve in accordance with the air demand. The inherent instability of the valve at small opening introduces a strong tendency for the valve to chatter and vibrate against its seat. This vibration and pounding of the valve against the seat resulted in destruction of the seat and consequent leakage. It also produced fatigue and breakage of the control diaphragms and springs.

4. Sticking and sluggishness (b) were found principally in certain types of valves in which the air pressure on the valve was balanced by means of a leather packed piston. The sticking of this piston packing in many cases caused slow and unreliable action.

5. Most of these valves were subject to freezing (e) during heavy air delivery. This was due to the fact that the valve stem, guides, and control mechanism for operating the valve were placed on the low pressure side of the valve, directly in the path of the outgoing air. The moisture contained in this air was deposited upon the valve stem and guides and subsequently frozen by the air which was cooled by expansion through the valve.

DESCRIPTION OF N.R.L. VALVES

General Features of Construction

6. The outstanding feature in the construction of the valves built at the Laboratory is the use of a number of small valves so interconnected that they open one at a time in sequence. This construction has several important advantages:

(a) A small valve can be made tight against air leakage much more easily than a large one.

(b) In case of failure to close, less damage is likely to be done to the low pressure system by the quantity of air flowing through the small opening than that through a large one.

(c) The stroke required for full opening is small and the valve parts are very light, so that the impacts of the valve upon its seat during operation are greatly reduced, adding materially to the life of these parts.

(d) With a number of small valves, it is not necessary to control the quantity of air flowing through the valve by varying the lift of the valves. Each valve may be made of the "pop" type, being either closed or wide open at all times, the flow of air being controlled by the number of valves which are opened. The "pop" valve construction eliminates the possibility of excessive valve chatter.

(e) The individual valves, being small and light, may be opened and closed quickly without pounding, thus allowing the air flow to be changed almost instantaneously to follow rapid changes in demand.

7. Another important feature of the design is the use of the "pilot" type valve, in which each valve is opened and closed by a small piston attached directly to it, the piston being controlled in turn by a small "pilot" valve. With this construction, it is possible to place all the valve guides and operating mechanism on the high pressure side of the valve where it is not subject to the cooling action of the outgoing air. This arrangement appears to have completely eliminated difficulties due to freezing.

8. A third important feature is the use of a bellows-type control unit instead of a piston or diaphragm. For pressures of 100 lbs./sq.in. to 200 lbs./sq.in. on the low side, difficulties are encountered with pistons in keeping them free from air leakage and sticking. Diaphragms are free from these troubles, but must be made so heavy that they lack flexibility and the allowable stroke is small. Both of these, of course, require separate springs to balance the air pressure. In the case of the bellows, the design and thickness of material may be adjusted so that the bellows itself serves as the spring. This results in a rugged design which is both compact and flexible.

The Mark I Valve

9. The Mark I valve is shown in sectional view on Plates 1 & 1a. The general construction should be self-evident from this drawing. A photograph of the experimental installation of this valve on the USS R-3 is shown in Plate 2.

10. The measured capacity of this valve was approximately 600 cu.ft. of free air per minute with 1500 lbs./sq.in. air pressure on the high side.

11. The service test of the valve on the USS R-3 was quite satisfactory, but it was believed that the capacity ought to be increased by at least 100%. Also, the design was found to be unsatisfactory in mechanical construction from the point of view of ease of manufacture and strength of some of the parts.

The Mark II Valve

12. In order to increase the capacity by as much as 100%, it was found necessary to make many changes in the design of the Mark I valve, and the design of an entirely new valve was decided upon. This new design, the Mark II valve, is shown on Plate 3. The same principles are incorporated in this valve as in the Mark I, but the general layout is entirely different.

13. The measured capacity of this valve was approximately 2800 cu.ft. of free air per minute with 1500 lbs./sq.in. on the high side. This capacity was found to be adequate for the medium sized submarines, but for the newer ships it was estimated that the capacity should be about 3000 cu.ft./min.

14. Although the difficulties experienced with this valve were due in large measure to the badly fouled condition of the air system on board the ship on which the tests were carried out, the pilot valve design used was not considered to be satisfactory. The corrosion of the pilot valve seats by the salt water passing through the valve, and erosion by the iron, copper and oil emulsion present, caused leakage at these valves and required frequent overhaul to keep them in proper working condition.

The Mark III Valve

15. The Mark III valve is an entirely new design in which the undesirable features of the previous designs have been eliminated. The maximum air capacity is also much greater.

16. Referring to Plate 4, which is a cross-section through the valve, it will be seen that the high pressure air enters from the bottom into the central cavity (1) in the high pressure block (2). This form allows any water or sludge which might accumulate in this cavity to drain back into the high pressure inlet, rather than remain trapped in the block where it might cause corrosion of the valve parts.

17. The 8-piston controlled valves (3) are placed radially around the periphery of the high pressure block, the air which passes through these units when they are open expanding radially outward into the low pressure chamber (4).

18. The air is delivered to the low pressure delivery line from the low point of the low pressure chamber (4a) so that any water or sludge which passes through the valves will drain into the low pressure delivery pipe and be carried away.

19. The pilot valve unit (5) for the control of all the main valves is placed in the center of the high pressure block and is a single piston valve controlled directly from the rubber-coated "Belleville" spring control unit (6). The vent ports (7) in the high pressure block connect the upper chambers of the main valve units (3) to the piston valve ports (8). The ports (8) are spaced so that as the piston (9) moves downward the ports are uncovered one at a time in sequence. The air vented through these ports

passes up around the stem of the piston valve and escapes into the low pressure chamber. The upper end of the piston valve has a beveled ground seat (10) which, in the closed position of the piston valve, prevents the air which leaks past the piston from venting into the low pressure chamber. The small pin valve (11) in the center of the piston valve stem is opened, when the valve is operated by the control unit, just prior to the opening of the piston valve seat (10). This vents the pressure under the seat (10) and greatly reduces the force required to open the piston valve.

20. An enlarged section through one of the individual main valve units (3) is shown on Plate 5. The cylinder (a), cylinder head (b), piston (c), and valve seat (d) form an integral unit with the screw plug (e). The design is such that all parts are self-aligning and the main valve and seat (d) may be lapped together in place before assembling the cylinder head (b). The main valve seat (d) is held in place by the lower end of the cylinder (a) and sealed against leakage by the lead gasket (f). The cylinder head (b) is sealed against leakage by the fish-paper gasket (g) and prevented from falling out during assembly and disassembly by the spring ring (h). The dished metal gasket (i) forces down against the interior face of the high pressure block, forming an effective seal against direct leakage of high pressure air into the pilot control port ((7), Plate 4). It also holds the cylinder head (b) tightly in place.

21. The stroke of the piston and valve (c) is made .45-.50 times the diameter of the valve port (d). This stroke is sufficient to give full air flow and at the same time produce sufficient air reaction to close the valve without the use of an auxiliary spring. The bevel of the valve seat being 45°, no change in the adjustment of the stroke is necessary when the diameter of the valve seat is changed; the requisite decrease in stroke takes place when the diameter of the valve port is reduced.

22. The top edge of each valve piston ((c), Plate 5) has four V-notches cut across the face. These act as vents to control the rate at which the air leaking past the piston is admitted to the space above it, and thus the rate of closing of the valve when the pilot port is closed. If the notches are too small, the valve will be sluggish in action, while if they are too large an unnecessarily large amount of air will flow through the pilot valve when the valve piston is in the open or upper position. It has been found that two 90° V-grooves .01 inch deep give satisfactory operation.

23. In any particular installation where the maximum demand for air is materially less than the maximum capacity of the valve, the diameters of the valve seat openings ((d), Plate 5) should be decreased by amounts sufficient to reduce the port areas in the ratio of the required maximum demand to the maximum capacity of the valve. This will result in quieter and smoother action.

24. The integral construction of the main valve units, and the use of the dished gasket (i) resting upon a flat face in the main block, eliminates the necessity for accurate alignment of the threaded holes in the main block or accurate seating of the copper sealing gasket ((12), Plate 4) at the outer end of the plug.

25. The rubber-coated "Belleville" spring disks (6) are vulcanized together at their inner and outer edges to form the spring bellows unit. This unit is held in place between the upper head (13) and the guide piston (14). The normal pressure of the unit is sufficient to form an airtight seal at the ends. The spring is held in proper operating position laterally by the guiding action of the piston (14) and its central extension through the top plate (13). As a matter of safety, the area of this guide piston is made equal to the effective area of the bellows unit so that in the event that bad leakage should occur through the bellows unit, such as by blow-out of the rubber covering, the piston will take up the control of the valve with only moderate air leakage past it, thus preventing any serious damage due to opening of the valve. Under ordinary slow variations in load upon the valve, this piston has little action on the control, the air leaking past it and acting directly upon the bellows unit.

26. The motion of the control bellows (6) is transferred to the pin-valve (11) and piston valve (9) by means of the threaded member (15) which may be screwed up or down, to set the regulating pressure, by means of the squared shaft (16). The low pressure air which leaks past the threaded piece (15) into the upper end of part (14) is prevented from escaping to atmosphere by the packing gland (17). In order to maintain atmospheric pressure on the inside of the bellows, this volume is vented to the atmosphere through the vent ports (18). The lock nuts (19) serve to prevent the bellows from fully expanding when the control assembly is removed for servicing of the valve.

27. It is evident that by removing the circle of bolts (20) at the base of the control unit assembly, the whole unit may be removed, exposing all the working parts. If trouble is experienced with any individual main valve, or the piston pilot valve, these parts may be removed and repaired or replaced by spare units.

28. Plate 6 is a photograph of the Mark III valve complete. The valve, with bellows control unit and housing removed showing main valve block and units exposed for overhaul, is illustrated in Plate 7. In Plate 8 the principal parts of the valve are shown disassembled.

29. The high pressure block and all internal parts of the valve, with the exception of gaskets, are made of stainless steel. To reduce corrosion as far as possible, all parts should be given a high polish. It is believed that the bronze low pressure housing is sufficiently far removed from the working parts of the valve to have little corrosive effect due to electrolytic action.

30. The Mark III valve was given a laboratory test at bank pressures ranging from 2000 lbs./sq.in. to well below 1000 lbs./sq.in. with the regulated pressure set at 200 lbs./sq.in. The regulation was good and the action positive, with no signs of trouble due to freezing. The air capacity was found to be nearly proportional to the pressure on the high side. At 1500 lbs./sq.in. on the high side, the maximum air delivery was 4500 cu.ft. of free air per minute. At a bank pressure of 3000 lbs./sq.in., the capacity should be over 8000 cu.ft./min.

GENERAL COMMENTS AND CONCLUSIONS

31. The results of shipboard tests of the Naval Research Laboratory valves definitely show that a large part of the troubles experienced, not only with the Naval Research Laboratory valves but with all air reducing valves, can be attributed to the badly fouled condition of the air systems on board most of the submarines.

32. Paragraph 3 of reference (a) indicates that fundamental defects in our high pressure air systems have existed for a considerable number of years. In every case, the reports of valve tests show that valves supplied "can be depended upon to function satisfactorily for only comparatively short periods, and require almost constant attention to insure reliable operation". It is believed that in the development of successive valves at this Laboratory, the objectionable features of reducing valves have been eliminated, but the comparatively early breakdown still exists.

33. In all shipboard tests of the Naval Research Laboratory valves it was found that large quantities of water were being carried along with the air. In most cases, this water carried salt in solution. This weak brine not only causes corrosion of the valves and equipment operated by the air, but also causes corrosion of the high pressure air receivers and copper pipe. This is evidenced by the presence of an oil-water sludge containing large quantities of iron and copper oxides. Although considerable damage results from corrosion by the water, the abrasive oxides cause accelerated erosion of all moving parts and valve seats. The heavy oil sludge containing these oxides is deposited on the pistons and other moving parts, causing sluggish action and in some cases failure in operation.

34. In the test of the Mark I valve on the USS R-3, the condition of the air system was found to be decidedly better than on any of the other submarines on which Laboratory valves have been tested. On this ship, a strainer having a screen area of about 18 sq.in. preceded the valve. The screen was lined with chamois skin as an extra protection from dirt. Although the valve was operated continuously for more than six weeks, the chamois did not become plugged and showed no signs of damage at the end of the test. On the other hand, the same strainer, <u>without chamois skin</u>, was used in the installation of the Mark II valve on the USS R-2, and in approximately a month the screen became completely plugged and burst. The Mark I valve, when dismantled for inspection after the test, was comparatively clean and in excellent operating condition, whereas the Mark II valve at the time of failure was badly fouled and gummed up with a heavy oil-water emulsion of the consistency of cup grease. This latter condition was found in all subsequent tests on other sumarines.

35. This fouled condition of the air systems materially decreases the service life of all air equipment. The resulting corrosion of banks and piping in time may weaken them to the point where they are unsafe to use. The accumulations of oil at various points in the high pressure system also introduce serious hazards from possible explosions.

36. Immediate steps should be taken to investigate this condition to determine what alterations are necessary in the general lay-out and design, and how the charging procedure should be changed to remove these hazards and improve the reliability of operation.

37. The installation of blow-downs at all low points in the system, with accessible controls so that they can be operated at frequent intervals, should go a long way toward eliminating most of the trouble.

38. It is understood that the general practice on board submarines is to blow down the high pressure banks at quarterly intervals. Such an interval between purgings is considered to be entirely too long to be of any value, especially so when the bad atmospheric conditions which usually obtain on shipboard are taken into consideration. The usual practice in commercial high pressure air plants, such as liquid oxygen plants, is to blow down all parts of the system where water and oil may accumulate <u>several times during each charge</u>.

39. Regardless of the cleanliness of the high pressure air system, the installation of an effective trap and strainer in the air line ahead of the reducing valve is considered to be essential as an added precaution against the entrance of foreign matter.

RECOMMENDATIONS

40. It is recommended that:

(a) An investigation be made of the fouled condition of the high pressure air systemsof submarines.

(b) As a result of this investigation, the lay-out of these systems and the charging procedure be modified to eliminate fouling.

(c) The N.R.L. Mark III, Mod. 2, reducing valve be given a thorough service test, and any modifications in its construction which appear necessary as a result of this test be made by the engineers at the Portsmouth Navy Yard.

(d) Efficient separators and strainers be placed in the high pressure air lines ahead of all air reducers, regardless of the cleanliness of the systems.

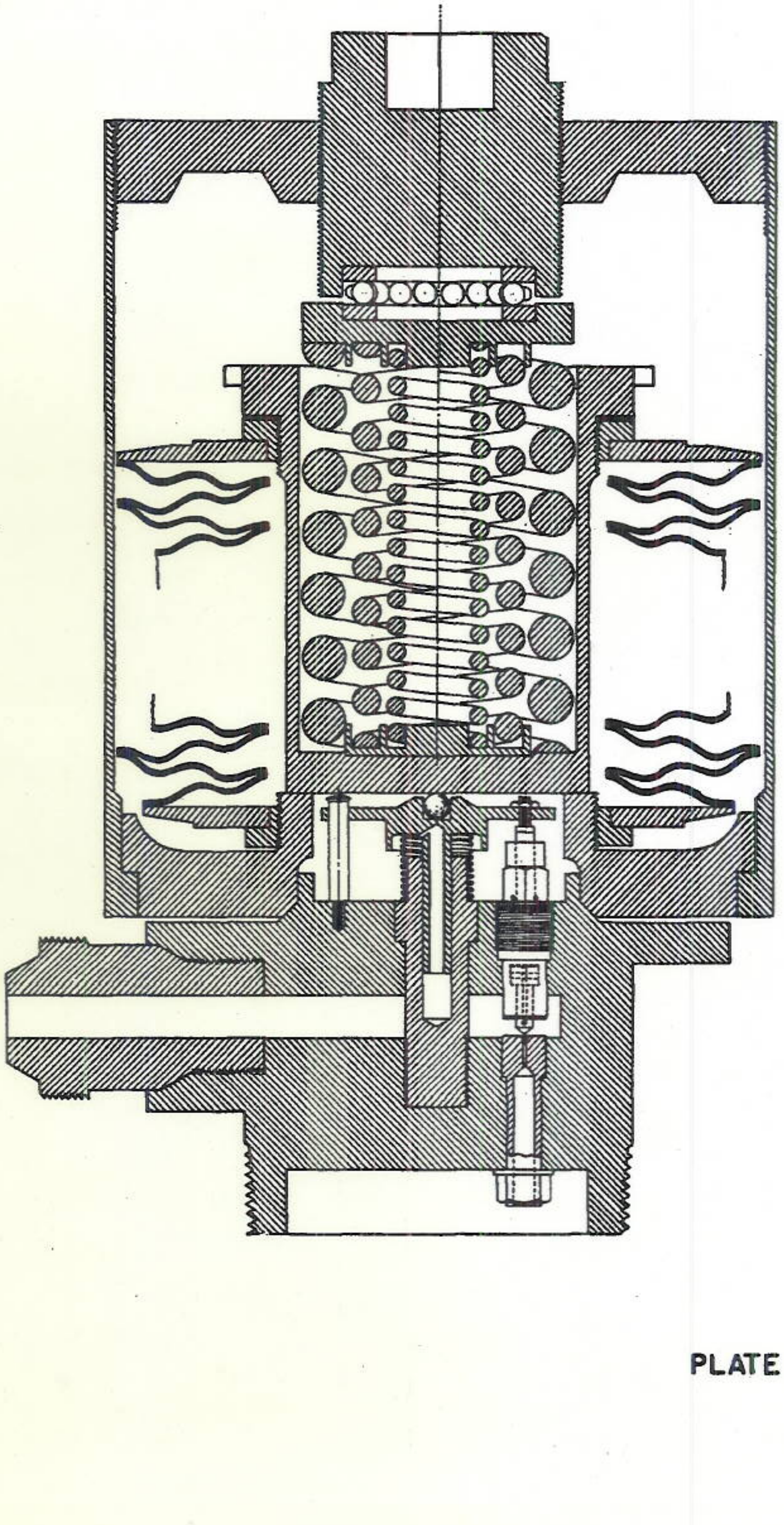


PLATE 1

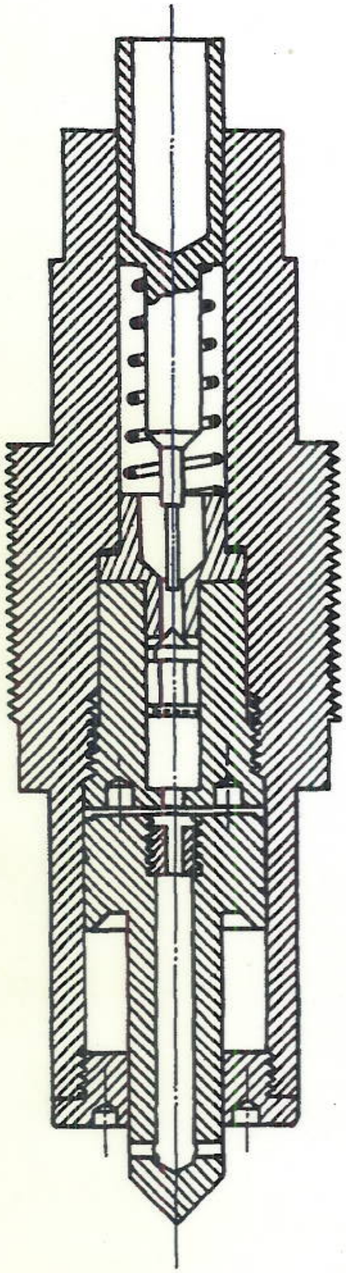


PLATE 1A

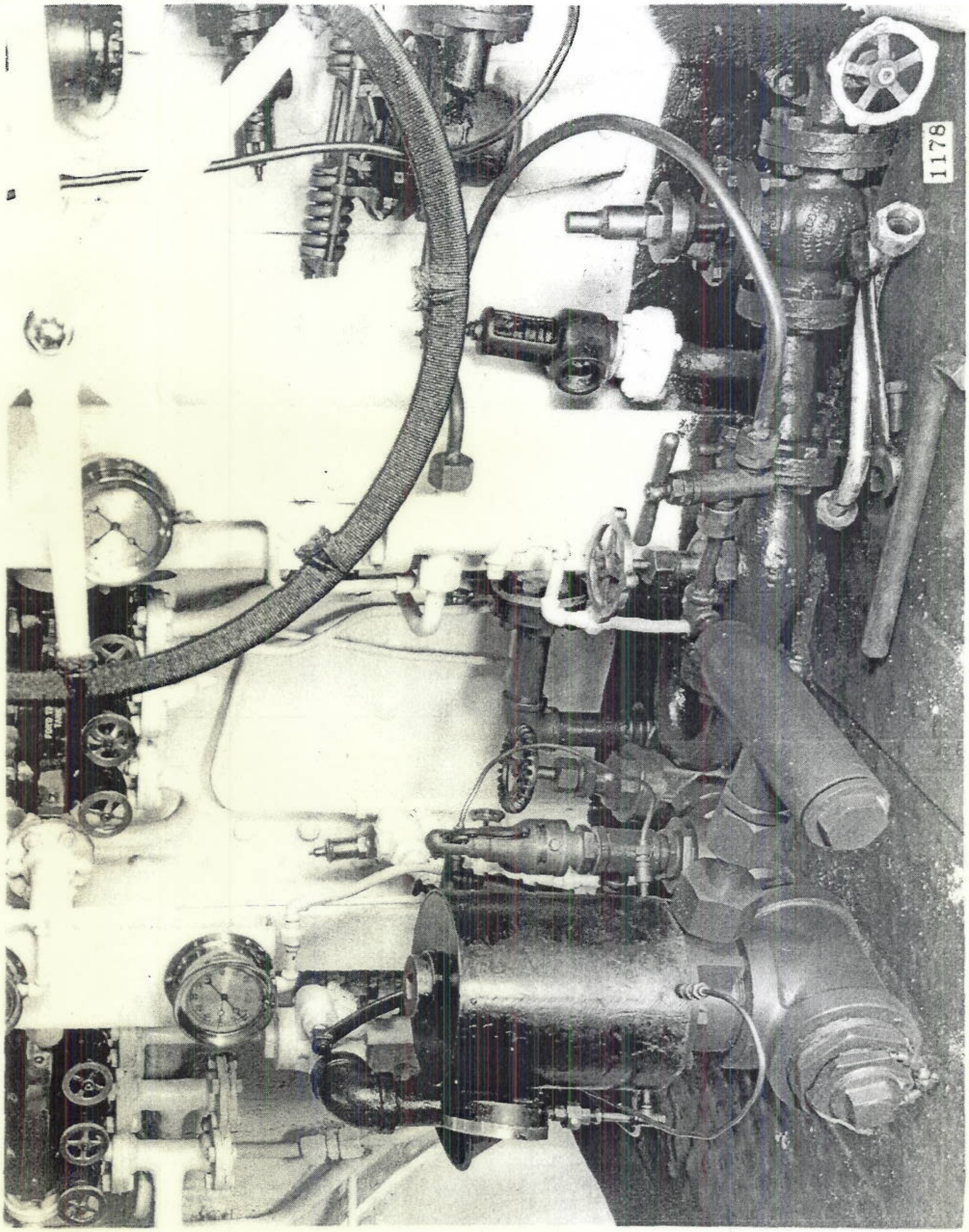
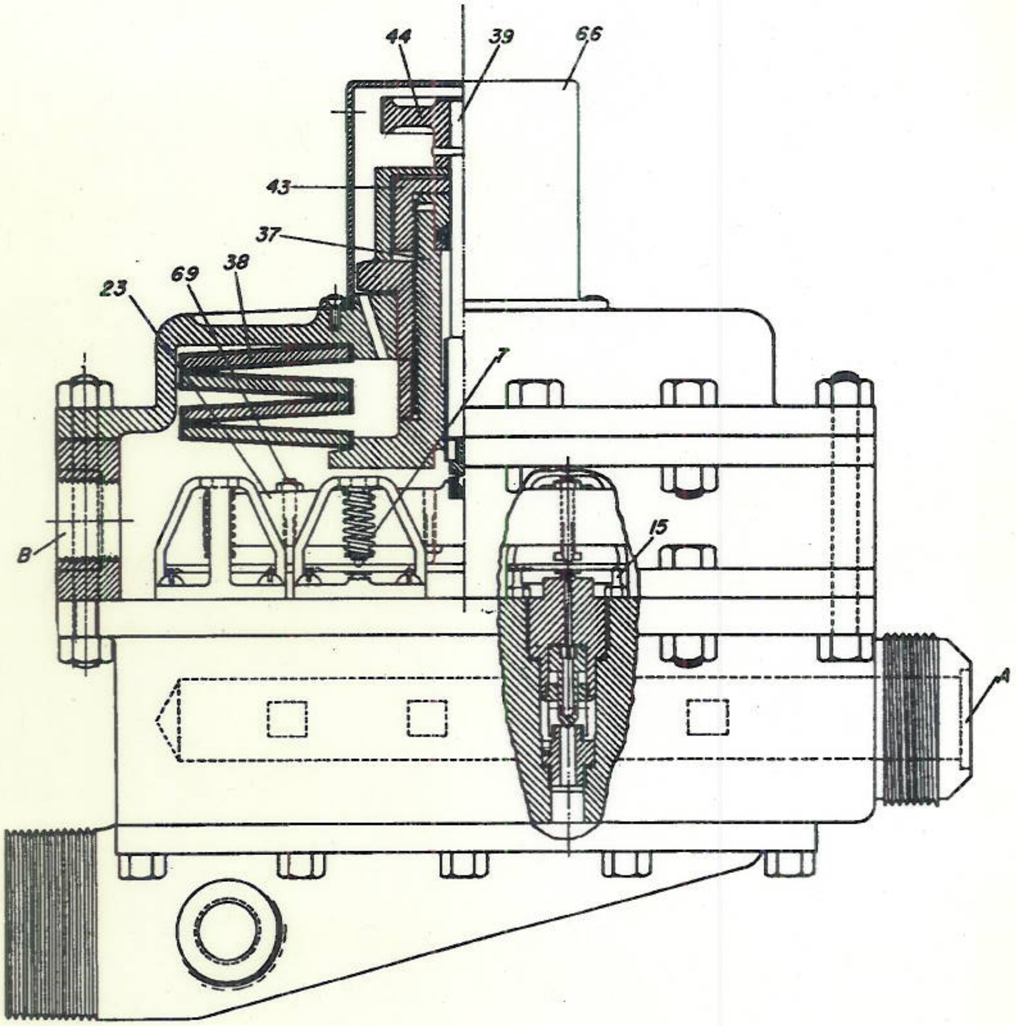


Plate 2



SECTIONAL ELEVATION

PLATE 3

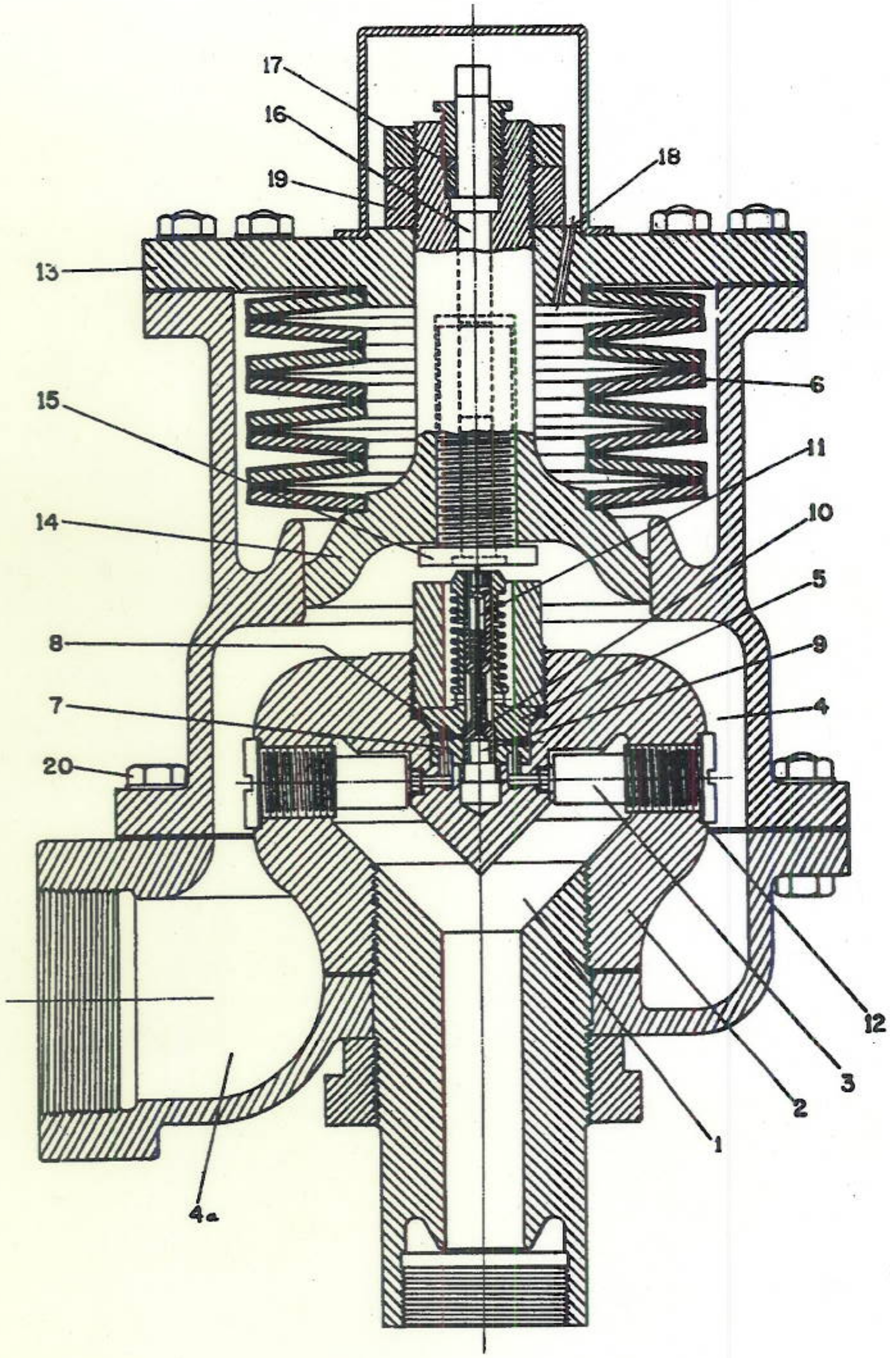


PLATE 4

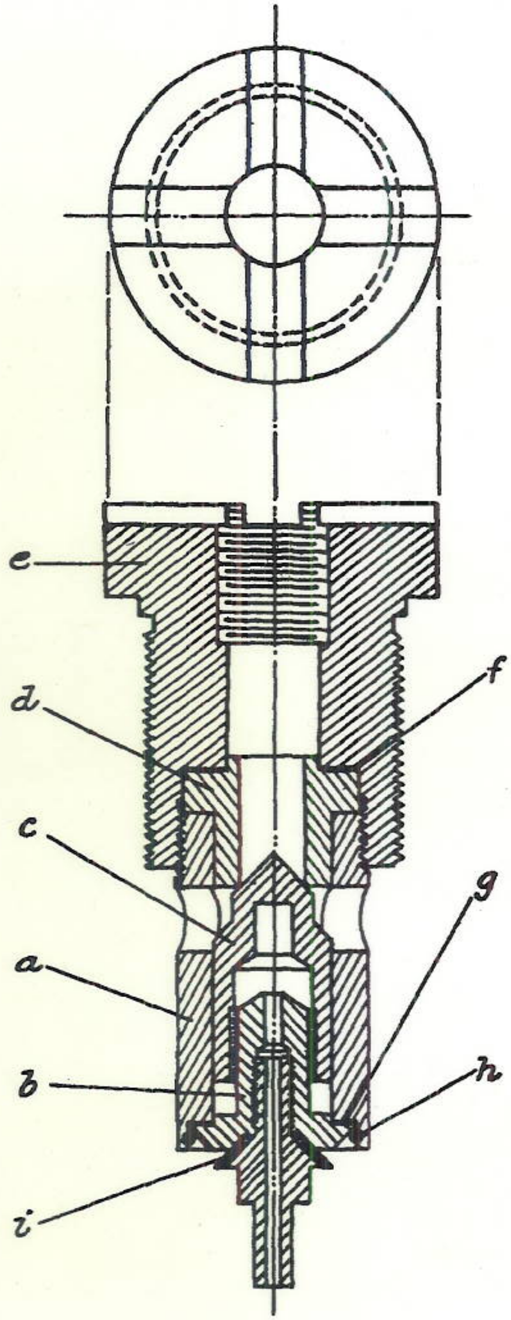


PLATE 5

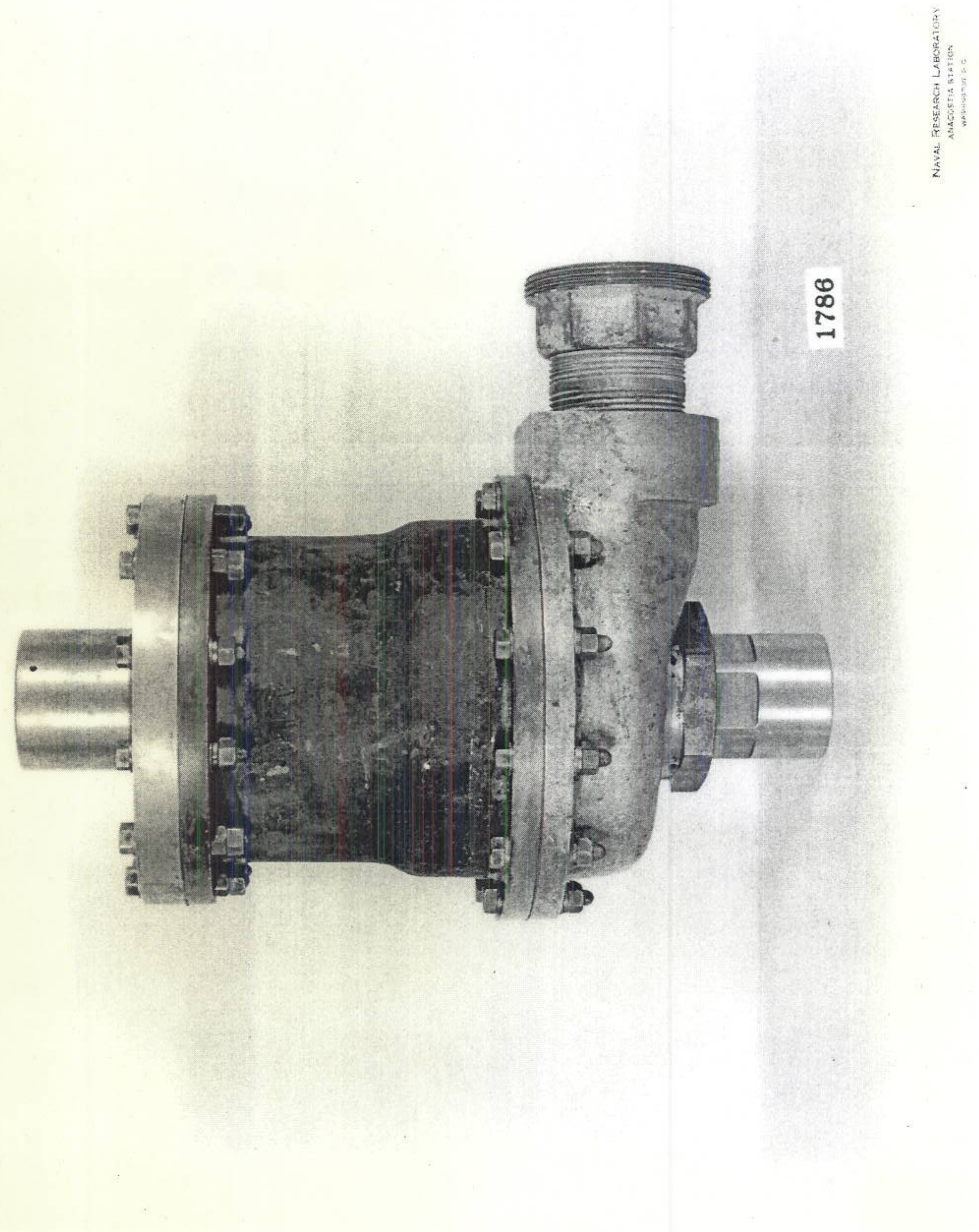

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Plate 6

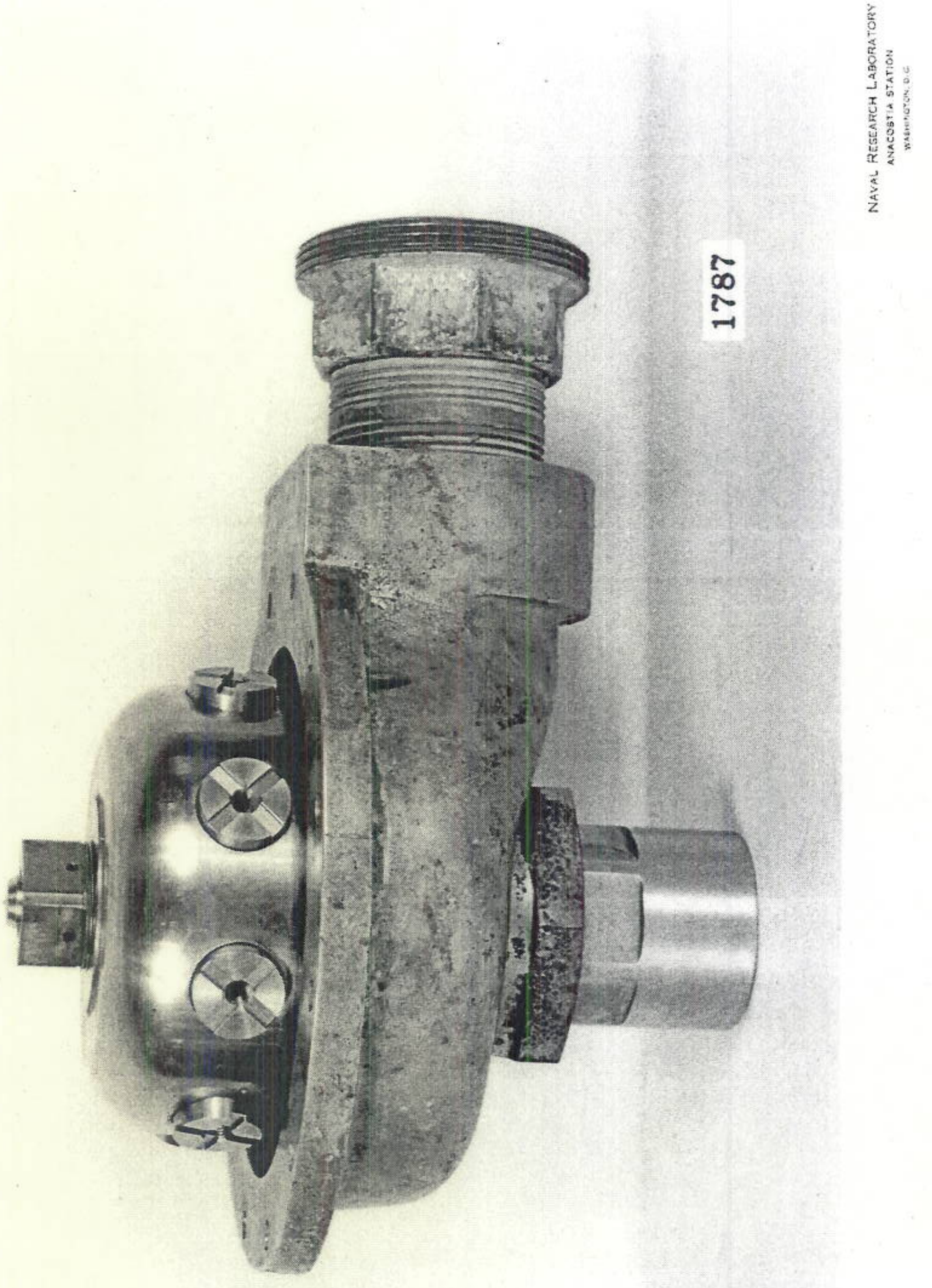
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Plate 7

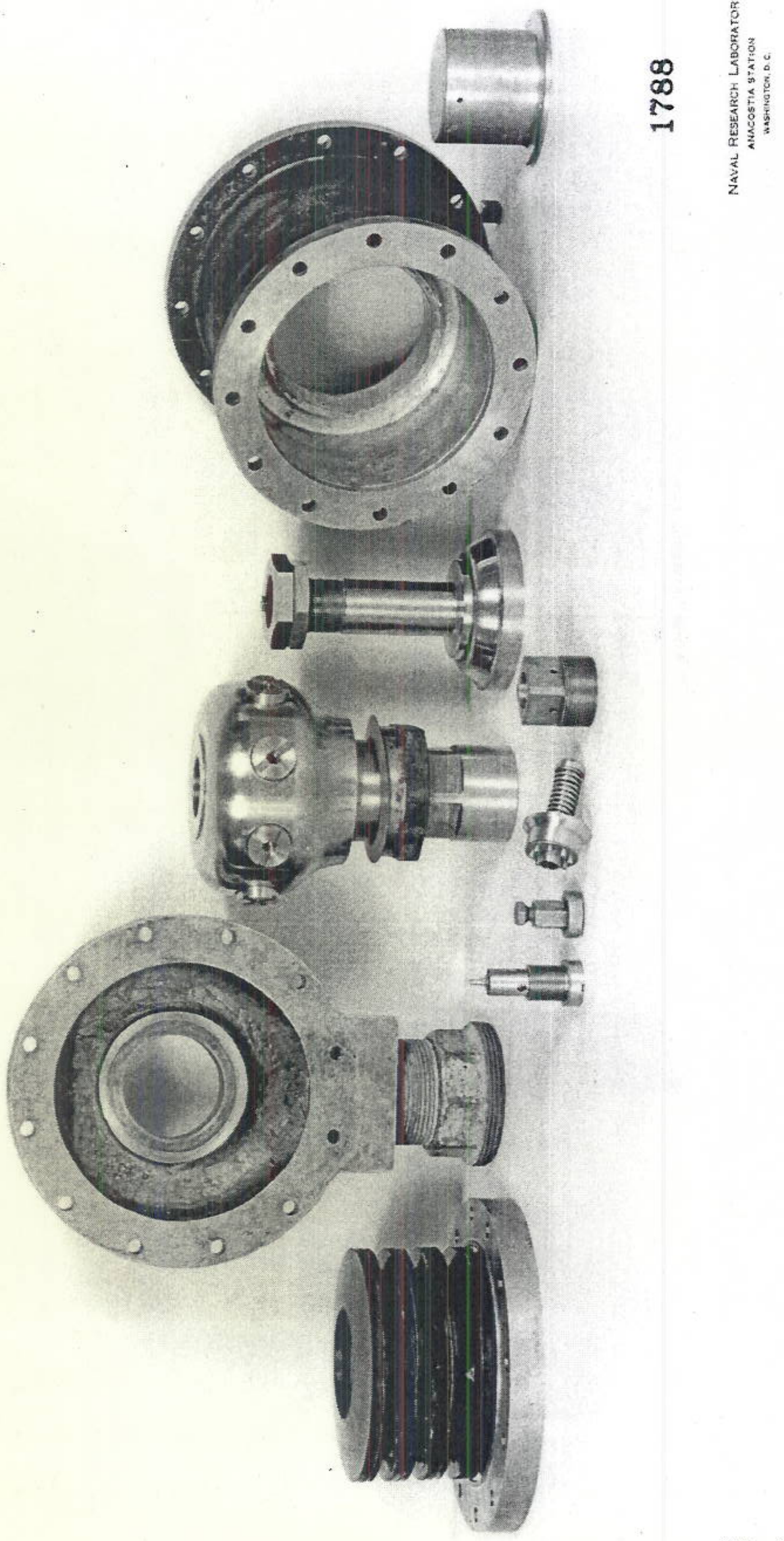

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Plate 8