Report CT-911
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Metallurgical Project

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TECHNOLOGICAL RESEARCH - P-9 PILE TTUDIES SECTION

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SLURRY PUMPS

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September 3, 1943

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SUMMARY

Pump requirements for the proposed slurry piles are discussed and a general consideration is given to all types of pumps. The volute centrifugal is recommended for this service as being the most easily adaptable and the longest wearing. Present designs and their characteristics are outlined. The problems to be met in meeting the requirements of the proposed application are reviewed with suggested solutions. Axial-flow pumps are also treated as a desirable possibility.

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I THE PROBLEM AND ITS REQUIREMENTS

The problem discussed in this report concerns the means of circulating slurries in the proposed slurry piles. There is a double aspect to this discussion because the proposed heterogeneous and homogeneous piles have different requirements. In a heterogeneous pile, the slurries will probably be dense, approaching the maximum percentage of solids that can form a stable slurry. Since cooling by flashing a portion of the slurry is proposed, a high head pump is required to return the cool liquid to the pile. The homogeneous slurry pile, on the other hand, will probably utilize a low density slurry, and present proposed liquid-liquid cooling methods permit the use of low head pumps. Both piles will require large capacity pumps.

Range of Conditions

Heterogeneous Pile		Homogeneous Pile
100 - 500 feet	Heads	30 - 100 feet
8000 - 12,000 g.p.m.	Capacities	1000 - 8000 g.p.m.
2.0 - 4.0	Densities	1.25 - 1.40

General Requirements

There are four features in common to the two problems.

1.) Minimum Hold-up: The requirement of minimum hold-up is clear from the nature of the process and the high cost of the circulated fluid. Every attempt should be made to decrease the free volume of a given pump.

2.) No Maintenance: From the nature of the process, it is evident that induced radiation in all parts exposed to active slurry will make servicing of the pumps practically impossible.

3.) Negligible Leakage: Since even small losses of fluid will be costly, leakage cannot be allowed. In practice, some leakage will always result from long service with no maintenance. It is imperative that this be kept at a minimum, which is several orders of magnitude less than any leakage heretofore considered.

4.) No Organic Lubricants: Organic lubricants prove to be unstable in a field of intense radiation. The use of an inorganic substitute or a non-lubricated bearing will be mandatory, unless some scheme can be developed whereby the lubricant is continuously replaced.

Specific Requirements:-

High density slurries will be more difficult to handle than low density material. Centrifugal pumps will not handle slurries which have more than 20% by volume of solids. The conditions of abrasion will be more severe in the upper density ranges; the pump efficiency much lower; and pump life considerably shortened. The proposed high density slurries are beyond the range normally handled by pumps; consequently, the characteristics and service to be expected will require more prolonged testing.

From the viewpoint of hold-up, leakage and wear, low head requirements are more favorable. An increase of head is provided for, by increasing either the speed or the diameter of the impeller or both. Increased speed results in increased wear. Increased impeller diameter requires greater free volume in the pump. The tendency for the pump to leak will increase with pressure. In addition the parts of the pump become more massive to provide increased structural strength for the greater pressures and stresses encountered.

With these points in mind, the fact that lower densities and heads are more easily and satisfactorily accommodated, and that a difference exists between the two problems, the following discussion will include a general outline of the different types of pumps, and a more detailed discussion of the characteristics and problems to be dealt with in centrifugal pumps, the type that should prove most adaptable to either problem.

II SLURRY PUMPS IN GENERAL

The problem of slurry handling is not a new one to the pump industry. Dredging operations, sand handling, transfer of paint pigments and paper stock, and the delivery of muds under pressure in drilling operations are among the most common problems.

Almost all types of pumps are used in this service: direct acting reciprocators for high pressure delivery, rotary pumps for viscous fluids where abrasion is not a prime factor and centrifugal pumps for high and low capacity, usually at low heads.

This investigation has been confined for the most part to centrifugal pumps for the following reasons:-

1.) Reciprocating pumps are essentially slow moving, low capacity pumps. To handle the capacities required would demand pumps that are far larger than any now built for slurry work. Such a design would be massive, cumbersome and expensive, and have a large hold-up. This type of pumps is capable, however, of delivering high pressures, handling thick slurries and operating at high temperatures.

2.) The rotary type pump is also a direct acting model, depending for high pressure performance upon its close clearances. Fluids abrasive in character cannot be handled well without constant maintenance. Large capacities, in the thousands of G.P.M., are handled only at low heads, there being a definite total pressure load which can be withstood by the shaft without undue leakage.

3.) The centrifugal pump has been adapted to slurry pumping service for large capacities and at heads up to three hundred feet. It is used extensively in dredging work, paper pulp circulation and similar services.

III CENTRIFUGAL PUMPS

The centrifugal class of pumps may be divided generally into four types:-

1. Centrifugal
    a.) Volute
    b.) Diffuser
2. Turbine or peripheral
3. Mixed flow
4. Axial flow

The centrifugal type of pump is so called because it produces its head by the centrifugal action of the impellers. Only the volute type is used in slurry service, since the diffuser type is not as rugged. Volute pumps employ a volute casing for converting velocity head into pressure head. Diffuser pumps use stationary vanes outside the impeller to perform the same function.

The peripheral type produces its lift by centrifugal action but recirculates the liquid between its vanes giving it a higher lift for the same speed and diameter of impeller. This recirculating action leads to increased wear and would make this type unsuitable for slurry service.

The axial flow or propeller type of pump produces its effect by the lift of its vanes, similar to the action of a ship's propeller. The mixed flow type produces its action partly by lift and partly by centrifugal force. Neither type has been specifically adapted to slurry handling but such an adaptation should require only minor alterations.

Centrifugal pumps are used in service requiring high capacity because of their simplicity, low cost and ability to operate under a wide variety of conditions. The efficiency in large sizes compares favorably with other types of pumps. Heads up to three hundred feet can be attained in a single stage. Multi-staging for higher pressures can be resorted to in most cases, but this design has never been found practicalbe in slurry service. The industry recommends that higher heads be attained by connecting several pumps in series, the limitation lying in the total pressure which the casing and stuffing box of the highest pressure pump would be able to stand.

Centrifugal pumps cannot handle liquids which are too thick or viscous to flow to the pump suction. The Worthington Pump and Machinery Company found that slurries higher than 20% by volume of solids cannot be handled by centrifugals.

To maintain suction, centrifugal pumps of the volute type must be kept primed or a gravity feed (positive head on suction) must be provided. Since the liquid to be handled may be close to boiling temperature, the latter course must be followed in order to prevent cavitation effects in the pump.

IV AVAILABLE CENTRIFUGAL PUMPS FOR SLURRIES

The pump industry was canvassed by letter and telephone in order to determine what designs were available to handle the problem at hand. A list of companies contacted is given in the appendix, together with a brief description of a few of the more adaptable types.

The volute type of centrifugal is the only type specifically recommended by the industry. It is being used at all heads up to 200 feet in the desired capacity range (1000 to 12,000 g.p.m.) Heads of three hundred feet are considered possible by some concerns.

The following discussion will present the various problems incident to handling slurries met by the pump industry and how they are best handled. Emphasis will be placed upon the recommendations of the Amsco-Nagle Pump Company, the Worthington Pump & Machinery Co, and the Morris Machine Works, as their pumps are considered most adaptable and their experience in slurry work extensive. For more general information on centrifugal pumps, their structure and characteristics the reader is referred to Mark's Mechanical Engineers' Handbook, Fourth Edition, page 1893 ff., 1941, published by McGraw-Hill Book Company, Inc. Reference may be made to figure 1 for construction and nomenclature.

a.) Erosion and abrasion:- Wear due to erosion and abrasion may be minimized by proper design, materials of construction and various mechanical contrivances added merely for this purpose. Erosion effects are chiefly due to cavitation and eddy currents. Abrasion is defined as the action of solid particles upon the pump parts.

Cavitation results when pressure head is converted to velocity head to such an extent that the vapor pressure of the liquid exceeds the static pressure, thus causing vaporization. Bubbles passing into higher pressure regions then collapse suddenly causing a water hammer which results in excessive wear of the metal surfaces. Cavitation is prevented in a properly designed pump by reducing the fluid velocity to within proper limits and by providing gradually curving impeller surfaces to prevent sudden velocity changes.

Eddy current effects appear at the periphery of the impeller and in the spaces between the shroud ring and the shield plate. These are caused by dead spaces within the casing and by the viscous shear between the rotating and stationary surfaces. Eddies may be reduced by properly curving surfaces particularly at the impeller tips and along the outside of the impeller.

The pressure difference between the discharge and the suction of the pump causes a reverse flow, known as slippage, to take place along the outside of the impeller. This reduces the efficiency of the pump and may be minimized by providing a path of high pressure drop against this flow. Such a path is provided by closely fitting surfaces and by 90° bends, the latter frequently taking on the configuration of a labyrinth. The use of sharp bends such as is shown in figure II violates the principle of gradually curving surfaces and so is apt to wear more quickly. Their use is to be avoided in slurry pumps. A wearing ring such as shown in figure I is preferred. Wear that takes place on this wearing ring is probably one of the most serious causes of a pump's failure to deliver rated capacity and head.

The proper choice of materials is also important. For slurry work, where particles are not abrasive, ordinary iron or any other pump material will suffice. Manganese steel has been found particularly useful in abrasive service and is used by Amsco-Nagle in their dredge and sand pumps because of its hardness and toughness. Worthington recommends the use of Worthite, a stainless, high nickel chromium steel containing manganese and molybdenum, for service where not only abrasion but also corrosion effects occur. A typical use of this material is in pumps handling brine slurries. Morris Machine Works recommends the use of a hardening or a surfacing treatment of the wearing parts, claiming that ordinary steel so treated may even be superior to manganese steel in wearing qualities.

Some slurry pumps are lined with rubber or plastic materials which are resistant to abrasive particles. Such devices are not practical in the proposed work because of their organic nature.

A method of preventing abrasive particles, lodging outside the impeller from abrading the surfaces with which they come in contact, is to sweep them out by injecting a stream of clear fluid (water) into all such spaces. Provided it is under a head high enough to cause flow towards the discharge, this stream sweeps away the particles. This device is used principally on rubber lined pumps. Perry Nagle of the Amsco-Nagle Pump Co. doubts the need of this in metal pumps such as manganese steel. The abrasive wear is not significant in comparison to the erosion effects.

b.) <u>Leakage</u>:- The only leakage occurs through the stuffing box, which encloses the shaft where it pierces the casing. The most common type of stuffing box employs a packing, which is pressed tight against the shaft reducing liquid flow outwards from the casing. Such stuffing boxes never prevent leakage entirely if the impeller end is under pressure, but rather reduce it to a minimum. A small flow is usually provided to lubricate and cool the packing. Slurry pumps require the injection of fluid into the stuffing box to prevent the lodgment of particles in the packing where they would contribute to shaft wear. Insoluble grease under pressure is also used but is not applicable in the proposed process due to its organic nature. The injected fluid (water) is used also to lubricate the packing and amounts, in medium capacity pumps, to about 20 drops per minute.

Leakage increases with wear on the packing and pressure drop from end to end of the stuffing box. This may be reduced by decreasing the pressure at the impeller end. This is commonly done by perforating the dead impeller shroud with a pressure relief port, so that the end of the stuffing box is at suction pressure, as long as the port is large enough to remove all slippage through the rear wearing ring on the back of the impeller. If the suction pressure is lower than atmospheric, no leakage can occur. An increased slippage due to wear will gradually increase the pressure at this point, however, if the capacity of the ports is exceeded.

Other types of stuffing boxes are the packingless variety, operating on the principle of rotary seals, and made up of impeller vanes, small rotary propellers and the like. The running characteristics of these seals is believed to be superior to the common stuffing box, although they tend to leak quite badly on shutdown. Further investigation of this possibility is being carried out.

c.) Lubrication and Bearings:- The best designs of pumps at the present time employ grease lubricants in a sealed bearing stand. Organic lubricants are barred from use in the proposed process, however. Other devices used are water lubrication with Bakelite, tar graphite or leather composition bearings, leading to the same difficulty. One possibility is the use of graphite bronze bearings, either of the composite or the inlaid type. These may be operated with or without water lubrication and cooling, depending upon the loads, Their use is restricted to radial bearings.

The thrust bearing is important in taking up the thrust forces of the pump and maintaining the proper alignment and clearances in the pump. This bearing is ordinarily placed directly behind the radial bearing in the bearing stand, grease lubricated and adjustable for wear. It is unlikely that graphite-bronze bearings would be applicable in this position. Pumps have been made with their thrust bearings placed behind the driver.

An extended shaft may be utilized in order to allow the thrust bearing and motor to be placed some distance from the pump. Mr. Nagle, of the Amsco-Nagle Pump Co., feels that such a design is feasible. Some of his designs use shafting up to fifteen feet in length.

V. ABILITY TO MEET REQUIREMENTS

a.) The heads and capacities required for the proposed processes may be met with existing designs. The possibility of heads above 300 feet will call for two or more pumps set in series.

b.) Hold-up:- Hold-up is a new consideration in the pump industry. The problem of reducing the free volume in a pump has never been handled before except under the guise of reducing the space requirements for the pump. In order to understand this problem, it will be necessary to discuss capacities, heads and the specific speed of a pump. The latter is a classification of pumps, empirical limits of which have been found useful in the design of pumps to avoid cavitation effects.

For a given capacity pump, the head is proportional to the diameter and the square of the impeller speed. The required capacity of the pump will govern the width or diameter of the inlet eye and discharge nozzle and hence the size. With the width being fixed by the nozzle size, a decrease in free volume of the pump can only be effected by a decrease in impeller and casing diameter. For a given head, a decrease in diameter calls for an increase in speed of the pump. A lower limit may be reached in the diameter of the pump impeller, because of inlet size and minimum vane lengths.

The Hydraulic Institute, an organization made up of pump manufacturers, has defined the specific speed of a pump as the speed with which a geometrically similar pump must operate in order to deliver one gallon per minute against a one foot head. Mathematically this may be defined as:-

$$S = \frac{\sqrt{\text{capacity}} \times (\text{r.p.m.})}{(\text{head})^{3/4}}$$

Capacity is expressed in g.p.m.; head in feet.

The Institute has set empirical limits to the maximum specific speed of various types of pumps, these limits being governed by the suction pressure and speeds at which cavitation has been found to result. For a single, side suction pump (the type used by all slurry pump manufacturers) this limit lies below 4000. Slurry pumps usually have values well below this figure, and the specific speed limit will vary with different designs.

The hold-up in present designs of centrifugal slurry pumps has been estimated to be 100 gallons for an 8000 G.P.M., 160 foot head pump. Lower free volumes should result with lower required capacities and heads. The above figures are for the Amsco-Nagle

Type S pump. Calculations, using the allowable specific speed for single suction pumps under varying capacities and heads, show that the free volume in commercial designs of water pumps is within 20% of the minimum allowable for single suction designs. Slurry pumps must be designed upon a slightly more generous basis.

The Nagle, "Type S", pump seems to be the best one of its type for slurry service demanding long life and minimum hold-up. Smaller required capacities will allow the use of a smaller pump. In P. Nagle's opinion, a lower head would only result in lower speeds, as the blade length now lies close to a minimum for proper hydraulic action, resistance to wear and ability to fabricate in this design. The impeller diameter is 39 1/2". The suction eye (governed by the capacity of the pump) is 16". The hub diameter does not permit the blade to begin at less than 10" on the radius. The blade length is, therefore, only 10" measured radially, and a reduction below this size would be inadvisable and, at best, insignificant in terms of hold-up. Smaller capacity pumpswill permit smaller suction eye diameters and a smaller vane length, so that a 1000 g.p.m. pump may use only a 16" wheel, and have about a 10 gallon hold-up.

Other types of pumps may require less free volume, but are not as satisfactory in slurry work. The axial flow type is considered in a later section.

c.) <u>Stuffing boxes:</u>- The packing type of stuffing box is objectionable from the point of view that it requires a water seal, loses efficiency through wear, and will never completely seal against a leak, as long as the liquid side of the stuffing box is higher in pressure than the atmospheric side. The following alterations of the present types have been suggested:

1. The stuffing box may be backed up on the atmospheric side with a gas pressure chamber balanced against the pile pressure by a direct pipe connection. This will reduce the pressure drop across the stuffing box to a very small value if not entirely eliminate it. (See figure II)

2. A direct pipe connection can be made between the liquid end of the stuffing box and the suction eye of the impeller, in order to keep the stuffing box at suction pressure. L. Ohlinger feels that this will be desirable as the pipe connection can be made large enough to handle all slippage to the rear of the impeller.

3. Sealing water, applied to the stuffing box, is allowed to flow outwards through the packing in order to provide lubrication and cooling. This flow may be collected in an air tight casing and drip pan, the liquid being returned to the system. A sling ring attached to the shaft would prevent loss by capillary action.

4. For a vertical position of the pump, the packing can be eliminated in the gas pressure balanced stuffing box, if the shaft is extended out through a loose sleeve and the pump placed at such a level that the liquid level at the stuffing box extends only a few inches into the sleeve. Such a seal would not require sealing water. (See figure II).

The rotary type seals may be preferealle to those listed above, and an investigation into their adaptibility is being undertaken.

d.) Erosion and slippage:- With no maintenance allowed on the pumps, it is expected that the life of centrifugal pumps may be 4 to 6 months, before the efficiency drops to an uneconomical level, or the pump becomes inoperable. The life of the pump will depend a great deal upon the speed, and pressure of operation and upon the size and abrasiveness of the particles. Lowered speeds and pressures and reduced particle size may be expected to extend the pump life.

e.) Bearings and lubrication:- For the radial pump bearings, it is likely that the graphite-bronze type will be applicable. The thrust bearing, requiring lubrication and adjustment, must be placed outside the shield. Correct design of an extended shaft should permit the placement of pump bearing and motor in such a position, although the problem of alignment will be a ticklish one if temperature variations are encountered.

VI AXIAL-FLOW PUMPS

The axial-flow pump is essentially a large capacity, low head centrifugal. It operates by the lift of its propellor pushing the liquid along the pipe line without a change of direction in the pump itself. Figure 3 is an illustration of this type of pump, together with alterations that may make it more adaptable to the proposed process.

Axial flow pumps have a narrow range of high efficiency at rated capacity. Decreased delivery increases the head to such an extent that the driver is frequently overloaded. Propellor pumps cannot be regulated by throttling, and so may be used only in constant capacity work.

The larger capacity pumps (thousands of g.p.m.) are capable of producing as much as 40 feet of head in a single stage, this maximum falling off with smaller sizes of pumps - below 14".

Axial flow pumps are not normally used for slurry work. They have been known to operate without appreciably accelerated erosion when handling sands in suspension. These pumps are not as long wearing as the pure centrifugal, since they employ an open type of impeller, i.e., they have shroud rings to protect the blades from the erosive action of slippage. Since the efficiency depends upon the close clearances between the casing the the impeller, wear at the blade tips decreases efficiency which in turn accelerates wear. The increased speed of the axial pump also contributes to its probably shorter life. The wearing rate of an axial-flow pump in slurry service would need to be obtained by test before its adaptability can be determined.

The chief factor in favor of axial-flow pumps is their decreased free-volume or hold-up. Axial-flow pumps can operate at a higher specific speed than pure centrifugals (about 9000). This means that the impeller diameter may be reduced to the size of the pipe-line carrying the liquid to be pumped. For an 8000 g.p.m. capacity, it is estimated that a hold-up of 20 to 25 gallons will be required in the pump casing itself. If the suction elbow is included in the calculation, the required liquid volume equals that required by centrifugals - 100 gallons. An axial-flow pump may, however, be included in the header of a heat exchanger. It may, furthermore, require less pipe line to fit it into the system, and with the present configurations considered in the external system of the homogeneous pile, it promises to simplify and reduce the hold-up of the entire system. These considerations may not be true of smaller capacity units, as the maximum head delivered per stage on smaller models is considerably below 40 ft. A two-stage, 1000 g.p.m. pump would be required to produce the same head.

VII CONCLUSIONS AND RECOMMENDATIONS

1.) The centrifugal pump is the preferred type for slurries on the basis of its known characteristics. It is more adaptable to slurry service, to a range of heads from 20 to 300 feet, in moderate capacities 1000-2000 g.p.m.

2.) The axial-flow type of pump promises a greater simplicity of pile design and probably lower hold-up in the system. This type of pump must be severely tested before acceptance.

3.) There are several problems that may require considerable development, namely stuffing-boxes (with emphasis on a rotary type seal), bearings and shafting with particular reference to maintenance of shaft and pump alignment. Testing of the adapability of graphite-bronze bearings is necessary.

4.) Hold-up in the pure centrifugal pump probably cannot be safely reduced from present values. Increased speed is likely to lead to harmful cavitation, and certainly to increased wear. Axial-flow pumps appear to be the only resort as regards decreasing hold-up.

VIII PRESENT STATUS

A general survey of the pump industry has been completed. There are further problems to be solved and more definite information to be received. It is not considered wise, however, to again approach the industry until definite conditions of pressure, differential head, temperature, slurry consistency and capacity have been decided upon. A loss of good will might be the unfortunate result, and maximum cooperation is required for a satisfactory solution of this problem.

Once definite specifications can be made, it is considered the best procedure to obtain test models of the various designs, putting them through exhaustive tests to determine their expected life and performance on the actual fluid to be pumped. This much needed information can be gained in no other way.

APPENDIX I

Pump Manufacturers:-

The pump companies which have been contacted with regard to the problem of high head, high density, large capacity slurry pumps are tabulated below:-

Aldrich Pump Co.
Allis Chalmers Mfg. Co.
Amsco-Nagle Pump Co.
Aurora Pump Co.
Beach-Russ Co.
Buffalo Pumps, Inc.
Dayton-Dowd Co.
Dean Bros. Pumps, Inc.
Denver Equipment Co.
Duriron Co., Inc.
Economy Pumps, Inc.
Fairbanks-Morse & Co.
Foster Pumps Works, Inc.
Frederick Steel & Iron Co.
Gardner-Denver Co.
Goulds Pumps, Inc.
Ingersoll-Rand Co.
Kingsford Foundry & Mach. Works
La Bour, Inc.
Lawrence Machine & Pump Corp.
McGowan Pump Div., Leyman Mfg. Corp.
Morris Machine Works
Nash Engineering Co.
Pomona Pump Co.
Quimby Pump Co., Inc.
Claude B. Schneible Co.
Smith Corp., A.O.
TaberPump Co.
Wilfley & Sons, Inc.
Worthington Pump & Machinery Corp.

The following pumps bear consideration in connection with the present problems:-

Amsco-Nagle Industrial Pumps:-Makers solely of slurry pumps, sizes ranging up to 12,000 g.p.m. and 200 ft. head, both horizontal and vertical types. Recommend enclosed impellers, side suction, single stage types. The construction is simple, and apparently hydraulically sound, consisting of shield, plate and impeller as only wearing parts, all made of manganese steel. This is probably one of the better slurry pumps built.

Buffalo Pumps:- Makers of slurry pumps of paper stock type as well as propeller type pumps. Rubber lining recommended for abrasives. Standard designs range up to 900 g.p.m. and 280 ft. head.

Denver Equipment Co.:- Makers of low head sand pumps, vertical and horizontal types, rubber lined. Gravity flow feed in the vertical type.

Gardner-Denver Pumps:- Vertical and horizontal pumps, capable of handling 56% by weight coal in suspension. The construction is good although likely to require servicing due to its use of square wearing rings. Pumps up to 300 ft. head and 3500-4000 g.p.m. are made. Use horizontal split casings.

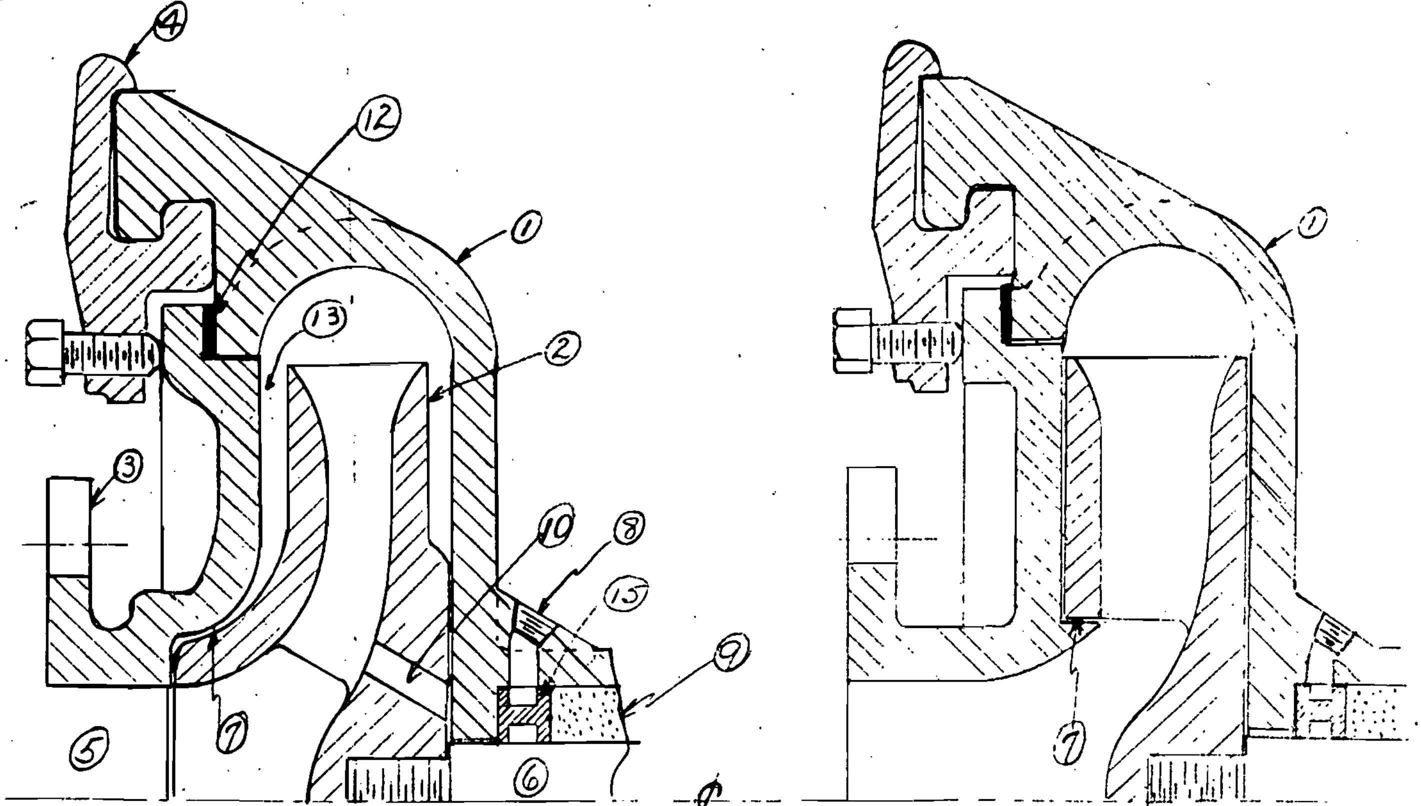
Kingsford Foundry & Mach. Works:- Makers of large size pumps for all services. Paper stock pumps in thousands of g.p.m. up to 300 ft. head included in standard designs. Employ enclosed impeller with double wearing ring at periphery of impeller and at suction eye.

Lawrence Machine & Pump Corp.:- Makers of slurry pumps in standard sizes in hundreds of g.p.m. up to 200 ft. head. Can build larger sizes for higher heads. The simple, side-suction impeller, the casing and the plate are the only wearing parts.

Claude B. Schneible Pumps:- Employs a unique flat plate impeller to minimize wear for difficult pumping slurries, at the sacrifice of efficienty. Maximum standard size is 500 g.p.m. at 100 ft. head.

Wilfley & Sons, Inc.:- Specialists in slurry pumps without a stuffing box. Standard makes up to 1500 g.p.m. and 175 foot heads.

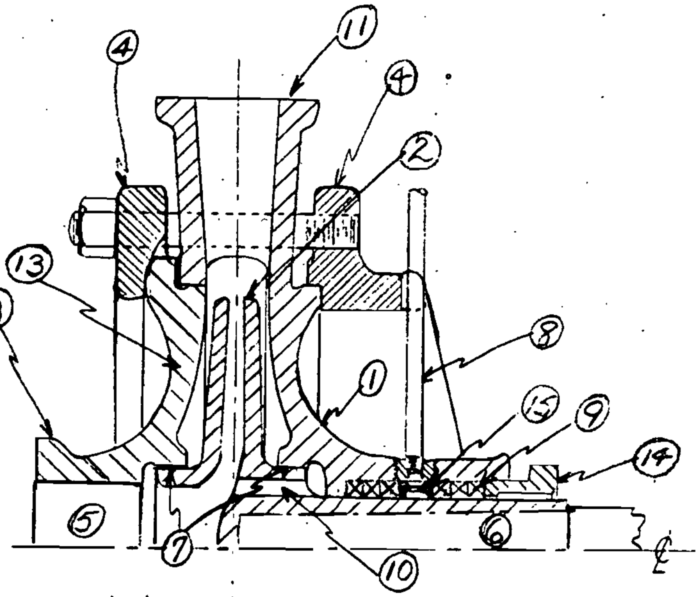
Worthington Pump:- Make slurry pumps in sizes up to 12,000 g.p.m. and 300 ft. heads. Specialize in "Worthite" capable of handling crystallized hot salt solutions. Construction simple, side suction, enclosed impeller, straight horizontal wearing ring of good esign.



Class S Assembly
I

Class D Assembly
II

AMSCO - NAGLE



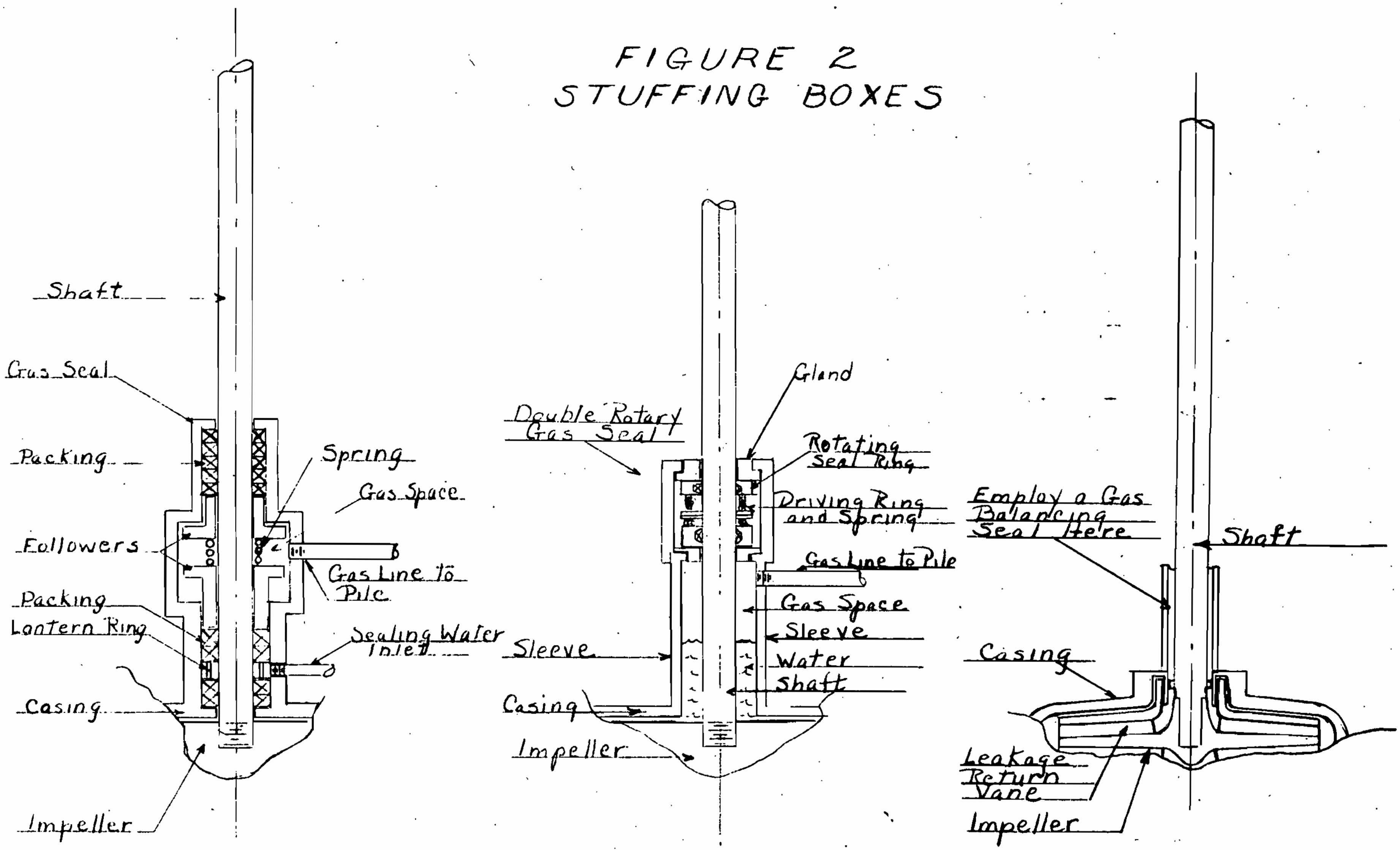
Worthington Pump
III

1. Casing
2. Impeller (Shroud)
3. Plate (Suction Flange
4. Dogs
5. Suction
6. Drive Shaft
7. Wearing Ring
8. Sealing Water Inlet
9. Packing
10. Pressure Relief Port
11. Exit Nozzle
12. Shims
13. Shield Plate
14. Follower
15. Lantern Ring

Figure 1
Pump Assembly

Dwg. No - LZ A - 65

FIGURE 2
STUFFING BOXES



Conventional Packed Stuffing Box Modified for Gas Pressure Balancing

Arrangement for Balanced Pressure Using Loose Sleeve and Showing Rotary Seal.

Wilfley Type Packingless Pump Showing Centrifugal Seal. Gas Pressure Balancing must be added.

LZD-86

John J. Goett 8/28/43.

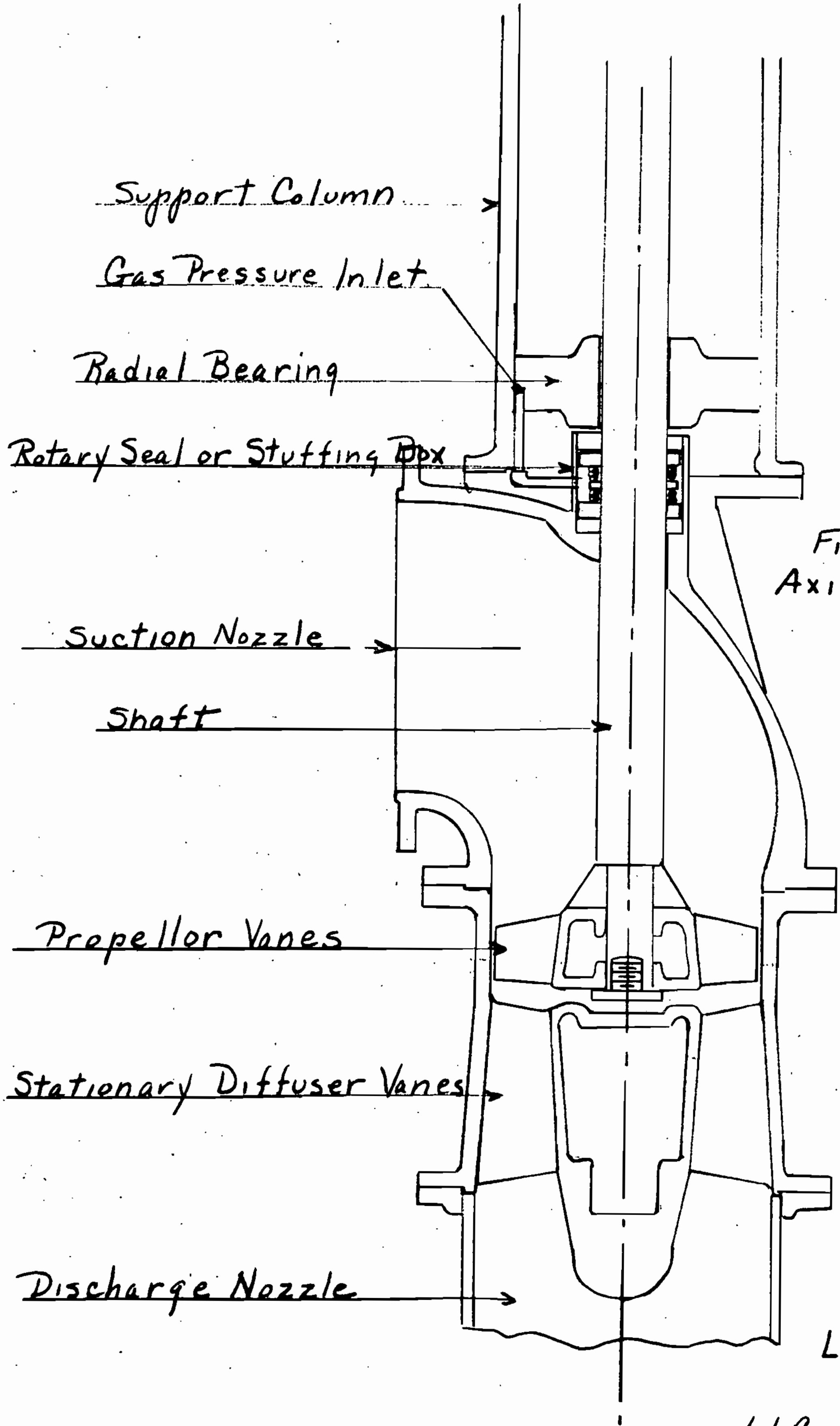


Figure 3
Axial Flow Pump.

LZD - 85

J. J. Goett - 8/25/43