Clinton Engineer Works

Oil Diffusion Vacuum Pump
Setup, Operation & Maintenance

OIL DIFFUSION VACUUM PUMP

20 INCH and 8 INCH

for

CLINTON ENGINEER WORKS

G.O. C.O. 23711-P - S.O. 23-P-367
G.O. C.O. 23154-P - S.O. 22-P-857

INSTALLATION-OPERATION-MAINTENANCE

Constructed in 1944

Instruction Book 5669-168

August 1944

Westinghouse Electric & Manufacturing Company

East Pittsburgh, Pennsylvania

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Bibliography

Procedures in Experimental Physics by Strong
Published By Prentice Hall

Westinghouse Research Laboratory Report No. R-94236-E for a
High Speed Oil Diffusion Pump written
by Dr. F. W. Stallman.

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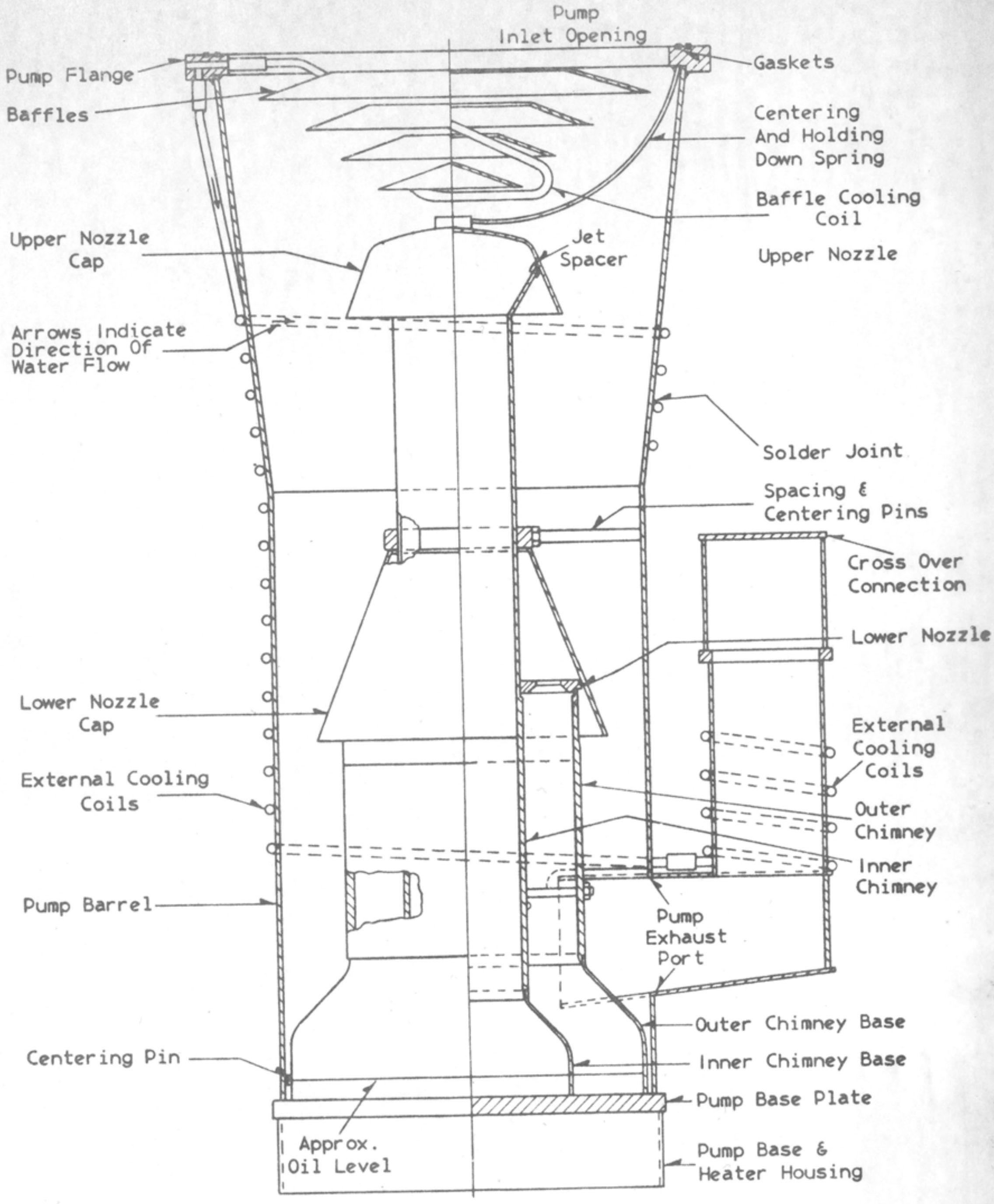
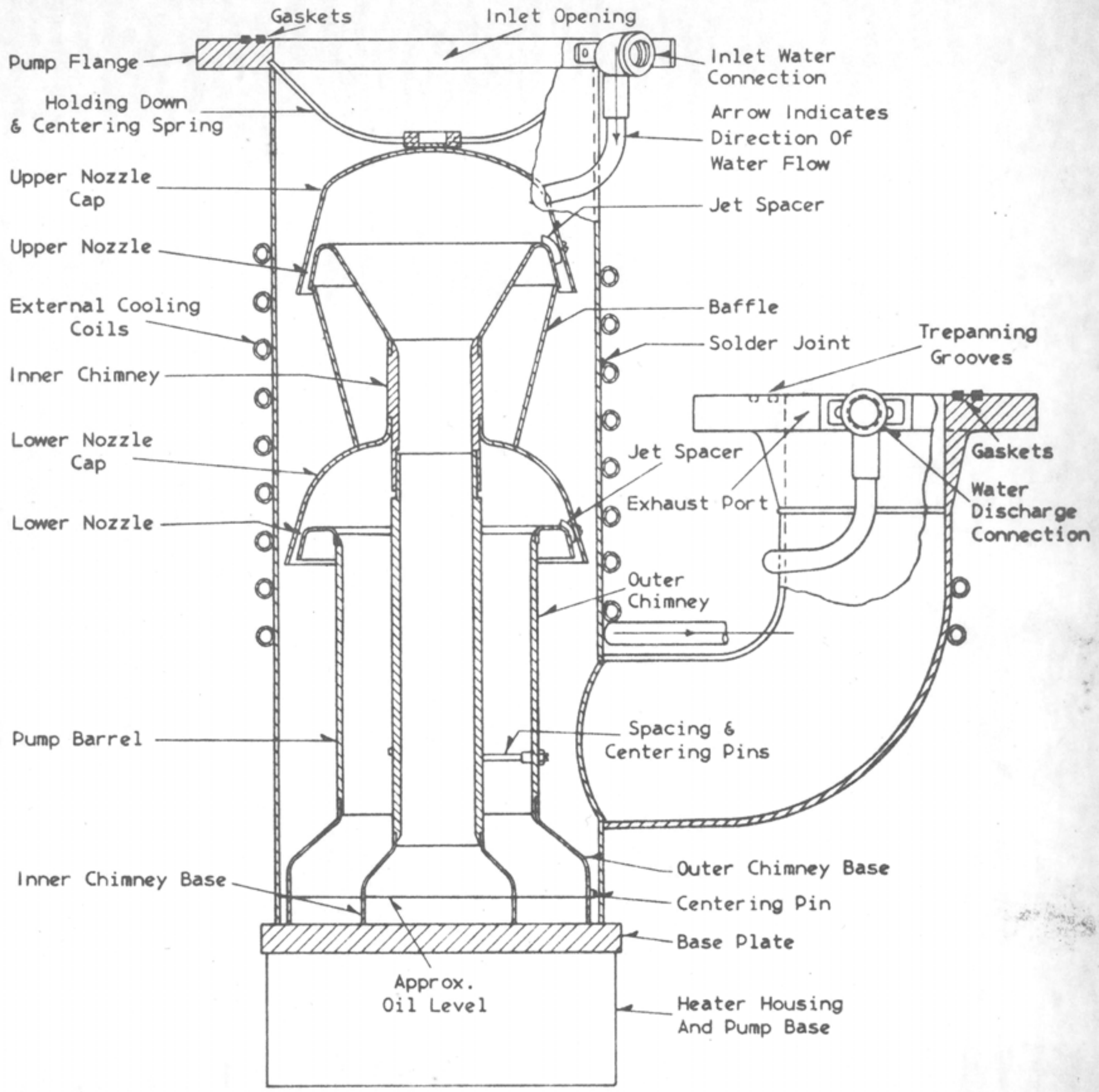


Cross-section of a 20-Inch Oil Diffusion Pump

R-1063

Optical Coating Facilities



Cross-section of an 8-Inch Oil Diffusion Pump

R-1062

OIL DIFFUSION PUMPS

PURPOSE

The purpose of this instruction book is to present the operating characteristics of oil diffusion pumps. The instructions given in this book will cover the installation, operation and maintenance of the diffusion pumps. An oil diffusion pump is new and relatively simple, however, its mode of operation is such that it is in a class by itself, beyond comparison to any rotating or centifugal type of pump. Included in the appendix of this book you will find a list of references for advanced reading on oil diffusion pumps.

When correspondence is sent to the company regarding the product that is covered by this instruction book, the complete nameplate reading should be referred to in the letter in order to give the correspondence the immediate attention which it demands. Also in case of field problems please be very careful to state the problems clearly and completely as well as stating the attendant conditions which prevailed when the trouble was encountered.

Vacuum systems are often times very difficult to get into operation and frequent sources of trouble are ones own impatience and carelessness. Good vacuum technique has as its basis patience and understanding. Another characteristic which can not be overlooked is thoroughness and cleanliness in methods of cleaning interior surfaces which are exposed to the vacuum. A clean surface for vacuum work must be free from oil, rust, water and dust. These impurities will prevent reaching the ultimate pressure without doing an excessive amount of pumping. By cleaning all the interior surfaces and keeping them protected during assembly it will be possible, if there are no leaks in the system, to reach the ultimate pressure within eight to ten hours.

The fundamental purpose of the oil diffusion pump is to produce a vacuum in the system. The pumps that are applied on this order will pump down to an ultimate pressure in a tight system of $5x10^{-6}$ mm. of Hg. The normal operating pressure of the pump is $1.5x10^{-5}$ mm. of mercury at the rated speed of 3500 liters/second.

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DESCRIPTION OF APPARATUS

An oil diffusion pump consists of a pump barrel which has a cylindrical section and a conical section welded together to form the external portion of the pump. The conical section is the throat of the pump as it is in this region that the low pressure, high speed pumping takes place. The throat is made conical for another reason and that is to provide sufficient space in the larger pumps to place a baffle with minimum decrease in the pumping speed. The baffle also is designed for the purpose of preventing migration of the pumping oil back into the system. The external portion of the pump has cooling coils soldered on to the pump barrel to provide the cooled surfaces inside the pump on which the oil vapors will condense. The baffle is also equipped with cooling coils in order to prevent as much oil migration as possible. The eight inch pump has cooling coils on the external surfaces only. The internal parts of the pumps, both eight inch and twenty inch are nearly the same except for their size. The boiler on the twenty inch pump is divided into two portions by two bell shaped spinnings. The pump chimneys are attached to the two spinnings in the boiler and the oil vapors are directed up the chimneys to the nozzles, then thru the nozzle opening out into the pump proper. The nozzles are arranged in series so that one nozzle, the upper one, can be referred to as a low pressure nozzle and the lower nozzle as the high pressure nozzle. The fore-pressure against which the pump will operate is determined by the lower stage nozzle.

The oil molecules travel in straight lines after emerging from the pump nozzles. Various types of jet design will give control of the vapor by directing it towards the condensing surfaces. After leaving the jet the oil molecules collide with air molecules and drive them out of the pump. It is by this molecular action that the pumping action is produced. It can also be said that the oil molecules while in their travel and impinging upon the air molecules give the air molecules a velocity which takes them down the pump and out the exhaust port. In this travel the oil vapor stream carries along such gas molecules as drift into the vapor stream and thus carry them from the space above the jet to that below the jet. After condensing on the surfaces the oil runs down into the outer boiler compartment and the process is then repeated.

The heat for the boilers comes from the 460 volt heaters which are clamped onto the base of the pump. There are seven nests of 66 volt heaters on the 20 inch pump which are all connected in series and then energized by a 460 volt supply. The heaters are equipped with shorting-out switches which can be opened or closed to lower or raise the heat respectively. When the units are shipped they are connected for normal operation with the shorting-out switch connected to the lead to short out one nest of heaters. If higher heat is required this one lead can be shifted in the conduit box to the other terminal for shorting out two nests of heaters. In regards to higher heating wattages for both pumps their connections are similar and the controls work in much the same manner.

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The oil diffusion pumps gain their speed of pumping action from the molecular collisions between the oil and air molecules. The pumping process can be described as driving the air molecules out of the pump when they drift into the vapor streams by the repeated molecular collisions. The ultimate vacuum pressure that one can expect from an oil diffusion pump is limited by the vapor pressure of the pumping medium itself. This limit can be lowered by a process fractionation. In this process the high pressure volatiles are boiled out of the pumping medium when it is in the first boiler compartment. The high pressure volatiles are then used in the lower nozzle of the pump which is in the high pressure pumping region of the pump. The oil which reaches the inner or second boiler compartment is relatively free from the higher pressure volatiles and its vapors can be used for the low pressure pumping in the region of the upper nozzle. It is these oil vapors which produce the lowest pressure or the ultimate pressure in the pump.

The pumping speed at which an oil diffusion pump operates is nearly constant thru out the pumping range of the oil diffusion pump. The pumping speed is affected somewhat by the wattage at which the pump is operated. As the wattage is increased the pumping speed will be decreased slightly. The reason for applying more wattage to the pump is to enable the pump to operate at higher leakage rates. For example, if a system has been in operation for some time and a leak occurs, rather than shut down, the additional heat can be applied and the pump will operate at somewhat higher pressures and of ten handle the increased amount of air which is leaking into the pump.

The occasion may arise when it will be necessary to check the oil in the pumps. This can be accomplished rather easily by using the oil drain and fill plug which is located in the base plate of each pump. It would be advisable in making this check to shut the pump down and allow it to cool before opening up the drain and fill plug. The depth of the oil in the twenty inch pump should be one inch and this requires approximately five quarts of oil. The eight inch pump is filled to the same depth and it requires about 7/8 of one quart.

The cooling water for the pumping unit should flow through the cooling coils on the baffle first, then thru cooling coils on the pump barrel and the cooling coils on the cross-over connection, then thru the cooling coils on the barrel of the eight inch pump and then to the discharge connection. This flow is indicated on the pump drawings by arrows and also by indicating the inlet and outlet connections. The water flow can be reversed if necessary, but the best method is to cool the baffle with the cold water and then cool the rest of the system.

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BOUGHT OUTSIDE APPARATUS

The following items are purchased complete from suppliers other than Westinghouse. These items include heaters, thermal releys and the vacuum oil. The following will give the proper identification for the various items for replacement.

1. Heaters - Bought Outside from - Edwin L. Wiegand Co. - Pittsburgh, Pa.
   20 Inch Pump
   Similar to A-20 - 66 volts - 230 watts - 7 per pump
   Similar to A-50 - 66 volts - 360 watts - 7 per pump
   Ball & Socket Beads - #W4574 - .35 I.D. from - American Lava Corp. Chattanooga, Tenn.
   8 Inch Pump
   Similar to RA-82 - 217 volts - 780 watts - 1 per pump
   Similar to RA-50 - 159 volts - 565 watts - 1 per pump
   Similar to RA-20-3 - 42.5 volts - 305 watts - 1 per pump
   Ball & Socket Beads - .25I.D. No. SL-1408-12 from - Stupakoff Ceramics & Mfg. Co.
2. Mercoid Riser therm - Bought Outside from - Mercoid Corp. Chicago, Illinois.
   Fig #35 - Clamp-On type - Hand Reset
3. Litton Oil - Bought Outside from - Litton Engrg. Laboratories, Redwood City, Calif. as Molecular Lubricant - Litton "C".

SAFETY FOR PERSONNEL

The installation and operation of equipment of this nature requires that certain precautionary measures be taken to prevent any mishaps or serious accidents to the operating personnel. The following list will offer a few suggestions.

1. Do not touch the portion of the pump which is painted gray, when the pump is in operation as this is in the heater area and the temperature is high enough to produce serious burns.

2. Care must be exercised in handling liquid air traps due to the fact they are made of glass in some applications and secondly liquid air can produce serious burns if it comes into contact with the body for any length of time.

3. Avoid the fumes of hot oil if cleaning a pump when it is comparatively warm. The fumes are not harmful but they have a very objectionable odor which may be nauseating.

4. Allow the pump to cool down before any openings are made into the pump. This will help keep the oil in good operating condition.

5. Be sure the heaters are open circuited before attempting to replace any of the heating elements.

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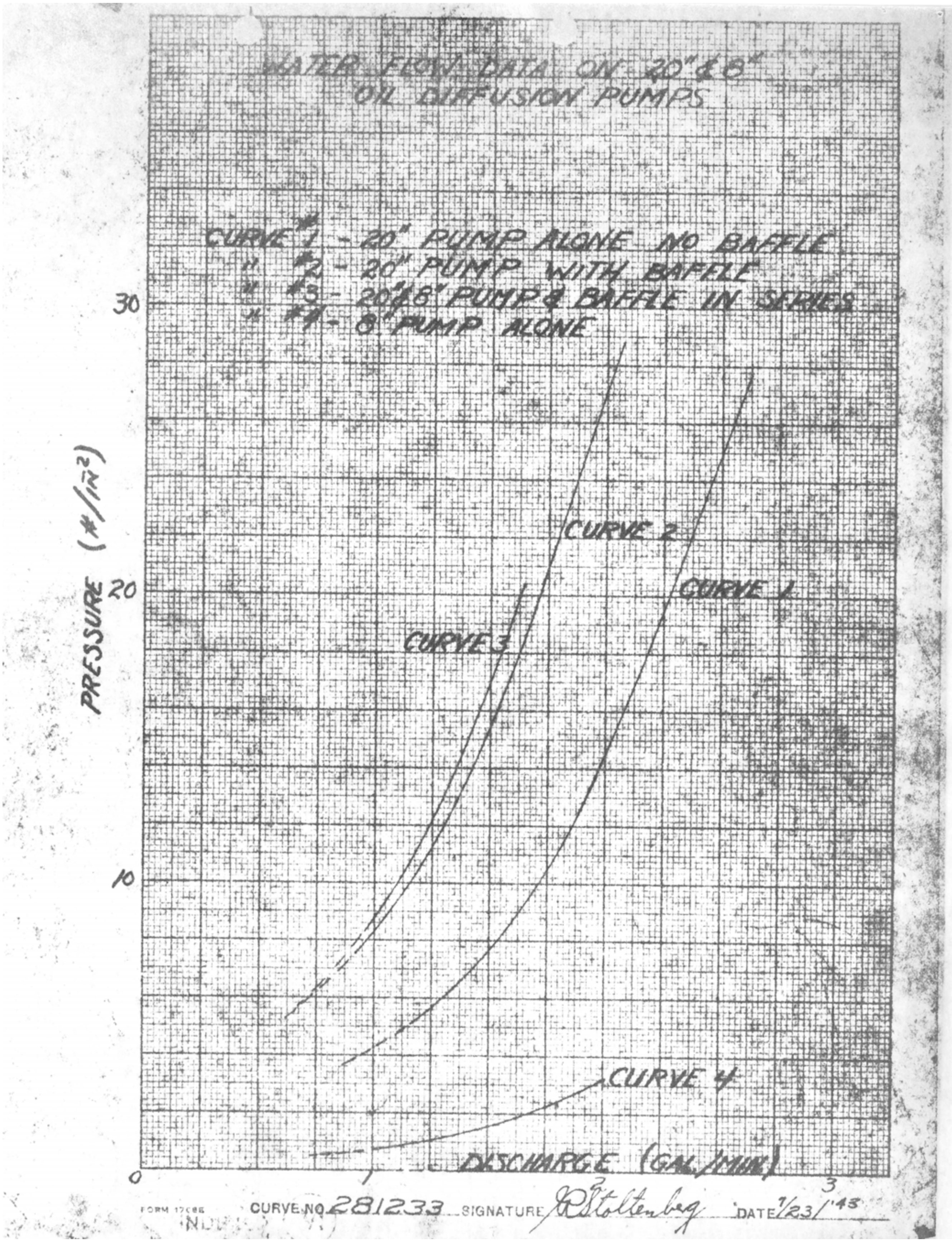
WATER FLOW DATA ON 20" & 8"
OIL DIFFUSION PUMPS
CURVE #1 - 20" PUMP ALONE NO BAFFLE
" #2 - 20" PUMP WITH BAFFLE
" #3 - 20" & 8" PUMP & BAFFLE IN SERIES
" #4 - 8" PUMP ALONE
CURVE 2
CURVE 1
CURVE 3
CURVE 4
PRESSURE (#/in²)
30
20
10
0
1
2
3
DISCHARGE (GAL/MIN)
CURVE NO. 281233
SIGNATURE
DATE 1/23/'43

INSTALLATION

Storage

The interior parts of the pumps are sprayed with Litton oil before shipment in order to prevent any rust from forming on the sand or shot blasted parts. The openings, the inlet to the twenty inch pump and the exhaust part of the eight inch pump, are closed off by blanking flanges to exclude dirt and other foreign matter. These flanges are not vacuum tight. The storage room should be dry. The pumps should be stored in a vertical position when possible and right side up to avoid oil seeping out of the flanges. If the pumps are being stacked several layers high, a crane will be required as the pumps are too heavy to lift by hand.

Handling & Unpacking

When the pumps are finally prepared for shipment they are wrapped in paper and then crated in a wood crate. This protects the walls and cooling coils of the pumpfrom bumps that they might receive while in transit. When the pump is being unpacked care should be taken not to use any long bars as they might puncture the 3/16 thick wall of the pump. Once the crating has been removed the pump should be picked up by the lifting lugs by a crane. The lifting lugs have been located to keep the pump in a near vertical position when picking up the two pump unit and also when picking up the twenty inch pump alone.

In lowering the pump to the floor care should be taken to lower it in a vertical position so that the small eight inch pump doesn't bear all the load.

After the pump has been uncrated and the flanges removed the interior parts should be inspected for rust which may have formed while the pumps were in storage or in transit. Any rust can be removed by any of the following methods.

1. Sand Blasting
2. Shot Blasting
3. Wire Brushing
4. Hand Sandpaper

After the surfaces have been cleaned it may be advisable to clean them with carbon tetrachloride or benzol. This will remove any dirt or oil which may have accumulated. It would be a recommendable practice to keep the pumps covered after they have been cleaned and before they are attached to the system in order to keep out the dust and dirt which is common around a new building under construction.

Installation

During the installation it is <u>very</u> important that all of the interior parts of the vacuum system be kept as clean and free from dirt as possible. This may be difficult and involve considerable

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inconvenience but it will pay large dividends in the end. Check all parts of the vacuum system for rust and dirt which may have accumulated and remove as previously described.

The thermal relay has been adjusted at the plant and it has been checked for operation. It has been set to trip out at 45°C with temperature rising. This relay is a lockout device and it is necessary to manually reset it once it has opened the operating circuit of the contactor. The relay is reset by removing the cover and prying back on a spring lever which has a small button welded on the flat side of the short spring and the mercury capsule will tip up so the mercury covers the contact points, if the temperature has returned to normal.

The water connections should be made with cold water flowing into the baffle and then into the cooling coils on the outside of the pumps. The preferred method of connecting the pumps is with the cooling coils of the two pumps in series. However, if the water pressure is not adequate, the twenty inch and the eight inch pump cooling coils may be connected in parallel. This method of connection will require a flow control valve on the inlet at the water line to each pump. The gallons per minute flow should be such as to limit the temperature of the discharge water to 45°C for the best pump operation. The pressure-flow curve in the fore part of this book will give the pressure drop across the pump for operating conditions as given above.

Water Rates & Pressure

Recommended Values based on 30° water

Original Design

	GPM	PSI
20 Inch	2.3	35.0
8 Inch	.7	.5
20 Inch & 8 Inch in Series	3.0	65.0

The rubber gaskets should be put in the grooves in the following manner. Place the gasket on the flange of the pump and then with the thumb press the gasket into the trepanning groove at intervals of perhaps every inch and a half. This should be followed until the gasket has been put in place in the groove. This procedure will give uniformity in the amount of rubber which is placed around the gasket seal. The loops of the gasket can then be pressed into place in the groove.

Power Connections

The pumps on this order are equipped with single phase 460 volt heaters to be energized from a 460 volt single phase supply to each pump set. The information concerning the heater connections

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is given on the following drawings.

20 Inch Pump - 14-A-8117
8 Inch Pump - 9-B-7113
Schematic - 9-B-7070

These drawings also give the calculated values of the wattages for the various heats that are available for use on the pumps. The circuits are protected from overload by thermal drop out elements in the shorting-out switches and also by heater elements in the combination linestarter. The short circuit protection is gained by the "AB" breaker ahead of the linestarter in the combination linestarter box. The normal wattage for continuous heating is:

8 Inch	20 Inch
1650 W	4070 W

Testing

When a vacuum system is assembled it is advisable to run tightness tests on as many parts of the system as possible. The tightness test consists of pumping the system down to a low pressure and then isolate the space to be tested from pumping action by valves and record the pressure rise over an hour or longer. If the leakage rate is too high as per contract specifications then a leak is present in the parts involved. There are several methods that can be used to find leaks in vacuum vessels.

1. Soap Bubble Test
When it has been established that a vacuum vessel has a leak in it the pump should be shut off the system and the system filled with air under about ten pounds of pressure or a value that is safe for the vessel being tested. Then with a soap solution and a small brush the welds and the suspected surfaces can be checked by painting with the soap solution. Only a small amount of weld, four inches of length, or several square inches of area should be covered at one time. If larger amounts are taken the test isn't nearly as effective as it is too difficult to watch. In case the leak is very small it may be necessary to watch the soap covered areas thru a magnifying glass. After a vessel has been checked by this method most of the leaks should have been uncovered. Testing technique will improve very much after this test has been tried several times and several leaks have been located.

2. Acetone Test
If the pressure will not come down to the ultimate pressure the vessel can be checked by the following method. Take a bottle of acetone and by using a small brush coat the suspected areas with the acetone. At the same time keep an eye on the ionization gauge pressure indicating meter. When the leak is filled with acetone

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the molecules will enter the vacuum vessel and cause the ionization gauge to produce a large deflection. When the large deflection occurs on the meter the leaking area has been located. The reason for the temporary rise in the pressure is that the size of the acetone molecule is much smaller than the air molecule and they will penetrate thru small leaks and cause the pressure to rise. The ion gauge should be watched very carefully in order to detect any small leaks which may be in the system. This test is very sensitive when used on small vacuum vessels and when used on larger vessels it requires very close watching of the pressure indicating meter.

3. Freon Gas Test

Another way of looking for leaks is to fill the vessel with freon gas and then by going over the surface of the vessel with a gas flame a leak can be detected by a greenish discoloration in the flame of the gas jet. This type of test is very useful if it is permissable to use a gas in the vacuum system.

4. Immersion Test

This test is mentioned only for checking the vacuum tightness of small vessels which can be immersed in a tank of water. In this type of test the vessel to be tested is out under five to ten pounds or a safe value of air pressure and then immersed in a water tank. Any air bubble which is formed and continues to form indicates a leak in the vacuum vessel. This is a very positive type of test if the leak is large enough to form visible bubbles in a reasonable length of time and the size of water tank is the only limit to the size of vessel which can be tested in this manner.

5. Gasket Test

The gaskets on the pumps on this order are double gaskets and they are provided with testing connections which will indicate whether the gaskets are tight. These seal tests can be made by attaching a pump connection to the test adapter and pumping out the space between the gaskets. The pressure rise can then be determined and also the condition of the seal will be indicated. If the space between the gaskets is pumped down to a few microns and then if pressure in the vessel decreases the leak is across the inner gasket. Also if the inner gasket is leaking it can be detected simply by attaching a McLeod gauge to the test connection. The pressure will decrease to a point where it can be read on the McLeod gauge which means that the vacuum pumps on the system are drawing air into the chamber across a faulty seal in the gaskets.

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OPERATION & MAINTENANCE

Starting Up

In starting the pumping unit it is first necessary to start the mechanical pump. As soon as the mechanical pump is started the valve in its water line should be opened a sufficient amount to permit a flow of water thru the cooling jackets of approximately one half or one gallon per minute. The cooling coils on the diffusion pumps should be filled and the water flow set for about three gallon of normal operation.

After the mechanical pumping system has been started it will be approximately a half hour before a vacuum pressure can be read on the McLeod Gauges. When the pumping unit has been in operation for a period of one hour the pressure should be approximately five microns. The pressure readings that are taken during this period indicate vacuum tightness and cleanliness conditions. If the pressure goes down to five to twenty microns and remains steady it is an indication that the vacuum system has moisture in it. The only way to remove water vapor from a vacuum system of this type is to continue pumping until the water vapor has been pumped out. In some cases it may be that the vacuum system contains rust which has absorbed moisture and will not permit pumping down to a good vacuum readily. In this case it will be necessary to clean the pump and start the pumping process once more.

When it is indicated that the vacuum system is tight and the cold leakage rate is satisfactory the heaters on the oil diffusion pumps should be energized. In some cases this may happen after a very brief pumping period, usually about forty five minutes. In about three hours of operation of the oil diffusion pump the pressure should be approximately $5x10^{-5}$ mm. of mercury. This is also a test on the system and if this pressure can be reached, another three hours of pumping should produce the ultimate pressure of $5x10^{-6}$ mm. of mercury. If the cold leakage rate of the system is unsatisfactory the system should be checked. Moisture will be the worst offender in attempting to get a good vacuum. If excessive moisture gets into an oil diffusion pump it will be very difficult to obtain any pumping action until the water that is present is exhausted.

The following table indicates the approximate conditions which may be expected from the pumping unit when operated on its three heats.

Wattage Table

20 Inch Pump	8 Inch Pump - 20 Inch Head Pressure No Leak Microns	8 Inch Exhaust Fore Pressure
4000 W	1640 W - 0.005	100
4900 W	1820 W - 0.004	125
5800 W	1940 W - 0.002	140

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When the pump is handling its maximum volume of air the needle of the ion gauge will fluctuate over the scale indicating that the pump has reached its maximum operating condition. This condition could be altered or helped by increasing the heat which is applied to the pump.

Shutting Down

In shutting the unit down, close the twenty inch valve first. This shuts the pumping unit off from the system. Then open the electrical circuit to the heaters. The cooling water should be left flowing thru the cooling coils on the oil diffusion pumps and also thru the mechanical pump. The mechanical pump should be left in operation in order to keep a vacuum on the pump side of the twenty inch valve to prevent the gasket from being dislodged from its groove. In case the system is being opened to atmosphere with the atmospheric pressure on the manifold side the gasket will be held in place by the flange groove itself. Another reason for leaving the mechanical pump in operation is to reduce the conditioning period when the unit is put back into service.

The oil in the mechanical pump reservoir should be inspected frequently and kept up to the proper oil level. In some cases, changing this oil helped the operation of the mechanical pump. This condition may be averted by decreasing the amount of cooling water flowing thru the mechanical pump and thereby increase its operating temperature. This will only be effective when the amount of water going through the pump is keeping the mechanical pump too cold.

The following list will give the items which may require maintenance and repair thru out the life of the pump.

a. Pumping oil

b. Heaters and heater connections

c. Gaskets

d. Cleaning or flushing water cooling coils.

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