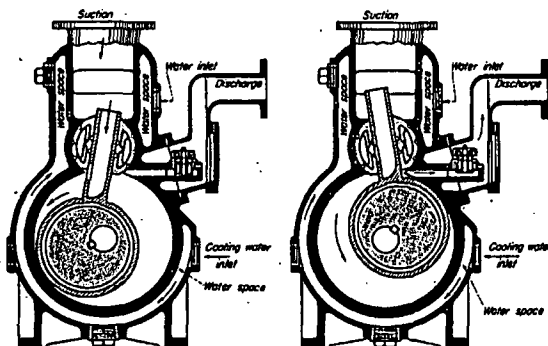
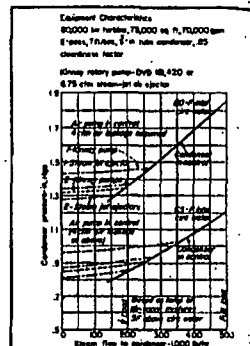
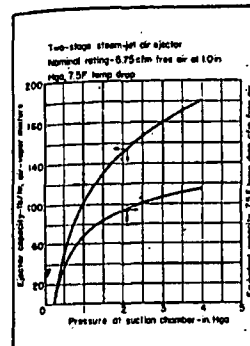




1 Rotary pump has eccentric rotor that creates space for gas entering suction at top while compressing previous charge to discharge pressure and forcing it out



2 At low condenser-steam flows the air pump capacity determines the vacuum



3 Typical 2-stage steam-jet air ejector performance at various suction conditions

Rotary or Steam-Jet Air Pumps?

► DURING THE PAST YEAR several large surface condensers have been installed with rotary-type vacuum pumps instead of steam-jet air ejectors. The decision on the proper vacuum pump is best made after comparing the merits of the two types. Here we report certain items to consider in preparing such a survey, and discuss the calculation of air-pump capacity.

For a number of years, ever since it supplanted reciprocating and hydraulic-type vacuum pumps, the steam-jet air ejector has been standard equipment for surface condensers.

Compared with a mechanical rotary pump the steam-jet air ejector has the following advantages: (1) lower first cost (2) no moving parts (3) greater air-removal capacity. Several factors, however, favor the rotary air pump and become increasingly important with the trend to higher operating pressures and temperatures. These are: (1) Ammonia contamination, believed to be introduced by returning air-ejector drains to the system, is a problem in some plants. (2) Steam jets normally operate at reduced pressure and sometimes excessive maintenance of reducing devices is encountered.

The rotary pump performs both the operations of normal air removal and of pumping down the unit when starting up. Large capacity "hogging jets" must supplement air ejectors to start

Here's a comparison of cost and operation of two types of surface-condenser air-removal equipment, made by W C Woodman, mechanical engineer, Stone & Webster Engineering Corp.

up large condensers in a reasonably short time. This duplication of jets, however, is not a serious operating disadvantage.

Rotary Pump. One type of rotary vacuum pump* is shown in Fig. 1. An eccentric rotor displaces air and vapor ahead of it, drawing these gases into a suction port and discharging through the outlet. No sliding vane or metal-to-metal contact exists between rotor and casing. A viscous fluid maintains the seal, tri-cresyl phosphate being employed for condenser-vacuum-pump service. The air-vapor mixture together with some of the sealing fluid discharges through a baffled tank in which the sealing fluid separates out and returns to the pump. In condenser-vacuum-pump service an additional whirl-type separating chamber completes the separation of air and moisture. This pump type has served for some years in evacuating electric light bulbs and in hydrogen-cooled generator-seal oil-conditioning systems.

*Rotary pump characteristics in this article are based on the type DV-10-151-152 rotary vacuum pump, as made by the Kinney Mfg. Co.

During the war they served as "roughing pumps" in certain high-vacuum processes. These pumps can reduce pressures below 0.001 in. Hg abs, well beyond power-plant requirements.

The largest available size of this pump has been customarily applied to surface condensers. This unit has a pumping capacity of about 700 cfm at atmospheric pressure and about 550 cfm at 29 in. Hg vacuum. A 40-hp motor is usually provided with this size, although continuous operation needs at 29-in. Hg vacuum are generally less than 25 hp. Maximum power demand occurs at about 22 in. Hg vacuum.

COMPARISON OF AIR PUMPS

In selecting the proper type of air pump, the following factors require comparison and study:

First Cost. In an installation of any appreciable size and importance two rotary pumps should be used for reliability. Normally one pump in operation should be sufficient, with the second held in standby reserve.

Condenser manufacturers often list

such a twin-element 2-stage air ejector with each element having enough capacity to handle normal air leakage. But these twin elements are mounted on a single inter- and after-condenser. To insure continuous service and provide the same degree of reliability as with two rotary pumps, the specifications given the condenser manufacturer should require furnishing of two banks of inter- and after-condensers, each with its own 2-stage steam jet. These ejector units should be piped in parallel in the condensate line, and each should have capacity to handle maximum expected normal air leakage. It is also necessary to furnish a high-capacity auxiliary hogging jet for starting.

Here's the first cost comparison:

Two rotary vacuum pumps complete with motor drives, baseplates and individual separators, but with common whirl chamber, capacity of each equivalent to 4-cfm free air leakage at 1.0 in. Hg abs and 7.5-F temperature depression—\$11,500

Two single-element 2-stage steam-jet air ejectors, each with its own inter- and after-condenser, capacity of each, 101.25-lb air-vapor mixture, equivalent to 6.75-cfm free air leakage at 1.0 in. Hg abs and 7.5-F temperature depression and one hogging jet—\$6700

The reason for choosing a 6.75-cfm air ejector is explained later. Ejector prices are proportional to capacity and if a 4-cfm unit were selected, it would have a lower first cost. These air-ejector prices assume purchase as part of condenser since prices of auxiliaries are higher when bought separately.

Installation Costs. It is necessary to compare piping and electric-power

service costs. Piping installation is less extensive for the rotary pump, but cost of electric-power supply must be added. Installation of steam and mechanical types often cost about the same.

Capacity. One of the most important items to consider is the pump capacity to remove from the condenser an air-vapor mixture resulting from free air leakage into turbine and condenser. Capability of the two equipment types differs considerably. It depends on a variety of conditions, including vacuum, temperature of air-vapor mixture at air offtake, air-leakage rate and the volumetric pumping rate of the air-removal equipment.

Given two examples of air pumps and assuming one has a capacity just equal to inward rate of air leakage, this pump would maintain a vacuum equal to that which the condenser can produce. If the second unit had a smaller capability, the condenser vacuum would fall off until, under the increased absolute pressure, the specific volume of the air-vapor mixture would bring the pump capability at the decreased vacuum in equilibrium with the inward air-leakage rate.

Air-removal equipment must have the capacity to deal with the maximum expected air leakage at the vacuum the condenser must maintain. Capability under varying conditions will be discussed later.

Starting Capacity. Characteristics of the rotary vacuum pump, Fig. 3, enable it to remove large quantities of air when starting up and to pump down the turbine casing and condenser shell to a partial vacuum, as well as to operate under running conditions. Initial pump-down time can be shortened by running both rotary pumps in parallel during the starting-up period, and later shutting down one and allowing the remaining pump to handle normal continuous leakage.

Steam-jet air ejectors have insufficient capacity for initial pump-down and must be supplemented by an auxiliary high-capacity hogging jet. No great difference in pump-down time results from the two methods, and either type of apparatus should be able to reduce condenser pressure to 10-in. Hg abs within 15 minutes.

Ammonia Contamination. The plant designer must judge whether ammonia contamination is likely to be present. This has been a serious problem in some plants, attributable to contaminating the air-ejector condensate with ammonia and its return to the system. This sometimes occurs when makeup

water is taken from a river or other source contaminated with sewage, or it may be caused by circulating-water leakage in the condenser.

Ammonia vapor is least soluble under condenser pressure and temperature conditions, so that the air-vapor mixture withdrawn by the air pump contains some free ammonia vapor. A rotary pump will permanently remove this vapor by discharging it to the atmosphere. In a steam-jet air ejector the ammonia will recondense and redissolve in the air-ejector drains and return to the plant cycle. Some plants are now wasting air-ejector condensate rather than risk recontamination.

Maintenance. Present-day air-ejector installations usually require reducing steam to 200-300 psig at the jets. Maintenance on high-pressure reducing valves has been excessive and some have been unduly noisy. Recently there has been a tendency to omit the automatic pressure reducing valve and substitute a plain manually operated valve of the ported type. After adjusting the valve by means of a pressure gage on the downstream side the valve is locked in position.

Rotary pumps will necessarily, in time, involve some maintenance, even where contact of internal parts has been eliminated.

Operating Costs. Comparative figures, based on coal at \$7.50 per ton, 13,750 Btu per lb and 7000-hr-per-year operation, indicate nearly equal operating costs for the equipment sizes selected. Steam consumption of an air ejector is very nearly proportional to its nominal rating and if an ejector with a smaller air-handling capacity were selected the annual operating cost would be proportionally less.

Operating cost of a single 2-stage 6.75-cfm air ejector that is using 405-lb-per-hr of steam, with correction for the condensate heating effect in the air-ejector condenser—\$550 per yr

Operating cost of a rotary pump that is using 25 hp—\$500 per yr

Part-Load Operation. At low loads the air-removal equipment, rather than the condenser, controls the vacuum. Higher-capacity air pumps will produce a slight improvement in vacuum. If light-load performance is important, the improvement in economy will have some effect on the selection of air-removal apparatus.

Theoretically a demand charge should be assessed against the air ejector for the boiler-plant capacity required and against the rotary pump for the boiler and generating capacity.