CENTRIFUGAL PUMP DRIVES
FOR BOILER FEED SERVICE

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ABSTRACT

The boiler feed pump is one of the most important pieces of equipment in a steam power plant. The water capacity of a boiler is only great enough to supply steam to the prime mover for a period of a few minutes when operating at full load. This fact outlines the extreme importance of an uninterrupted water supply to the boiler. This is why, when selecting boiler feed pumps, its performance record, installation and operation must be considered prior to any commitment in order to insure this uninterrupted flow of water to the boiler. However, there is one more factor which is as important as the performance record of the boiler pump itself. It is the initial and operational cost of the boiler feed pump, which depends not only on proper sizing of the boiler feed pump, but also depends on the type of drive to be used. The purpose of this paper is to consider the alternative drive arrangements used and their effect on the operational cost.

INTRODUCTION

In most cases, present day steam plants are using centrifugal pumps for boiler feed service. Pumps used are either multi-stage or high speed units driven by electric motors or steam turbines. In the past, due to the low cost of energy, the majority of the small and medium size steam plants have practically eliminated steam turbine driven boiler feed pumps from the service. However, spiraling energy costs in recent years have forced many steam plant operators to reevaluate the steam plant requirements, operation, and selection of boiler feed pumps and drives in more energy conscious ways than has been the practice in the past. During the last few years, there is a noticeable trend away from electric motor drives back to steam turbines to be used for boiler feed service. The reason is obvious; lower operational cost.

CENTRIFUGAL PUMP AND SYSTEM HEAD

It is important to realize that a centrifugal pump will operate along its characteristic curve, as shown in Fig. 1. Also, it should be noted that the characteristic curve for any particular pump will remain the same for corresponding speed and impeller diameter. The point on the pump characteristic curve at which the pump will operate is determined by the system head curve (see Fig. 2), which illustrates graphically the requirements of the boiler system. The point of intersection of both these curves when plotted on the same graph is the operational point of the pump. This is shown in Fig. 3. When observing these curves, one may note that the pressure developed by a centrifugal pump at a constant speed is increasing with lower flow. At the same time, the system head curve is dropping with lower flow requirements. We have stated before that the point on the pump characteristic curve at which the pump will operate is determined by the system head curves, which in the case of boiler feed service can vary instantaneously due to the sudden change in boiler demand. This variation in system head curve can move the operational point of the pump from the maximum rating of the
CONVERSION FACTORS:

PSI = 7.03 x 10^2 lb/in^2

GPM = 2.27 x 10^4 ft^3/hr

H = Q CONSTANT SPEED = 5200 RPM
CONVERSION FACTORS:

PSI = 7.03 \times 10^6 \text{ kg/cm}^2

GPM = 2.27 \times 10^{-1} \text{ m}^3/\text{hr}

FIG. 2
CONVERSION FACTORS:

PSI = 7.03 x 10^2 kg/cm²
GPM = 2.27 x 10^1 m³/hr

FIG. 4
FIG. 5
pump to as low as 10-20 percent of design capacity, as shown in Fig. 4. The difference between the pressure developed by the pump and the pressure required to feed the boiler, as represented by the system head curve, is the energy lost. One of the acceptable ways to prevent this loss of energy is by operating the pump at variable speed. For all practical purposes, there is no less expensive or simpler way of doing this than to use steam turbine drive. When using this method of operation, the energy saved, expressed in terms of horsepower, is illustrated in Fig. 5.

STEAM TURBINE DRIVES

There is nothing new in using steam turbines to drive boiler feed pumps. The steam turbine has been used to drive centrifugal pumps and other rotating equipment in such key industries as electric utilities, refineries, pulp mills, etc. These turbines may range from a few horsepower to as much as 450,000 kW. The largest ones are used for generator drives in central power stations. The small turbines for auxiliary drives are usually a single stage, noncondensing type, occupying a large and important segment in power and marine installations. The simplicity, reliability and low maintenance cost of the turbine and its ability to supply both power and heat is one of the many justifications for industrial turbines and their use. A careful economic assessment, particularly in the range of small turbines as prime movers, can result in considerable savings over other types of drives. Unfortunately, many users have overlooked the advantages offered by the steam turbines when used as prime movers. Let us consider some of them.

1. When using steam turbines, rated pump speed can be chosen for maximum efficiency and optimum mechanical design, eliminating needs for gears or other speed control devices, since the pump and the turbine will operate at the same speeds.

2. The variable speed inherent in a steam turbine will coincide with the operating pump speed for maximum efficiency at part loads. This eliminates throttling losses and high losses in hydraulic coupling at partial loads.

3. Economics particularly favor steam turbine drive when exhaust steam can be used for heating or process work.

4. The cost of electricity against "recovered" steam, etc.

On one of our applications, our recent experience has shown that the cost per horsepower of 1000 hp range constant speed boiler feed pump driven by electric motor was almost the same as turbo pump, $109 against $105.

The operational cost comparison of constant speed and variable speed boiler feed pump illustrated in Fig. 6.

The cost of steam and electricity used in Fig. 6 was based on the following.

Cost of steam $/year = 2545 \times \frac{h_{PT}}{H_1 \times T \times F} \times \frac{Steam cost}{1000}

Where \( h_{PT} \) = turbine output horsepower in hp (= 0.746 kW)

\( H_1 \) = enthalpy of inlet steam in Btu/lb (= 0.556 kcal/kg)

\( F \) = mechanical loss factor

\( T \) = time of operation (hours per year)

Steam cost are in dollars per 1000 lb.

Cost of electricity $/year = 0.746 \times \frac{h_{PM}}{E} \times \frac{T}{T} \times \text{current cost.}

Where \( h_{PM} \) = motor rated output horsepower in hp (= 0.746 kW)

\( E \) = motor efficiency

\( T \) = time of operation (hours per year)

Current cost is assessed in dollars per hour.

CONCLUSION

From all the above examples related to boiler feed pump service, it should be obvious that the steam turbine drive should receive utmost consideration when acquiring new or replacement equipment.

REFERENCES


[2] Estimated cost of steam based on average cost of fuel (gas and oil) required to generate replacement steam used to drive steam turbine, 8760 operational hours per year.

[3] The steam conditions used in this example were as follows:

- Steam Inlet Pressure = 600 psig (42.2 kg/cm² g)
- Steam Temperature = 750 F (399 C)
- Exhaust Pressure = 60 psig (4.2 kg/cm² g)

[4] The cost of electricity, oil and gas is based on national average energy prices as of December, 1980 published by DOE monthly energy review.

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