SPECIFYING AND OPERATING STEAM EJECTORS IN STEEL DEGASSING APPLICATIONS

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Steam ejectors have been used successfully to remove entrained gasses from molten metal for nearly forty years. The removal of hydrogen, oxygen and nitrogen by this method produces ‘clean’ steals with superior properties and a higher level of reliability without the addition of ferroalloys.

Steam ejectors are well suited to this application for many of the same reasons they have been used in other industrial processes. Ejectors have a low capital cost relative to other types of high vacuum producing equipment. Since they have no moving parts maintenance requirements are very low. An ejector system can be expected to operate indefinitely without downtime.

System Configuration

The number of ejector stages required is generally determined by the final vacuum required. Typically this value varies from 0.1 mm Hg Abs. to 0.5 mm Hg Abs. A system optimally designed for 0.1 mm Hg Abs would almost always be a five-stage system with two intercondensers. A system optimally designed for 0.5 mm Hg Abs. would almost always be a four-stage system with two intercondensers. Somewhere between these two design pressures is a transition point between these two configurations. The exact location of this point depends on cooling water temperature, motive steam pressure and the cost of these utilities relative to capital cost.

Any safety factor added to a design should be applied to capacity, not to suction pressure. A decrease in design suction pressure may do very little to improve the performance of a vacuum system at the required design pressure but may add significantly to capital costs by adding another ejector stage.

The use of a hogging ejector with a vacuum degassing system, to reduce evacuation time on start-up, is common. It is used in parallel with the last stage or the last two stages to quickly evacuate the vacuum system and the vacuum vessel down to some intermediate pressure. The hogger is then turned off and isolated before the ejector stages ahead of it are turned on. This allows the last stage/stages of the vacuum system to be efficiently sized to handle the continuous noncondensable load from the process. Although the use of a hogger requires the purchase of an additional ejector as well as a steam valve, suction valve and a discharge silencer or tail leg, it can usually be justified by the shortened cycle time as well as lower steam usage per cycle.

Figure 1 shows a typical arrangement of a five-stage vacuum degassing system with the minimum recommended components for operation.

System Size

The major factor in determining ejector system size in this application is noncondensable gas loading. The gas load from molten steel is determined by the following:

A) HEAT SIZE; The amount of noncondensable gas removed from the steel at a given pressure is directly proportional to the amount of steel.

B) CARBON CONTENT IN STEEL; Published data(1) has shown that as the carbon content of unkilled steel in an open-hearth atmosphere decreases the oxygen content increases rapidly. The equilibrium data of reference 1 can be used to predict the oxygen content. Most of this oxygen is removed as carbon monoxide in accordance with the stoichiometry of the reaction:

$$C + \frac{1}{2} O_2 \rightarrow CO$$

C) DEGASSING TIME: The total amount of gasses to be removed divided by the time allotted for the cycle will give the mass flow rate that must be removed by the vacuum system on a continuous basis. In addition, the amount of air that must be removed to evacuate the vacuum vessel from initial pressure to the final vacuum required should be included in the noncondensable load.

Additional sources of ejector load are air leakage and gas evolved from the refractory lining of the ladle. This additional load is normally accounted for with the use of a safety factor applied to the process gas load. These safety factors (multipliers) vary from 1.5 to 3.0.

It is important to keep in mind that ejector manufacturers are not metals producing experts. It is unwise to rely on them to determine off gas loads. The best way to ensure proper sizing of the vacuum system is to provide the ejector vendor with actual operating data.

Overload capacity is also an important factor, which must be considered in ejector design. Occasionally the introduction of a flushing or stirring inert gas is used during degassing cycle. In addition, noncondensable gas removal rates are not linear with time. Instantaneous flow rates have shown to peak at pressure between 5 and 10 mm Hg Abs.(2). The last two ejector stages must be designed to handle these gas loads so that the system remains stable during degassing.

Utilities

Steam must be available to the ejectors at all times, at or slightly above the specified design pressure. The steam lines should be insulated and all the lines should be sized to match the connection sizes on the ejectors.

Steam should be dry and saturated. Even a fraction of a percent of moisture will adversely affect the performance of an ejector. High vacuum units are particularly sensitive to wet steam. It is normally recommended that a superheater be used at the steam inlet to the first stage ejector to raise the temperature 30 to 50 F above saturated.

The ejector diffusers of the first two stages of a five-stage system and the first stage of a four-stage system are furnished with a steam jacket to prevent freezing in the diffuser. These jackets must be provided with a continuous flow of low-pressure steam.

A continuous supply of cooling water must be provided at or below the design temperature, at the quantity specified, to each condenser whenever the ejectors ahead of the condenser are running.

The size of the first two or three ejector stages of most vacuum degassing systems makes it impossible for the ejector manufacturer to run performance tests on these stages prior to installation. It is therefore essential to deal with an ejector vendor with a proven track record in high vacuum degassing applications. One way to ensure that this is the case is to request installation lists and evidence of field tests for these installations.

References

(1) “The Making, Shaping, and Treating of Steel,” published by U.S. Steel Corporation, April 1957.

(2) Mund, A., “Methods of Degassing and Vacuum Treating Liquid Steel,” Journal of the Iron and Steel Institute, October 1962.