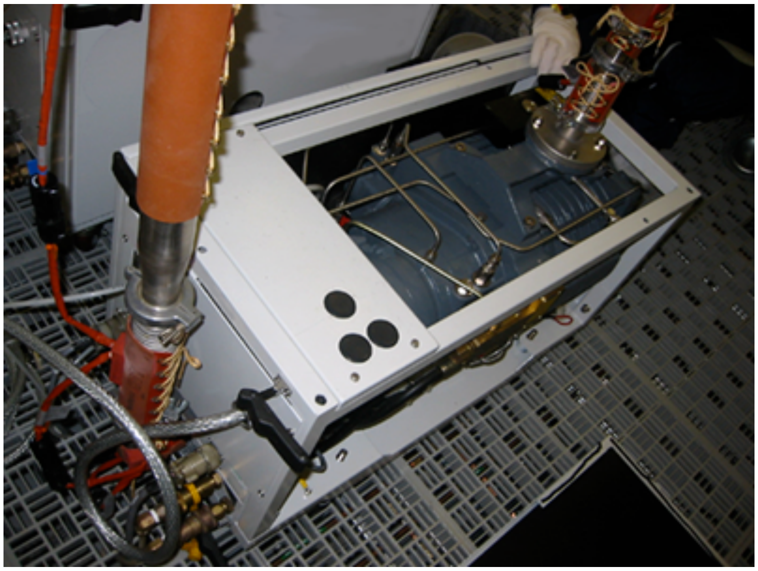
Process Systems

Vacuum Pump Optimization



Summary

The use of rotary vane vacuum pumps to support a number of different types of process equipment is widespread in industry. Semiconductor cleanroom facilities, laboratories, pharmaceutical, and biotech facilities rely heavily on the use of vacuum pumps. Vacuum pumps typically account for 5-10% of a semiconductor cleanroom facility's total electricity consumption. Recent advances in vacuum pump technology have improved the efficiency of vacuum pumps by 50 to 60%. Through integration with process controls, further savings are possible through implementation of an idle mode when vacuum is not needed by the process. Combining best practice technology and design, such as placing vacuum pumps close to the supported equipment, makes it possible to reduce vacuum pump energy use by 50 to 90%. Further benefits include less noise, smaller electrical infrastructure, and smaller central cooling equipment.

Principles

- Use of high efficiency dry vacuum pumps available on the market today can allow a 50 to 60% reduction in energy over conventional dry vacuum pumps, often through a direct plug-in replacement.

- First cost savings may be realized by reduced electrical and central plant equipment sizing required by high efficiency dry vacuum pumps.

- Turn down of vacuum pumps when the process does not require vacuum, referred to as idle mode, can save additional energy.

Approach

Vacuum pump design has dramatically improved over the last few years. A high efficiency vacuum pump should be considered during the design phase or when existing vacuum pumps have reached the end of their life. High efficiency dry vacuum pumps, which use up to 60% less energy than conventional dry vacuum pumps, are interchangeable with most traditional pumps and are readily available in today's market. In new construction, the use of high efficiency pumps throughout the project will not only reduce operating costs, but may yield first cost savings via downsizing of the central plant equipment and the electrical infrastructure. In a retrofit situation, the reduction on plant utilities may be able to forestall costly central plant expansion during minor buildouts.

Variable speed capability in stand-by mode is being integrated into the design of some high efficiency dry vacuum pumps. To implement idle mode operation, process equipment is being supplied with the ability to send an idle signal to the vacuum pump.

High efficiency vacuum pumps also offer lower noise and vibration. Vibration is reduced due to the lower average rotational speeds required of a high efficiency vacuum pump. Noise levels in high efficiency vacuum pumps have been reduced by up to 65% when compared to conventional vacuum pumps. Where low noise levels are required in the operator environment, the lower noise operation combined with a reduced footprint design can allow the vacuum pump to be located very close to the process, realizing additional energy savings.

Depending on the cleanroom layout, placing the pump closer to the process can require less piping. A minimal amount of piping both upstream and downstream of the pump results in a lower amount of work that the pump has to do since there is a lower amount of pressure drop through the pipe. In addition, the potential for leakage and, in some cases, the total evacuated volume is reduced.

A high efficiency vacuum pump produces less waste heat than a conventional vacuum pump due to the reduced power consumption, requiring a lower amount of air cooling or process cooling water (PCW). PCW removes the heat generated by a vacuum pump so that heat is not introduced into the surrounding environment while maintaining the pump within its operating temperature range. Whether air or PCW cooled, a reduction in waste heat reduces the total load on the central cooling system.

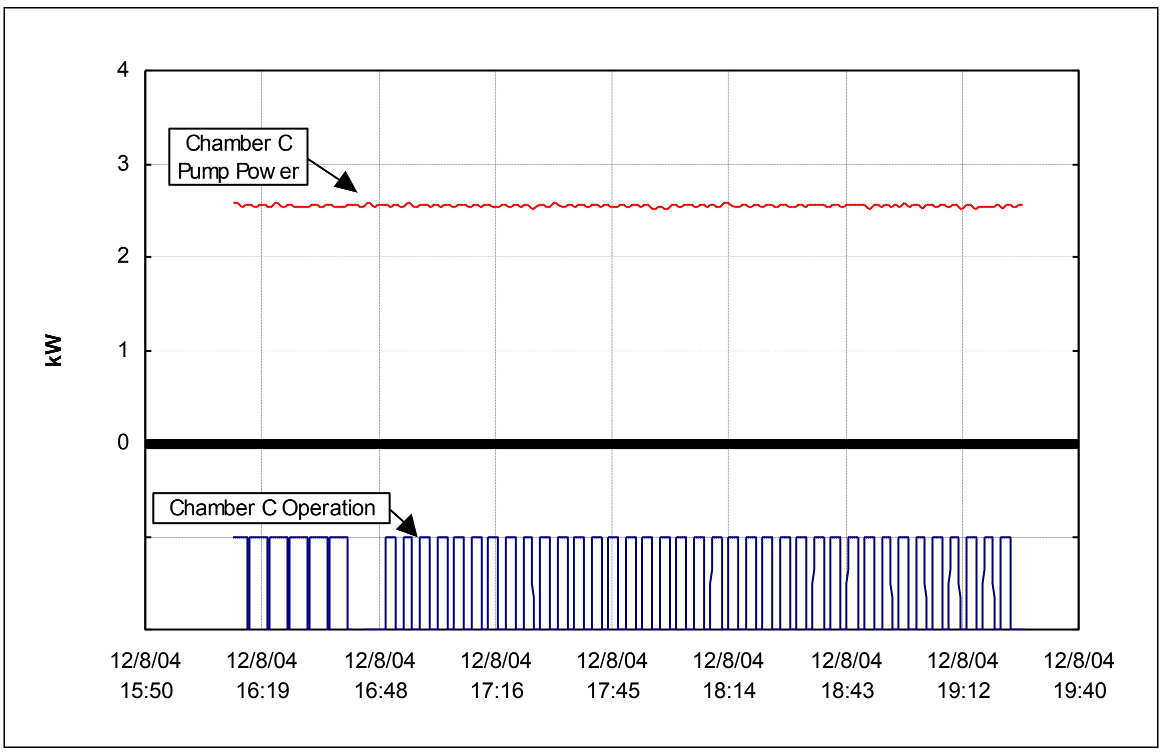
Research is currently in progress on process equipment idle mode vacuum setback. Turning the pump speed down when a particular portion of the process equipment is idle offers a large opportunity for energy savings. Developing this capability is a joint effort between process equipment and vacuum pump manufacturers. A robust communication link between the process equipment and vacuum pump is necessary so that the pump can respond instantaneously to the demand of the equipment, providing transparent operation.

Real World Experiences (Benchmarking Findings / Case Studies)

The LBNL Benchmarking study included power measurements of six dry vacuum pumps serving a semiconductor wafer etch process tool in operation. The vacuum pumps were the conventional dry type and were being used as chamber, load lock and transfer pumps.

The data collected showed that the chambers in the process equipment tool oscillated between being in use ("on") and not being in use ("off"). During this time, the six vacuum pumps continued to draw a constant amount of power. The particular chamber shown in the graph below (chamber C) oscillated between "on" and "off" approximately every two minutes. A high efficiency, variable-speed driven pump with idle mode capability would be well tailored to this application. During the times when the chamber is not in use, the vacuum pump would automatically adjust its speed down since a lowered amount of vacuum pressure is required. The pump speed would immediately increase speed when the tool called for vacuum to prepare a chamber. Process throughput would be unaffected.

Figure 1. Operation of Process Tool



The 300,000 square foot facility consisting of 100,000 sf of cleanroom space in this study had approximately 300 conventional vacuum pumps in use. An average consumption of 3 kW was measured per pump.

The current energy cost of the vacuum pumps is:

300 pumps X 3 kW = 900 kW

900 kW X 8,760 h/yr X 0.10 $/kWh = $788,000 per year

Potential savings of 50% = $394,000 per year

Essentially all power used is removed through the central cooling system as waste heat. A 50% reduction in vacuum pump power usage would free up over 125 tons of cooling capacity for additional operational savings, in excess of $100,000 in a baseline California semiconductor facility, or to support additional facility build-out.

Related Best Practices

Process Chillers	Variable Speed Chillers
Dual Temperature Cooling Loops	Free Cooling

References

1)

Resources

-