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DRY PUMP SHUTDOWN PROCEDURE

Edwards' dry pumps are designed to run 24 hours a day, 365 days a year. From time to time however, users in the semiconductor industry find it is necessary to switch them off for reasons of exhaust maintenance, plant shutdowns etc. This note is intended to provide guidance on the best procedures to adopt when shutting down a pump with the intention of restarting it sometime later.

Issues to consider

Shutting down a dry pump that has been used on a semiconductor process triggers a number of events that may lead to difficulties when trying to restart the pump. This is generally true for all clearance type dry pumps including roots, claw and screw mechanisms.

Loss of vacuum

Perhaps an obvious point but when a pump is shutdown the vacuum is lost. The gas from the exhaust line and exhaust stages of the dry pump will rapidly flow back through the clearances of the pump mechanism and into the low-pressure foreline. When a check valve is fitted in the pump exhaust it will help to prevent exhaust gases (including air) from contaminating the foreline. However, if the pump is stopped for any length of time, any external leaks into the foreline or pumping system, or internal leaks across the check valve, will cause the pump and foreline pressure to drift up towards atmospheric pressure. Depending on the process involved this may lead to reactions occurring with any by-products in the system. This in turn may lead to a change in nature of the by-products that may lead to corrosion, some build-up of hazardous gases, or to cause the rotor and stator of the pump to 'gum' up and make it difficult to restart.

Temperature changes

The next important point is that the pump will cool down when it is stopped. As the pump cools the clearances between moving and static components will change. If the semiconductor process is one that generates a solid by-product either in the form of a powder, or through condensation mechanisms, or via film growth, then this by-product will tend to build up to an equilibrium level in the running clearances. That is, the material will steadily build up in the clearances until it comes into contact with a pump component when it will either be pushed through the mechanism or vaporized by the heat of friction. When the pump cools some of the clearances will contract with consequent compression of any by-product material. This can lead to very high frictional forces when trying to restart the pump leading to motor overload and the pump failing to restart.

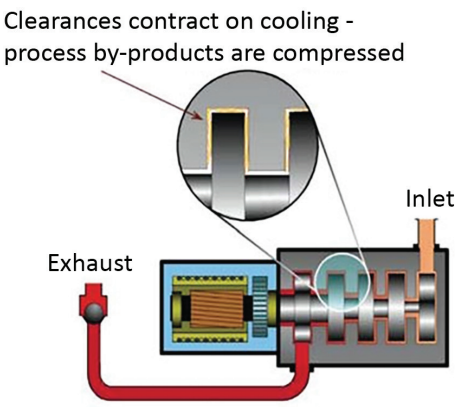

Figure 1 – Temperature changes cause changes in clearances

Loss of purge

A further point to consider when stopping a pump is that all the pump purges will stop. This is a necessary feature to prevent the foreline pressure rising above safe design levels in the event of an exhaust blockage. However, it does mean that unless an external exhaust purge is employed then any by-product in the exhaust will, over time, be exposed to moist air or whatever is at the exhaust outlet. This may lead to corrosion or reactions with possible safety implications.

Process considerations

The relative importance of the above issues will depend on the processes to which the pump is attached. 'Clean' processes such as loadlocks and transfer chambers should not suffer from any such potential restart issues. Similarly, for PVD and implanter beamline applications. Corrosion is more likely to be an issue for thin walled flexible pipework on applications such as aluminium etch, poly etch using HBr, and CVD processes that employ chamber cleans using ClF3 or that generate high levels of fluorine. The 'gumming' up of components caused by the potential change in nature of by- products is more likely to be an issue on some TEOS, Epi and aluminium etch processes.

Dielectric ALD and CVD processes such as the ALD of oxides and nitrides together with LPCVD Nitride, PECVD Oxynitride and SACVD USG tend to suffer more from high levels of solid by-products that may tend to fill clearances causing problems if the pump is allowed to cool.

Reducing frequency of shutdowns

A number of things can be done to reduce the need to shutdown a pump. The first is to fit a gate valve above the pump. This allows a pump to be kept running when routine foreline maintenance has to be carried out (e.g. when cleaning a throttle valve at the rear of the tool).

If a point of use abatement system is employed that requires frequent maintenance, then fitting a bypass around it may allow the pump to be kept running whilst the scrubber is being maintained.

If the pump is switched off regularly due to problems with the process tool, then consideration could be given to running the pump independently of the tool, with the tool controlling a gate valve above the pump instead.

Before employing these options a hazard analysis should be undertaken to ensure that they are safe for the particular installation.

Shutdown procedure

Assuming it is necessary to shut the pump down then the following procedure should ensure the best chance of the pump restarting without problems.

- If the pump is attached to a deposition process that employs a chamber clean, then the chamber clean should be the last process step before the pump shutdown.
- Where possible, purge the process chamber, foreline and pump with nitrogen or an inert gas from the process tool for a minimum of 15 minutes. The flow level will depend on the available mass flow controller but should be in the region of 5 to 10 slm.
- Close all the valves in the foreline.
- Where fitted run inlet purge for a period of at least 15 minutes. For metal or dielectric CVD and metal etch processes, then purging for an hour or more is recommended. On pump models where inlet purge is not fitted then the pump should be run with the harshest duty purge level available. The purging keeps the pump hot, flushes out any residual gases, encourages sublimation of solids, and allows for some desorption of process related gaseous species previously adsorbed on to powders or pump surfaces. In addition, it will purge the exhaust line, filling it with nitrogen. There may be some processes where safety practices dictate longer purges.

- Shutdown the pump. Where the pump is equipped with a pulsed or ramped shutdown feature this shutdown method should be used if there is likely to be any solids in the pump.
- Turn off the cooling water supply but leave the return open to avoid possible high pressures. This will reduce the rate of cooling, which should help if the pump is only to be off for a short period. Where the water supply is cooler than room temperature then stopping its flow will also mean that the pump will not get so cold.

Where possible, minimise the time the pump is off. If it is off due to work on the foreline then it may be possible to disconnect the pump inlet, blank it and restart the pump. The time it takes for a pump to cool from its operating temperature to room temperature depends on a number of factors such as levels of extraction, presence of enclosures, proximity of other equipment, etc., but will take a number of hours. If the pump is to be off for an extended period, e.g. for a plant shutdown, then consider purging the pump before disconnecting and blanking the pump exhaust. This is particularly relevant if moisture could be present in the exhaust system.

Restart procedure

- Ensure that the pump is connected to the system, with all blanks removed, and that the services are connected. All foreline valves should be closed.
- If the installation allows, and hazardous out-gassing of by-product is possible, then pre-purge the stationary pump and exhaust system with nitrogen.
- Switch on the pump and allow it to run for at least 15 minutes to allow its temperature to start to rise.
- Open the foreline valve, if fitted, and pump down the foreline. If the process is one that generates significant quantities of loose by-product, then there is the possibility that the sudden movement of gas in the foreline will entrain the by-product and deposit it abruptly in the pump causing failure. If this is likely then a soft start mechanism or anti-surge valve incorporated into the foreline design is recommended.
- Where the process contains condensable source materials or by-products then ensure that the pump is allowed to attain its full working temperature before starting any processing. Depending on environmental conditions and the pump model this may take up to several hours.

Summary

Dry pump systems are designed to run continuously and should not be stopped unless it is essential.

If they are stopped then there may be potential hazards or restart problems arising from either the loss of vacuum (exhaust gas back-streaming or external leaks); the pump cooling (contraction of clearances on to by-product deposits); or lack of purge into the pump and exhaust (reactions of moisture with exhaust deposits).

Installations can be designed with gate valves and abatement bypass systems to reduce the frequency that a pump needs to be shutdown.

- The likelihood of problems occurring will depend on both the process and on the way in which the pump is shutdown. Processes that generate solid (or liquid) by-products are more likely to cause problems. These include dielectric and metal CVD and metal etch.

Pumps should be properly purged before shutdown. The length of purge required will depend on the application but on the dielectric and metal CVD, and metal etch applications (including the ALD of oxides, nitrides and metals, LPCVD nitride, PECVD oxide and oxynitride, and TEOS processes (including SACVD)) then purges of at least 1 hour are recommended. Some processes may need longer for safety reasons. If the pump is fitted with a pulsed or ramped shutdown feature this should be used to shut down the pump if there are likely to be solid by-products in the pump.

The cooling water supply should be shut off to avoid over cooling the pump. If extended shutdown is anticipated, then consider capping the exhaust.

The pump should be restarted as soon as possible, preferably before it has been allowed to completely cool.

Take steps to pre-purge the pump before restart if it has been on a hazardous process and design the installation to avoid entraining loose by-product on startup.

Allow the pump to warm up fully before running the process.