Maintenance procedures for vacuum furnaces

Maintenance procedures and safe working conditions are essential in maintaining vacuum furnaces as is proper preparation of components to be heat treated prior to charging to the furnace.

By Jeff Pritchard*

VAC AERO International operates more than a dozen vacuum furnaces in its own heat treating facilities. In addition, it has manufactured hundreds of vacuum furnaces for sale to the global market. Through these activities, the company has gained extensive experience in the care and maintenance of vacuum furnace equipment.

As with any piece of equipment, proper maintenance at regular intervals is essential for long service life and trouble free operation of vacuum furnaces. The mechanical components in a vacuum furnace require standard maintenance practices (ie cleaning, lubrication, etc). However, successful use of a vacuum furnace depends on the purity and reliability of its vacuum. Additional maintenance activities are required to ensure good vacuum levels in the system. Leaks in joints and contamination of furnace internals will greatly affect operating vacuum levels and the quality of the processing. Leaks are the most time-consuming and troublesome of the maintenance items. Small leaks can only be isolated using helium leak detectors. However, by keeping track of where leaks most frequently occur, preventive measures can be taken to minimise the problem. The operating manuals supplied with most furnaces provide detailed information on maintenance and trouble shooting. All maintenance manuals should be read and understood before commencing furnace operation.

Safety

There are a number of safety issues that must be considered when maintaining vacuum furnaces. Standard safety practices must be adhered to in order to avoid injury, burns and electrocution. In addition to these, there are several special considerations specific to vacuum furnace equipment. On furnaces equipped with oil diffusion pumps, maintenance should only be attempted after the pump has been allowed to cool to ambient temperature. The diffusion pump works by boiling oil to form a vapour. Heated by coils in the base of the pump, oil temperatures reach 240ºC (464ºF) and higher. At these temperatures, vapours from hydrocarbon-based oils can react explosively with air. As a result, the fill port in the pump should never be opened while the pump is operating. Silicone-based pump oils eliminate this explosive risk.

Maintenance of furnace chamber internals should only be conducted using approved confined space entry and electrical lockout procedures. Residual quench gases remaining in the tank even after the door is opened can cause asphyxiation. Particular care should be taken entering furnace chambers after argon has been used as a quench gas. Argon is heavier than air and can remain in low lying areas for some time. It has no discernable odour and there is usually no advanced warning before unconsciousness occurs. Vacuum conditions in a furnace tank are even more lethal. Lockout procedures to prevent furnace operation must be in place before entering any furnace chamber.

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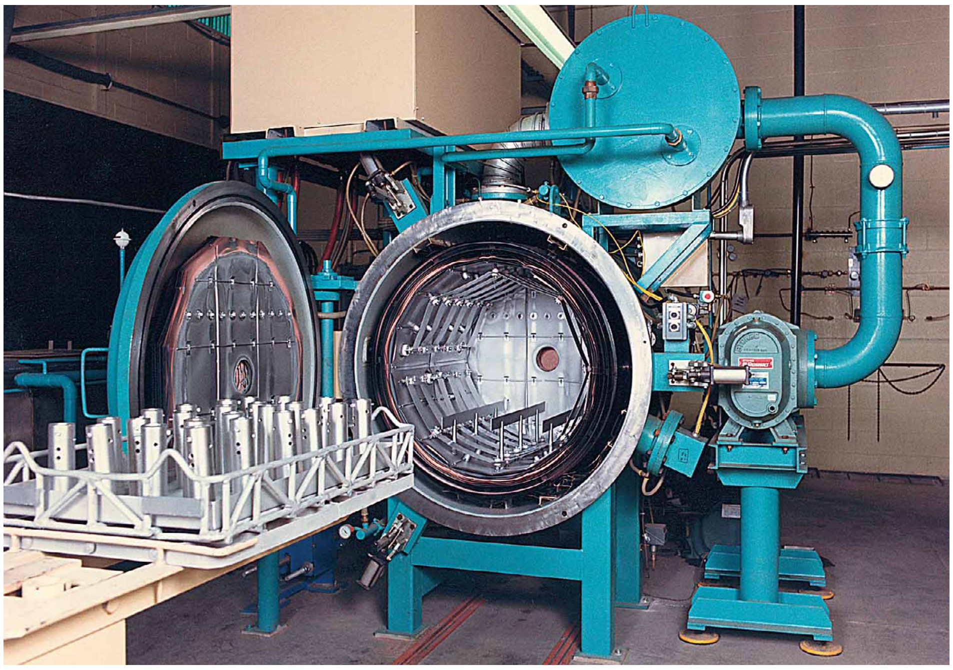
Vacuum seals

During construction, all welded joints in a vacuum furnace are inspected for hermetic integrity and should remain intact for the life of the furnace. However, there are also a number of demountable connections that can be separated and reconnected for component changing or repair access reasons. These connections are generally sealed with a gasket sandwiched between two flanges. Though different gasket materials are used depending on the vacuum level required, most seals in a standard vacuum furnace incorporate an o-ring made of natural or synthetic rubber. Buna-N, silicone and Viton o-rings are readily available in many sizes. These materials are resilient and can be used repeatedly without loss of integrity. The common squish rates of 20% to 50% of the original cross section will not stress o-ring materials past their elastic limits. O-rings must be properly retained within the connection to prevent being sucked into the vacuum system. Usually, they are set in a groove machined into a flange on one side of the connection. They are then squeezed against the opposite flange as the flanges are tightened together. A less common method of o-ring retention involves a retaining ring that is thinner than the o-ring cross section. The retaining ring fits inside the inner diameter of the o-ring.

The surface finish on the flanges between which the o-ring is squeezed should be no more than 125 RMS. A coarser finish may result in gas penetrating through the seal. Flange faces should be inspected for burrs or scratches prior to assembly. Standard practice is to coat the o-ring with a thin layer of vacuum sealing grease prior to assembly to improve its sealing properties. A common cause of leakage in o-ring sealed joints arises from damage to the o-ring. O-rings should never be removed from grooves using sharp objects, such as screwdrivers or knives. Not only can these objects cut the o-ring, they may also cause scratches in the bottom of the o-ring groove which will provide another path for gas penetration. O-rings should be regularly inspected for damage and cleaned of all dirt and particulate matter.

Because of frequent opening and closing, door o-rings are most susceptible to damage and should be inspected prior to every run. They should be checked for nicks, cuts or flat spots. Both o-ring and door flanges should be wiped clean before the door is closed. Re-coating of the o-ring with a thin layer of vacuum grease should be performed at regular intervals though any build up of vacuum



Parts loaded into a VAC AERO VAH2636 vacuum furnace for vacuum hardening

grease must be avoided. Improperly assembled feedthrough seals may also be a source for leaks. When changing control or over-temperature safety thermocouples, feedthrough seals must be properly tightened to ensure vacuum integrity. Small leaks may be temporarily overcome by applying a sealing compound on external surfaces of the vacuum joint. However, this is not a permanent corrective measure.

Minimising outgassing

Whenever the door to a vacuum furnace chamber is open, humidity from the air will enter the chamber and condense in a very thin film on the chamber walls or be absorbed into the hot zone materials. When the chamber is subsequently evacuated (before heating) and the furnace internals are exposed to this lower pressure, 'outgassing' of the entrapped moisture will occur. If sufficient moisture has been entrapped (such as in very humid environments), the outgassing effect will slow the pumpdown process and may even give the appearance of a malfunction in the pumping system. Eventually, the outgassed moisture will be pulled out of the chamber by the pumping system and evacuation rates will improve. This same effect will be apparent when oily or contaminated workloads are placed in the furnace. It may be slightly more pronounced in furnaces with graphite-based hot zone insulation materials.

To minimise the outgassing effect, it is important to keep the chamber door closed whenever possible. Ideally, the chamber should also be kept at least partially evacuated whenever the furnace is not in use. Maintaining the recommended temperature of the coolant entering the chamber cooling jacket is also important. Condensation of moisture is more pronounced on cooler surfaces.

In addition to problems created by moisture, vaporisation of volatile elements when heated under vacuum will eventually contaminate the furnace internals with undesirable residues. The evolution of this condition may become apparent by deteriorating ultimate vacuum levels. Deposits of

Parts washer used to remove machining residue prior to vacuum heat treating

metallic residues can also cause electrical short circuits. Often, however, considerable amounts of contaminants can be present with no discernable change in operating pressures. Regular dry run cycles must be performed to burn off contaminants before they begin affecting load quality or create electrical problems. The furnace maintenance manual will provide detailed instructions for performing a dry run cycle. As a minimum, at least one dry run cycle should be performed each week. Depending on the cleanliness of the work processed previously, a dry run cycle may also be required immediately prior to processing a critical workload or materials that are particularly prone to contamination (ie titanium alloys).

Cleaning prior to vacuum heat treating

One of the best preventive measures to minimise maintenance issues arising in vacuum processing is to ensure the load is properly cleaned before it enters the furnace. Cleanliness of both the workpieces and baskets or fixtures is very important. They must be free of oil, dirt, machining lubricants or other contaminants prior to being loaded into the furnace. Some lubricants contain sulphur compounds which can adversely affect the alloys being heat treated. Inadequate cleaning can also cause staining and discolouring of the end product or result in poor braze alloy flow. Contaminants with high vapour pressures will evaporate during heating causing loss of vacuum. The vapours may eventually condense on colder surfaces in the furnace only to re-vaporize to cause contamination problems in subsequent runs.

It is good practice to check all workpieces for cleanliness prior to loading for vacuum processing. Tubular assemblies or parts with deep holes or recessed passages should be inspected for entrapped lubricants, machining chips or residual casting core debris. Particular attention should be paid to castings. In some cases, they are cleaned in molten salt baths to remove core residues. These corrosive salts may remain entrapped after removal from the salt bath. If not cleaned out prior to vacuum processing they will vaporize during heating. Workpieces should also be inspected for metal identification tags. Both the tag and the wire that is used to attach it to the workpiece should be checked to ensure it is not made from a low melting point material such as aluminium.

Selection of the cleaning process depends on the prior processing history of the workpiece and the alloy from which it is fabricated. For parts contaminated with stamping lubricants or cutting oils, it is important to know the type of fluid that was used. Performance of some cleaning processes may be adversely affected depending on the nature of the contaminant (eg mineral- versus water-based oils). When the composition of the contaminant is unknown, solvent or vapour degreasing is usually the first choice for cleaning. However, these cleaners do not work well on water-based contaminants. In these cases, an alkaline or emulsion cleaner should be used. It should also be noted that water can cause the deterioration of many fluids used in vapour degreasing, creating an acidic solution that can attack both the workpiece and degreasing equipment.

Certain materials may require specific cleaning precautions. Titanium, zirconium and their alloys should never be cleaned in chlorinated solvents such as trichlorethylene or methylchloride. Chloride residues can cause stress-corrosion cracking in titanium and zirconium alloys when they are heated above 280ºC (550ºF). Instead, these alloys should be cleaned in non-chlorinated solvents such as acetone or alcohol or in alkaline solutions. Many deep drawing lubricants contain sulphur and lead. Both elements can attack nickel alloy surfaces during heating, causing the formation of low-melting point eutectics that will severely embrittle the base metal. Nickel alloy workpieces must be carefully cleaned to ensure complete removal of the lubricants. After cleaning, workpieces must be thoroughly dried before loading into the furnace. Solvents and water residues will volatilise during heat treating and degrade pumping performance.

Good preventive maintenance will ensure years of reliable vacuum furnace operation. Most furnace manufacturers like Vac Aero provide expert training in trouble-shooting and design of preventive maintenance programmes specifically suited to the user's unique processing applications. ■