Maintenance Practices, Procedures and Tips

by
Daniel H. Herring
"The Heat Treat Doctor"®

This is the eighteenth in a series of articles about Vacuum Heat Treatment and looks at various vacuum furnace maintenance practices and procedures as well as offers tips from industry experts on what areas need to be maintained, how often, and why certain components should be inspected and/or replaced.

To ensure reliability and repeatability of operation as well as uncompromising safety, maintenance practices need to be well defined, understood by all, and implemented in a prudent and well thought out manner. Only trained personnel experienced in vacuum technology should be allowed to service vacuum furnace systems.

The frequency of maintenance (i.e. interval between routine repairs) is highly dependent on such factors as:

1. Type and number of heat-treating processes performed.
2. Skill level of the operators.
3. Equipment design.
4. Quality of prior maintenance and type of spare parts used.
5. Quality of the water system, gas system, etc.

When performing maintenance it important to have a written plan defining the specific task to be performed, and reason why a particular task is necessary (i.e. purpose of the task). A work order should be issued and the work signed off upon completion (which includes testing to ensure that the repair was successful).

The following conditions should be met before any repairs are undertaken:

1. Power should be switched off for any repairs not directly involved with the electrical systems, controls or instrumentation. Lockout/Tagout procedures should be in place (Fig. 1).
2. The furnace should be cool, less than 120°F (50°C).

The HERRING GROUP, Inc.
Home of *"The Heat Treat Doctor"*
P.O. Box 884
Elmhurst, Illinois 60126-0884
Tel: 630.834.3017 / Fax: 630.834.3117 / Cell: 630.640.9048
E-mail: dherring@heat-treat-doctor.com / dherring@ameritech.net
www.heat-treat-doctor.com

3. The furnace door(s) should be in the open position and secured so that they cannot be closed.
4. Disconnect all utilities including gases, water, and air. Lockout/Tagout procedures should be followed.
5. Check that the furnace environment is safe and that adequate ventilation is in place and functioning properly.
6. Wear protective clothing including safety glasses and safety shoes.
7. Be sure that all Confined Entry procedures are thoroughly understood and followed without exception.
8. Use the buddy system.
9. Before entering the vacuum furnace, confirm that the oxygen level is safe for human exposure.

Figure 1
Lockout/Tagout

The HERRING GROUP, Inc.
Home of *"The Heat Treat Doctor"*
P.O. Box 884
Elmhurst, Illinois 60126-0884
Tel: 630.834.3017 / Fax: 630.834.3117 / Cell: 630.640.9048
E-mail: dherring@heat-treat-doctor.com / dherring@ameritech.net
www.heat-treat-doctor.com

Figure 2 [2]
Typical Horizontal Vacuum Furnace Maintenance Areas
(Photograph Courtesy of SECO/WARWICK Corporation)

Figure Key

1. Chamber door seal care – after each run
2. Water system & hoses – visual inspection daily
3. Pumping system – daily/weekly checks
4. Hot Zone inspection – daily checks
5. Instrument calibration – per AMS 2750D
6. Hearth inspection – after each run

The HERRING GROUP, Inc.
Home of *"The Heat Treat Doctor"*
P.O. Box 884
Elmhurst, Illinois 60126-0884
Tel: 630.834.3017 / Fax: 630.834.3117 / Cell: 630.640.9048
E-mail: dherring@heat-treat-doctor.com / dherring@ameritech.net
www.heat-treat-doctor.com

Figure 3
Typical Vertical Vacuum Furnace Maintenance Areas
(Photograph Courtesy of Vac-Aero International)

Figure Key

1. "O" Ring seal care – after each run
2. Water system & hoses – visual inspection daily
3. Cooling & Blower motor – inspect every 6 months
4. Heat exchanger – annual inspection
5. Vacuum gauge calibration – biannual
6. Pumping system – daily/weekly checks
7. Hot Zone inspection – daily checks
8. Hearth inspection – after each run

The HERRING GROUP, Inc.
Home of *"The Heat Treat Doctor"*
P.O. Box 884
Elmhurst, Illinois 60126-0884
Tel: 630.834.3017 / Fax: 630.834.3117 / Cell: 630.640.9048
E-mail: dherring@heat-treat-doctor.com / dherring@ameritech.net
www.heat-treat-doctor.com

General Maintenance

Safety is MANDATORY and cannot be compromised during any maintenance activity. Safety interlocks must never be bypassed and verification that all potentially hazardous energy sources have been isolated and disabled is a necessary first step in the maintenance process.

Lockout/Tagout procedures are required to disable machines or equipment during maintenance to prevent injury is part of OSHA code (Regulation 1910.147). A vacuum furnace may have different places in which electrical power must be disconnected; a single main electrical disconnect (i.e. circuit breaker) for the entire furnace or power supplied from several electrical sources each with a separate disconnect device. The electrical drawings for the specific unit in question should be reviewed as well as physical inspections conducted in the event that undocumented changes have taken place.

In addition, a vacuum furnace may also have pneumatic or hydraulic systems including sources of compressed air, inert gases, and process (reactive) gases that must be isolated from the system.

Confined Entry Space restrictions also apply.

All safety interlocks present in normal equipment operation should be tested on a regular basis to ensure proper operation. These include:

- Over temperature instrumentation (test monthly)
- Process interlocks (test semi-annually)
- Water interlocks (test semi-annually)
- Air interlocks (test semi-annually)

Several additional points regarding vacuum maintenance can be summarized as:

- Cleanliness is essential
- Part placement and location (whether in baskets or on grids)
- Care in loading and unloading the equipment
- Quality of the backfill gas and backfill piping – from the supply to the equipment;
- Small parts in loads must be adequately constrained (Fig. 3);

The HERRING GROUP, Inc.
Home of *"The Heat Treat Doctor"*
P.O. Box 884
Elmhurst, Illinois 60126-0884
Tel: 630.834.3017 / Fax: 630.834.3117 / Cell: 630.640.9048
E-mail: dherring@heat-treat-doctor.com / dherring@ameritech.net
www.heat-treat-doctor.com

- Maintenance must be done with extreme care not to damage adjacent components or systems.

Figure 3
Small Parts Embedded in the Heat Exchanger System
(Photograph Courtesy of SECO/WARWICK Corporation)

Vacuum Vessel Maintenance

The most common maintenance practice performed on the vacuum vessel is leak detection (c.f. Vacuum Heat Treatment Series Part 12).

For most furnaces the front door "O" ring or door seal is the single most important area of focus. Inspect and wipe clean this seal each time the door is opened after a furnace cycle. On "O" ring seals look for cracks, lack of elasticity, flat spots, dirt and metallic fines. Wipe the door "O" ring and flange with a clean "lint free" rag before closing the door. Reapply a thin coating of vacuum grease as necessary. Once a week, wipe the door "O" ring and mating flange with a clean rag soaked in denatured alcohol. Reapply just enough vacuum grease to produce a sheen on the "O" ring surface and check that a rubber-gloved finger glides freely along the surface (c.f. *The Ubiquitous O-Ring*, Industrial Heating, November 2009).

Vacuum Pumping System Maintenance

In most cases, the vacuum pumping system requires the most maintenance of any area on the vacuum furnace.

The HERRING GROUP, Inc.
Home of *"The Heat Treat Doctor"*
P.O. Box 884
Elmhurst, Illinois 60126-0884
Tel: 630.834.3017 / Fax: 630.834.3117 / Cell: 630.640.9048
E-mail: dherring@heat-treat-doctor.com / dherring@ameritech.net
www.heat-treat-doctor.com

Mechanical Pump

Mechanical (wet) pumps rely on oil for proper operation and the correct oil type for the pump in question should be used. The oil level and the condition of the oil must be checked daily, usually at the beginning of the first shift of the day. The correct oil level for most pumps is at the center of the site glass or just below center when the pump is operating at high vacuum. Oil should be added when the pump is stopped, however, it can be added in some instances during operation if the vacuum level is below 1 Torr. Overfilling will cause a loss of efficiency as well as create the potential for backstreaming of oil into the hot zone.

The oil condition should be checked daily. Good oil is translucent and clean. Cloudy or milky oil indicates the presence of moisture. If this is observed the pump should be ballasted "offline" in accordance with manufacturers instructions. Dark or discolored oil indicates the presence of dirt, carbon (often in the form of soot) or other contaminants. If this is observed, the oil should be changed as needed or after 300 operating hours (whichever comes first). Every six (6) months or when the oil is excessively dirty, the oil reservoir should be drained and the oil reservoir cleaned with denatured alcohol and clean lint-free rags. At the same time the exhaust valve springs (poppet valves) and all discs should be replaced.

Observe and check the oil temperature under normal operating conditions. Normal operating temperature is between 140°F and 160°F as indicated by the gauge on the side of the vacuum pump.

Monthly, check the drive belts for wear and adjust for proper tension. The pump manufacturer's instructions should be followed regarding proper belt tension settings. A useful tip is that, with a new belt, at the belt midpoint (between the drive and motor pulleys) apply pressure (typically 5 – 7 pounds) to the belts. Record the resulting deflection and use this value for future adjustments. If the belt tension is too tight, damage can occur to shaft bearings. If the belts are too loose, slippage will occur causing excessive wear.

The gas ballast valve and spring should be checked and replaced, if necessary, every three (3) months.

The HERRING GROUP, Inc.
Home of *"The Heat Treat Doctor"*
P.O. Box 884
Elmhurst, Illinois 60126-0884
Tel: 630.834.3017 / Fax: 630.834.3117 / Cell: 630.640.9048
E-mail: dherring@heat-treat-doctor.com / dherring@ameritech.net
www.heat-treat-doctor.com

Vacuum Valve Maintenance

Vacuum valves require the least amount of routine maintenance of any component on a vacuum furnace due in large part to their design. In most cases, no lubrication or adjustments are required. However, maintenance is not only necessary but also critical at certain intervals in a valves operating life. For example,

> Butterfly type roughing and foreline valves should be removed from the vacuum line every two (2) years to inspect their rubber seats for cracking and dryness. When the valve is replaced between flanges in a vacuum line, the disc should be rotated to the open position before the flange bolts are tightened.
>
> Poppet valve pistons and shafts should be lubricated weekly with vacuum grease through the fitting on the cylinder mounting block. Semi-annually the valve disc "O" ring should be cleaned and lightly lubricated. Annually, it should be replaced.

Booster Pump

The booster pump does not require a great deal of maintenance. However, the oil level in all reservoirs should be checked daily and drive belts checked monthly for wear and adjusted for proper tension, similar to the mechanical pump belts. Every 2000 hours of operation, the oil in the bearing and gear oil reservoirs must be changed.

The HERRING GROUP, Inc.
Home of *"The Heat Treat Doctor"*
P.O. Box 884
Elmhurst, Illinois 60126-0884
Tel: 630.834.3017 / Fax: 630.834.3117 / Cell: 630.640.9048
E-mail: dherring@heat-treat-doctor.com / dherring@ameritech.net
www.heat-treat-doctor.com

Diffusion Pump

The oil level on the diffusion pump should be checked daily. Oil must only be added to a cold (< 130°F (oil temperature) pump and only to the cold mark on the site glass. Never open the drain plug when the pump is hot (CAUTION: there is a risk of explosion). An oil change is recommended every six (6) months or immediately if discoloration or contamination are observed. The inside of the pump should be cleaned every six (6) months.

Cooling water to the pump must be checked daily for adequate flow. If proper cooling is not provided to the diffusion pump the oil can fractionate (i.e. breakdown and form solid carbon deposits) damaging the pump, which will need to be factory repaired. The heating elements should be checked for tightness and proper operation at least once a year.

Holding Pump

On holding pumps, the oil level and condition of the oil are critical for efficient operation. The correct oil level is at the center of the site glass or just below center with the pump operating at high vacuum. Oil should be added only when the pump is stopped. The oil condition should be checked daily and, similar to the mechanical pump, the holding pump should be ballasted or replaced if the oil is not translucent and clean.

Hot Zone Maintenance

After ensuring proper ventilation and following all safety guidelines with respect to asphyxiation and confined space entry, the interior of the hot zone should be inspected after every load. The bottom of the hot zone should be cleaned of all debris and foreign matter and the heating elements and heating element connections inspected for damage and tightness.

Graphite heating elements cannot be patched and the damaged section should be replaced with a new element section. Molybdenum heating elements can be repaired although no more than three (3) repairs are recommended per element band. Special procedures are required since molybdenum is brittle and molybdenum dioxide fumes should not be inhaled. Once a month, heating element resistance to ground should be checked with a digital volt/ohm meter. A good reading is between 90 – 100 ohms for most furnaces. As

The HERRING GROUP, Inc.
Home of *"The Heat Treat Doctor"*
P.O. Box 884
Elmhurst, Illinois 60126-0884
Tel: 630.834.3017 / Fax: 630.834.3117 / Cell: 630.640.9048
E-mail: dherring@heat-treat-doctor.com / dherring@ameritech.net
www.heat-treat-doctor.com

molybdenum elements age or the element standoff metalizes, their resistance to ground drops. A bad reading would be 20 ohms or less.

A hot zone bake-out cycle should be run every 100 – 200 hours or when deemed necessary by the performance of the equipment.

Several additional points regarding hot zone maintenance can be summarized as:

- Checking for insulation degradation
- Maintain proper tension on electrical connections (e.g. heating elements, power feedthrus)
- Measure resistance to ground
- Inspection of heating elements for wear and/or oxidation (e.g. thinning or a "sugar cube" appearance – indicating attack by oxygen)
- Check that thermocouples and controls are functioning properly.

Water System Maintenance

Most vacuum furnaces are cold wall designs with an annular spacing between an inner and outer shell. As such, proper conditioning of the water is important for effective cooling. Water should be treated for pH, hardness, bacteriological agents and (if appropriate) have rust inhibitors present to help minimize sediment and scale build-up, particularly in the bottom portions of the shell. A blockage of the vessel wall will result in a "hot" spot, so the shell should be periodically checked since most blockages occur slowly over time.

Several additional points regarding water system maintenance can be summarized as:

- Checking water quality;
- Cleaning/maintenance of the heat exchanger(s);
- Establishing corrosion protection;
- Maintaining coolant levels to various subsystems (e.g. pumps power feedthrus, vessel)

Record Keeping

The HERRING GROUP, Inc.
Home of *"The Heat Treat Doctor"*
P.O. Box 884
Elmhurst, Illinois 60126-0884
Tel: 630.834.3017 / Fax: 630.834.3117 / Cell: 630.640.9048
E-mail: dherring@heat-treat-doctor.com / dherring@ameritech.net
www.heat-treat-doctor.com

Accurate record keeping is an often over-looked aspect of a successful maintenance program. It is at the heart of any efficient and effective maintenance plan. Record keeping should start on equipment installation and document any and all changes to the equipment over its lifetime. After the unit is put into service it is essential to create and maintain a performance log containing information such as:

1. Blank-off pressures (esp. mechanical pumps)
2. Pumpdown time to a given pressure.
3. Ultimate vacuum and the time required to achieve it.
4. Leak-up rate when the chamber is blanked off.
5. Heating rate (empty, fully loaded) to processing temperature.

This type of data is invaluable when evaluating a future problem or when trying to determine if the vacuum system has deteriorated.

Training

The value of training should never by underestimated. Over the years, the majority of vacuum furnace failures can be traced to the following causes:

- Inadequate training of operators;
- Lack or proper maintenance;
- Improper use of the equipment.

All operating personnel, supervisors, maintenance and quality control individuals should have a good understanding of what heat treating is, how vacuum technology differs from other types of heat treatment and how the equipment should be operated and maintained to ensure safety, efficiency and proper results. It is further recommended that annual retraining be conducted to maintain a high level of proficiency and effectiveness.

Preventative Maintenance Checks

Setting up a planned preventative maintenance program will minimize equipment downtime; ensure that proper spares are on hand for repairs, and simply the overall maintenance effort. As a minimum, the following checks should be performed:

The HERRING GROUP, Inc.
Home of *"The Heat Treat Doctor"*
P.O. Box 884
Elmhurst, Illinois 60126-0884
Tel: 630.834.3017 / Fax: 630.834.3117 / Cell: 630.640.9048
E-mail: dherring@heat-treat-doctor.com / dherring@ameritech.net
www.heat-treat-doctor.com

Each Run

The following activities should be performed before each run:

1. Inspect the front door "O" ring for cleanliness and damage. Clean and regrease as necessary.
2. Inspect hot zone insulation and heating elements for signs of damage, deterioration and that are connections are snug and secure.
3. (If appropriate) Inspect the load thermocouple(s) for damage.

Daily

The following activities should be performed daily:

1. Inspect the exterior and interior of the vacuum furnace for indications of damage, discoloration, dripping fluids, and the presence of foreign material (e.g. dirt, grease, oil).
2. Check the water flow and temperature from each drain line.
3. Check the oil level on all pumps.
4. Ballast the vacuum pump (20 minutes minimum) before processing the first workload of the day.
5. During operation, inspect for hot spots, leaking fluids, excessive noise and/or vibration.

Weekly

The following activities should be performed weekly:

1. Perform a leak (rate-of-rise) test on the main vacuum vessel and pumping system. The furnace should be clean, dry, empty and outgassed before testing.
2. Check mechanical pump oil for contamination (e.g. dirt, particulates, water).
3. Check instruments for functionality.
4. Inspect the pumping system (pumps, valves, piping).

Monthly

The HERRING GROUP, Inc.
Home of *"The Heat Treat Doctor"*
P.O. Box 884
Elmhurst, Illinois 60126-0884
Tel: 630.834.3017 / Fax: 630.834.3117 / Cell: 630.640.9048
E-mail: dherring@heat-treat-doctor.com / dherring@ameritech.net
www.heat-treat-doctor.com

The following activities should be performed monthly:

1. Flush all cooling lines and clean all in-line filters, strainers, etc.
2. Check all electrical connections. (Caution: a licensed electrician trained in the procedure should only perform this activity).
3. Check for hot zone deterioration (insulation and heating elements) including doors.
4. Test the pressure relief valve in accordance with manufacturers instructions.
5. Check calibration of vacuum instruments.
6. Check all thermocouples (e.g. control, overtemperature, load)
7. Remove, clean and reinstall thermocouple vacuum gauges.
8. Change vacuum pump oil.
9. Check belts for proper tension (e.g. mechanical pump)
10. Change all filter elements.

Quarterly

The following activities should be performed quarterly:

1. Replace or recalibrate all thermocouples.
2. Inspect all vacuum gauges.
3. Clean all mating flanges.

Semi-Annually

1. Check, remove and inspect all vacuum valves for proper operation, sealing and wear.
2. (If applicable) Clean and replace diffusion pump oil.
3. Replace door gasket or "O" ring seals.
4. Make all necessary repairs to hot zone components (including power feedthrus)

Annually

1. Drain and inspect the cooling water system (including temperature sensors)
2. Service all motors.
3. (If applicable) Clean the furnace heat exchanger.
4. (If applicable) Drain and filter quench oil.

The HERRING GROUP, Inc.
Home of *"The Heat Treat Doctor"*
P.O. Box 884
Elmhurst, Illinois 60126-0884
Tel: 630.834.3017 / Fax: 630.834.3117 / Cell: 630.640.9048
E-mail: dherring@heat-treat-doctor.com / dherring@ameritech.net
www.heat-treat-doctor.com

5. (If applicable) Check the convection fan and/or oil agitators for proper operation.

Summing Up…

Maintenance should be performed in such a manner as to return the equipment to full operational service. Never compromise; a job worth doing is worth doing right. This will ensure years of productive service from your vacuum furnace!

References

1. *Vacuum Furnace Training Manual,* Abar/Ipsen "U".

2. Kowalewski, Janusz, *Maintenance Program Essential For Safe, Consistent Heat Treating*, Modern Application News, March 2000.

3. Kowalewski, Janusz, *Maintaining Vacuum Furnaces*, Advanced Materials and Processes, April 2000.

4. Craig, Roger A., *Vacuum Furnace Maintenance: Essential for Reliable Operation*, Conference Proceedings, Society of Manufacturing Engineers, February 1999.

5. DeWeese, Ted, *Furnace Maintenance*, Furnaces & Atmospheres for Today's Technology, Conference Proceedings, June 2010.

Next Time: Part nineteen of this series discusses gas pressure quenching from sub-atmospheric to ultra-high pressure including a discussion of the factors that influence the heat transfer coefficient.

The HERRING GROUP, Inc.
Home of *"The Heat Treat Doctor"*
P.O. Box 884
Elmhurst, Illinois 60126-0884
Tel: 630.834.3017 / Fax: 630.834.3117 / Cell: 630.640.9048
E-mail: dherring@heat-treat-doctor.com / dherring@ameritech.net
www.heat-treat-doctor.com