# Applications of Vacuum Tempering

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## Abstract

Vacuum tempering is being used for tempering high-speed steels and alloy steels to produce scale-free finish. A vacuum tempering furnace is very versatile and can be used for bright tempering, aging and annealing. Other less common applications include degreasing , resin bake-off and preferential oxide treatment of low carbon steels.

## Introduction

Vacuum tempering is being used for tempering high-speed steels and alloy steels to produce scale-free finish. In addition to these applications, there are several other applications, which make this style furnace very versatile. A vacuum tempering furnace can be used for bright tempering, aging and annealing. Other less common applications include degreasing, resin bake-off and drying of parts.

A new application for a vacuum temper furnace is a preferential oxide treatment. This application removes oily films on surfaces of low carbon steel parts, while creating an atmospheric corrosion resistant oxide layer. This preferential oxide leaves a uniform color on the parts, which is quite resistant to corrosion. Low carbon steel parts can be transported between work cells within a company or between different companies without requiring the parts to be preserved in rust inhibitors.

## Background

Vacuum temper furnaces are designed to create oxide free surfaces when tempering or aging parts. Vacuum temper furnaces operate generally as follows1: The furnace is loaded and door closed. A vacuum is established in the furnace of typically below .3 Torr (3.99x 10-2 kPa) with a mechanical pump. If a blower pump is used with the mechanical pump, much lower pressures can be achieved. After evacuating the furnace, the furnace is backfilled with an inert gas such as nitrogen or argon to about 500 Torr (66.5 kPa). The parts are heated in this inert atmosphere to the required temperature and held for the required time. The HHT vacuum temper furnace constantly purges in nitrogen gas during the heating and soaking of the parts at a rate of 10 cfh (.28 cubic meters per hour). This helps to purge out impurities that may come off the parts at elevated temperatures. A vacuum-tight fan is used to circulate the atmosphere throughout the workload during heating. After soaking, the parts are cooled by circulation of the atmosphere. A rear "bung" and a front insulating panel open to force the atmosphere out of the heat chamber and along the cold walls of the vessel. The work is removed from the furnace when the parts are below 300F (150C) to insure oxide-free surfaces.

## Applications

**Bright Aging and Tempering:** The most common application for a vacuum temper would be for bright aging precipitation hardening materials such as stainless steels and beryllium copper and bright tempering alloy steels, stainless steels and tool steels. A vacuum temper furnace can reduce atmosphere gas usage, and total cycle time as compared to a bell-type controlled atmosphere furnace. It takes far less time to pump down the furnace before ramping to temperature as compared to the amount of time it takes to purge out the air in a bell furnace. Also, it takes much less time after the parts are cool to remove them from the furnace. With an atmosphere bell furnace, the hydrogen has to be purged out at the end of cycle. The following example shows the productivity improvement possible using a vacuum temper furnace instead on a hydrogen bell furnace.

*Table 1.Bright aging Beryllium Copper 172 alloy: The process requirement is to ramp to 600F (315C) and hold for 2-2.5 hours at temperature. Cool to below 200F (93C). The load consists of 160000 pieces of an electrical contact. There are 80 lots, 2000 pieces*

*per lot. Each lot has to be kept separate and put into an individual basket. Therefore, the load consists of 80 small baskets loaded into larger framed baskets for support.*

| | Bell-Type Retort | Vacuum Temper |
|---|---|---|
| Furnace work zone | 36" diameter x 36" high | 24x24x36" |
| Max Load Size | 1000 lbs | 1000 lbs |
| Gas Usage | 175 cfh | 10 cfh |
| Gas Type | Dissociated Ammonia | Nitrogen |
| Cycle | Load furnace<br>Purge with nitrogen<br>Introduce Atmosphere<br>Ramp to 600F<br>Hold for 2-2.5 hours<br>Cool to below 200F<br>Purge out with nitrogen<br>Unload | Load Furnace<br>Establish vacuum<br>Ramp to 600F<br>Hold for 2-2.5 hours<br>Cool to below 200F<br>Backfill<br>Unload |
| Total Floor to Floor Time | 7 hours | 4.5 Hours |

**Degreasing/Drying:** Vacuum tempers have been used for degreasing of oily parts or drying of parts that have been cleaned in a hydrocarbon solvent. To degrease, the cycle requires the oily parts to be heated under the partial pressure of nitrogen with a constant purge of gas. The parts are heated to the required temperature to vaporize the oil on the parts. Some of the vapors are removed from the furnace by the vacuum pump, while it is constantly pumping on the chamber while nitrogen is flowing in. During cooling, some of the vapors condense on the cold wall of the furnace leaving the parts relatively clean and dry. This cleaning application is somewhat crude and may only apply to in-process cleaning between machining operations. Furthermore, the furnace itself gets contaminated with the oil and may not be suitable for other "bright" work before the oil is baked out of the furnace.

If the vacuum temper furnace is used for drying parts dipped in hydrocarbon solvent; the cleaning results are far better. Solvent dipping the parts to dilute the oil will improve on the parts' cleanliness as compared to not using a solvent pre-clean. A vacuum temper can be used for drying parts cleaned and rinsed in water-based cleaners also. Maintenance of the vacuum pump becomes a greater concern since a great deal of water vapor will accumulate in the mechanical pump and affect its performance. Again, anytime a vacuum temper is used for drying of parts; a proper bake out of the furnace is needed before processing any bright work.

**Filter Paper's Binders Bake Out:** One unique application for a vacuum temper furnace is the baking out of binders used in the production of filter paper. The filter paper is wound inside a cold rolled steel mesh liner. Once inside the liner, the binders are burned off in air. To reduce emissions into the work environment, the vacuum temper furnace was used instead of a box furnace. The vacuum temper furnace was plumbed with air inlet gas instead of nitrogen. Running a partial pressure of air in the furnace allows for the baking off of the binders. The gases that are formed are drawn through the pumping system and exit the building through ventilation ducts installed on the exit side of the mechanical pump. The vacuum furnace offers a work environment that is user-friendly as compared to the same process being performed in a box furnace.

**Preferential oxide treatment:** A new process has been developed using a vacuum temper oven, which yields an corrosion resistant oxide on the surface of low carbon steel. The process requires careful control of the time and temperature parameters during heating, soaking and cooling along with the use of partial pressure of air in the vacuum furnace. The process results in a uniform greenish-blue oxide layer on the surface of the parts. The process would be beneficial for applications requiring steel parts to be stored or shipped that can not have a rust preventative applied to them.

To prove out the corrosion resistance of the oxide layer, a humidity test was performed on test slugs of cold rolled steel. The slugs were first ground to remove any previous corrosion pits. A test slug was put through the preferential oxide treatment process. The oxide treated test slug and a non-treated test slug were placed in a humidity chamber for 26 hours at 110F and 98% relative humidity. The non-treated test slug had its entire surface covered with red rust. The preferential oxide treated test slug did not show any evidence of red rust forming on the surface.

In production, low carbon steel parts have been processed with this oxide treatment in Rhode Island and shipped to Mexico for assembly. Parts arrive at the customer corrosion-free and oil-free. It should be noted that the oxide layer formed has not been tested for applications in place of steam treating or chemical bluing where increased wear of the surface is desirable. Steam treating is performed at temperatures higher than this process and result in a thicker oxide layer 2.

## References


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