These horizontal furnaces have features that help minimize operating costs without sacrificing quality. They also can be equipped with a process gas system to enable surface treatments such as gas nitriding.

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There is growing demand for “universal” furnaces for annealing, tempering, nitriding, ferritic nitrocarburizing (FNC), and related processes in the medium temperature range up to 1400°F (750°C). These furnaces are usually chamber or retort furnaces operating with an air, vacuum, or protective atmosphere (Fig. 1).

The vacuum purge retort furnace is a special case. It operates with a protective inert-gas atmosphere, and features horizontal loading and external cooling systems. It also is capable of vacuum purging, where air is pumped out of the retort before heating begins and a high-purity inert gas is pumped in. Thus, the entire process is carried out in the protective atmosphere. This results in a high-quality surface on treated metal parts and minimal inert gas consumption.

Usually, vacuum purge retort furnaces operate in pairs: a high-pressure furnace is used for gas hardening, while the other — a vacuum retort furnace — is used for tempering. This effectively increases the capacity of the hardening furnace (Fig. 2).

This article highlights a vacuum purge retort furnace that is suitable for a variety of heat treating applications. Its major advantages:

- Quality surfaces on processed parts
- Temperature uniformity
- Uniform load heating and cooling
- Flexibility
- Low operating cost
- Computer control system that facilitates integration of the furnace in the production process

Furnace Technical Data
The most popular vacuum purge retort furnaces have workspace dimensions of 24 in. wide × 24 in. high × 36 in. long (600 × 600 × 900 mm) and 36 in. wide × 32 in. high × 48 in. long (900 × 800 × 1200 mm).

A smaller furnace is shown in Fig. 1. Its specifications include:

- Gross load weight, 1320 lb (600 kg).
- Operating temperature, 1400°F (750°C).
- Workspace temperature uniformity, 7°F (4°C).
- Heating system power, 75 kW.
- Vacuum level (with mechanical pump only), 10⁻¹ torr.

Note the temperature uniformity throughout the load during heating.

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Fig. 1 — Two VTR-5035/36 vacuum purge retort furnaces used for tempering.
soaking, and cooling. The maximum temperature difference between the lowest and highest temperature in the furnace workspace does not exceed 7°F (4°C). Tests were performed under stabilized conditions.

**Design and operation:**

After loading the furnace and shutting its door, the operator selects the heat treatment program number on the control panel and pushes a button to initiate the furnace cycle. All that follows is automatic.

The vacuum pump is switched on, the valve opens, and air is pumped out of the retort until a vacuum in the 10⁻¹ torr (mbar) range is obtained. After a preselected vacuum “conditioning” time, the valve closes and the retort is filled with inert gas up to atmospheric pressure.

The retort’s heating system and gas mixer are then turned on. The mixer assists heat transfer from the heated retort wall to the load. The preselected temperature ramp-up is included in the process program. Precise temperature regulation is achieved thanks to a “cascade” system that controls the temperature of both retort and heating elements. Load temperature also is measured. A valve on the vacuum pump automatically regulates gas pressure during heating, keeping it constant.

**Gas cooling:** Cooling begins after the programmed heating stage ends. The heating system is turned off and the valves connecting the external cooling system are opened. A fan blows hot gas through a water-cooled radiator. Cool gas is then returned to the retort, where it flows through the load and absorbs heat from it. The gas continues to circulate in this closed system until the load has cooled to the appropriate temperature. A constant pressure above atmospheric is maintained by adding gas through a valve to compensate for any gas volume decrease due to reduced gas temperature.

A complete heat treatment cycle may include several heating and cooling stages. The operator is told when the cycle is finished and parts can be unloaded.

**Control System Details**

The control system for the vacuum purge retort furnace consists of a freestanding control cabinet that contains a programmable logic controller (PLC), human-machine interface (HMI), sensors, circuit breakers, and safety equipment (Fig. 3).

Furnace operation is supervised and controlled by the PLC, to which all input signals from equipment and sensors, both digital and analog, are connected. It also controls mechanical components by means of digital and analog signals, and, as already mentioned, analog furnace operating parameters, such as temperature (according to PID [proportional-integral-derivative] regulation), vacuum, and pressure.

Note that all actuating systems are equipped with individual protections and elements that confirm or analyze the action. The system is 100% diagnosed and localization of possible problems takes place in real time.

**Programmed cycles:** The furnace operating sequence is recorded as a program in the controller’s central
processing unit (CPU), where it’s stored in permanent memory. Control commands and furnace operation programs are loaded into the PLC at the operator’s graphical interface. The HMI combines industrial personal computer (IPC) with a waterproof and dustproof color touch screen. Communication between the PLC and operator interface is via an Ethernet local area network (LAN), which is equipped with devices (hub, router, modem) that enable connection to an external communication network and a telephone line.

The user-friendly, flexible program ensures real-time communication between furnace and operator using dedicated screens. A typical program has these functions and capabilities:

- Graphic and dynamic furnace display.
- Status of elements visualization.
- Technical parameters display.
- Editing of recipes (furnace operating programs).
- Operation control (start, stop, hold-up, skip, programmed start).
- Current recipe editing (can be modified on-line).
- Data registration in real time, with data exchange and processing.
- Operating cycle reports.
- Alarms.
- Built-in preventive maintenance program.
- Automatic or manual operating mode.

Other essentials: Four energy-related inputs — electricity, compressed air, water, and gas — are needed for the furnace to perform its basic functions. Requirements for a typical vacuum purge retort furnace cycle (VTR-4035/36 furnace) are given in Table 1. (Temperature uniformity test results for this furnace are graphed in Fig. 4.)

Electricity supplies thermal energy to the process and powers vacuum pump motors, mixers, and controls. Compressed air actuates vacuum and gas valves and nozzles. Water cools components that might be damaged by overheating; for example, mixer seals and door and furnace flanges. It also is fed to the external heat exchanger during cooling of the workload. A clean and inert gas (nitrogen, argon) provides the protective atmosphere.

Summary
In conclusion, these retort tempering vacuum furnaces provide a unique heat treatment solution for extrusion dies, stamping dies, and other tooling for aerospace and automotive components such as camshafts, crankshafts, and gears.