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High-velocity gas flow seen as key to rapid quench

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Both theoretical calculations and experience indicate that high-velocity gas flow resulting in gas turbulence within the furnace hot zone is the *principal* factor for rapid quenching. Therefore, a high-volume recirculating gas atmosphere is essential for providing high-cfm flow through the work zone while conserving gas.

Of secondary importance is the relatively low temperature (ambient) of the recirculated gas entering the hot zone. This maximizes the thermal exchange during interaction with the high-temperature product. Thus, an efficient heat exchanger in the gas recirculation system is necessary.

A third factor is the thermal conductivity of the cooling gas. Candidates, listed in descending order of performance, are hydrogen, helium, nitrogen, and, considerably poorer (by roughly 30%), argon.

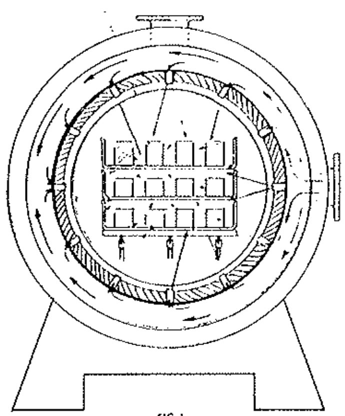
Hydrogen is not generally recommended because of explosion and fire hazard, and helium gas is expensive. Nitrogen is the most universally accepted gas except for alloys that will nitride—those containing small additions of titanium, tantalum, or columbium.

Importance of pressure

Also of importance is the system's operating pressure: sub-atmospheric, atmospheric, or positive pressure. Quenching pressure acts as a "coupling factor" and greatly influences fan-motor-horsepower loading design. For example, a fan-motor system designed for optimum performance at atmospheric pressure will be overloaded at 5 psig, probably causing the motor to shut down from thermal overload.

If a recirculating gas system is designed for operation at 5 atmospheres pressure (5 bar), grossly inefficient operation will result when quenching at only 1 atmosphere, as the fan and motor will be lightly loaded, resulting in low gas-flow rate and poor cooling performance. Furthermore, operating at gas pressures in excess of 15 psig requires that the equipment designer conform to a more stringent ASME Pressure Vessel Code, with resultant high equipment cost. Higher maintenance costs also must be considered in the light of periodic certifications required by law in many localities.

Fig. 1: VFS gas flow pattern inside hot zone



The preferred VFS quench design utilizes a gas plenum chamber enclosing the furnace hot zone with gas nozzles completely surrounding the hot zone and distributed throughout its entire length. Quenching gas pressurizes the plenum chamber and is forced through the cooling nozzles at speeds in excess of 100 mph. The quench gas interacts with the workload and is forced out through large, fixed, radiation baffles at both ends of the furnace hot zone. Hot gas exiting the hot zone first transfers a significant portion of its heat to the water-cooled furnace chamber walls, which act as a preliminary heat exchanger (25% Btu load factor). The gas continues its flow to an external fin-and-tube-type, gas-to-water heat exchanger (75% Btu load factor), and then passes through the inlet of the high-capacity gas blower to be forced back into the furnace. (See **Figs. 1** and **2**).

Cooling water circulates first through the heat exchanger and then through the jacket of the vacuum chamber, and to an open site drain. From there it flows into a 1,000-gallon water reservoir tank, which serves also as a large thermal sink, and then it is re-pumped to the heat exchanger to complete the loop. The water in the reservoir is cooled with cold make-up water from a domestic source or by an outside, thermostatically controlled, evaporative-type cooling tower. (See **Fig. 3**).

Since the furnace vessel is generally at full vacuum just prior to quench, a large gas accumulator tank (750-gallon capacity) is positioned next to the furnace and employed as an immediate source of quench gas. The tank is charged with 75- to 100-psig gas, and is connected to the furnace chamber by a 1½-inch-diameter backfill line with a solenoid-operated valve. This arrangement allows the furnace chamber and hot zone to be brought from full vacuum conditions up to a positive pressure of 15 psig in less than 10 seconds. The gas turbine blower (fan) is started during the backfill period, usually within two seconds after the backfill valve is opened. With this system, a furnace with a 50-inch-diameter hot zone can be quenched from 2400°F to below 1000°F in less than 30 seconds.

The VFS design provides excellent uniformity of gas cooling flow through the workload. This is ac-

Fig. 2: Recirculating gas system

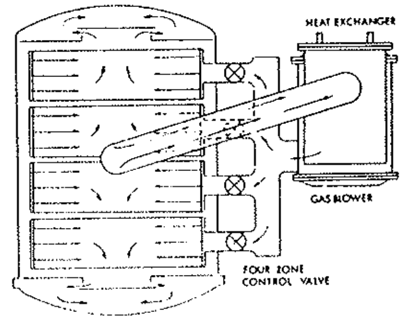


Table I
VFS Model HL36 Blowhard quench performance

Part cross-section (3" length)	Cooling rate per minute (2000°F-1000°F range)
1/2"	700
3/4"	650
7/8"	425
1¼"	400
2¼"	250

As-quenched hardness data

M1 or M2	RC scale
1/4"	67
1/2"	66
3/4"	65
1"	64
1½"	63
01 grade	
1/4"	64
1/2"	63
3/4"	62
1"	55
1½"	55
4340 grade	
5/8"	55
7/8"	55
1 1/8"	53
2 1/8"	52

Quench gas:	Nitrogen
Operating pressure:	15 psig (2 atmospheres)
Turbine gas blower:	7,500 cfm, 100 hp
Principle heat exchanger:	5x10⁶ Btu/Hour
Hot zone size:	24" W x 24" H x 38" D

Fig. 3: Water cooling system

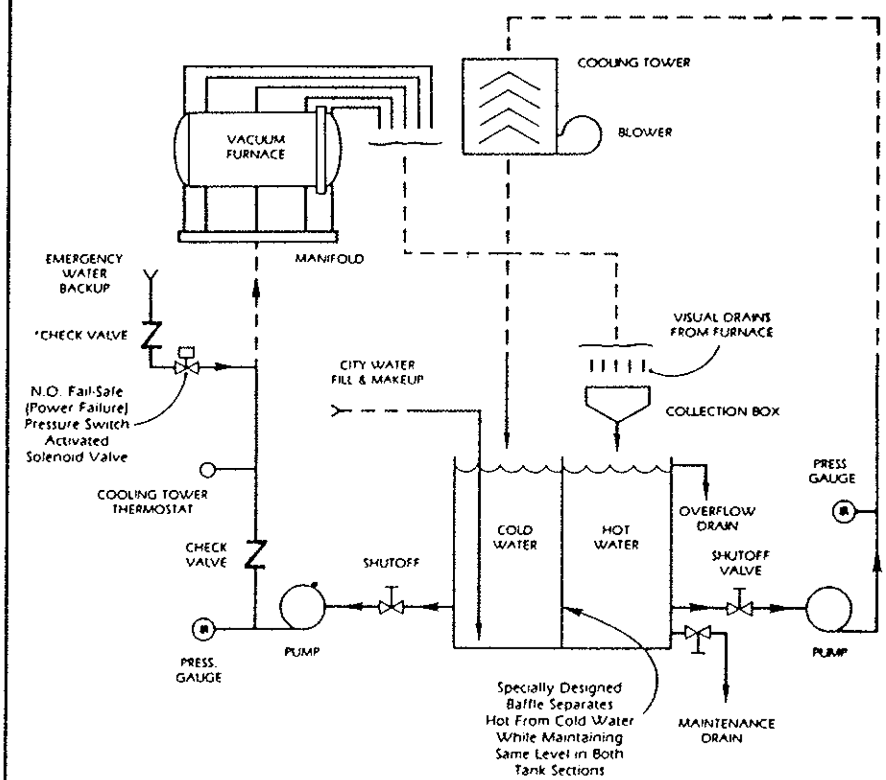


Table II: Typical quench uniformity

Time/ seconds	Control T/C	Center	Left front	Right front	Left rear	Right rear
0	1875	1885	1870	1870	1870	1870
15	1854	1885	1868	1870	1869	1868
30	1653	1818	1853	1861	1858	1859
45	1458	1668	1818	1823	1828	1817
60	1303	1553	1753	1772	1794	1757
75	1173	1426	1529	1717	1757	1630
90	1068	1314	1537	1659	1717	1621
105	970	1237	1577	1601	1674	1555
120	892	1180	1519	1543	1630	1499
150	711	1031	1351	1379	1490	1381
180	622	916	1294	1305	1402	1312

Workload 500 pounds, jet engine blades, tightly packed in two stacked baskets, 18 inches wide x 27 inches long x 7 inches high, work thermocouples located inside 1-inch-square slugs, nitrogen gas, 15 psig, 4,500 cfm, 50-hp, VFS furnace Model HL26.

complished through the gas nozzles surrounding the hot zone (full 360°) and the balanced effect of large, fixed, radiation baffled gas exit ports at each end of the hot zone. The result is uniform hardness and a minimum of part distortion. (See **Tables I** and **II**).

New design

In final testing at our Souderton, Pa., plant and ready for shipment to Metal Treating Inc. of Cincinnati, is the first example of a newly designed gas quench system that consists of four valved zones along the horizontal axis of the furnace. With this arrangement, the two end-zones could be valved closed to provide maximum gas velocity in the center section of the furnace for quenching a particularly sensitive part extremely fast. Or, in another case, a long part with nonuniform geometry could be quenched with gas-flow patterns adjusted to suit the specific part. This design provides flexibility in quenching characteristics that isn't easily obtainable in conventional systems.

VFS has begun a technical cooperation effort with the Schmetz Co. of West Germany, which has developed a sequentially reversible gas-flow arrangement within the hot zone. This concept offers considerable promise for rapid gas quenching of heavy, dense workloads of material such as 4140 alloy. Other development efforts continue at VFS, as the company is committed to optimum performance utilizing gas as a media with the vacuum furnace. **HT**

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