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# Gas Quenching With Air Products' Rapid Gas Quenching Gas Mixture

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## Introduction

Quenching is a key operating step in heat treating of steel parts. The objective of the quenching process is to cool the parts from the austenitizing temperature at a required cooling rate to produce a controlled amount of martensite in the microstructure for hardening. Selection of a quenching medium is based on steel composition, part dimension, and surface quality. The function of the quenching medium is to control the rate of heat transfer from the surface of the quenched parts. The common quenching media used are either liquid (oil, aqueous polymer solutions, and water) or gas (helium, argon, and nitrogen).

Gas quenching is an environmentally friendly quenching medium, and it produces cleaner products, eliminating the need for washing the parts after quenching and disposal of liquid quenching fluids. In addition, gas quenching provides more uniform cooling and less distortion compared to liquid quenching, thus reducing post quenching machining. One disadvantage of gas quenching is that its heat transfer coefficient is lower than that of liquid quenchants. Air Products' rapid gas quenching (RGQ) helium-argon or helium-nitrogen gas mixture increases the gas cooling rate compared to 100% helium at a given gas pressure and velocity.

## Heat Transfer Coefficient

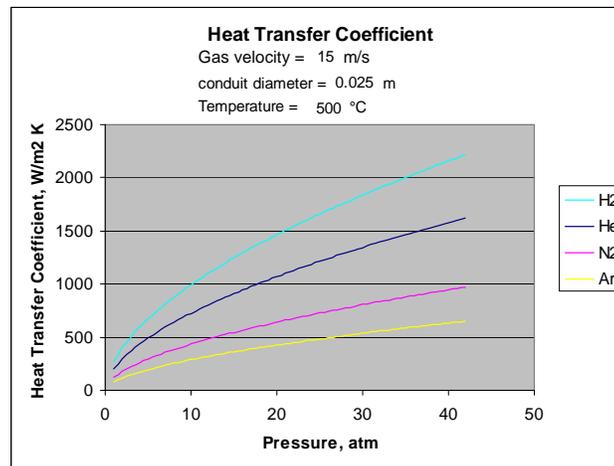
High pressure gas quenching is generally used in a pressurized chamber to quench parts from austenitizing temperatures. During gas quenching, cooling of the parts is a result of forced convective heat transfer between part surface and gases. The cooling rate of the quenched part is proportional to the heat transfer coefficient ( $h$ ) between cooling gases and the surface of quenched parts. The heat transfer coefficient can be expressed as [1]

$$h = 0.023 \frac{k}{D} \left( \frac{DV_{\max} \rho}{\mu} \right)^{0.8} \text{Pr}^{1/3} \quad (1)$$

where  $D$  = diameter of cylinder,  $k$  = gas thermal conductivity,  $V_{\max}$  = gas maximum velocity,  $\rho$  = gas density,  $\mu$  = gas viscosity,  $\text{Pr} = \text{Prandtl number} = (C_p \mu)/k$ , and  $C_p$  = gas specific heat. According to equation (1), heat transfer coefficient is proportional to gas thermal conductivity ( $k$ ), gas flow rate (velocity), gas density, and specific heat capacity ( $C_p$ ). Since gas density is proportional to gas pressure, heat transfer coefficient increases with gas pressure.

## Effect of Gas Type and Gas Pressure

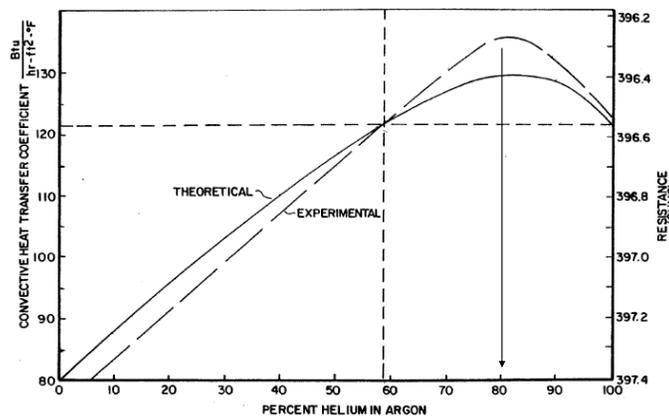
Gases with smaller and lighter molecules exhibit a greater thermal conductivity because they can move faster and longer distance without a collision. Consequently, hydrogen and helium molecules exhibit a greater heat transfer coefficient compared to heavier and larger nitrogen and argon gas molecules (Figure 1). For a given gas, heat transfer coefficient increases with increasing gas pressure. The use of lighter gases decreases the required blower motor power for gas circulation and therefore allows higher pressure to be used for a given blower design. Helium is generally used for quenching of thicker work pieces. The cost issue with helium can be overcome by helium recycling or by using Air Products' RGQ (He-Ar) gas mixture.



**Figure 1.** Effect of gas pressure on heat transfer coefficient ( $\text{W/m}^2 \text{C}$ )

## Air Products' Rapid Gas Quench (RGQ) Technology

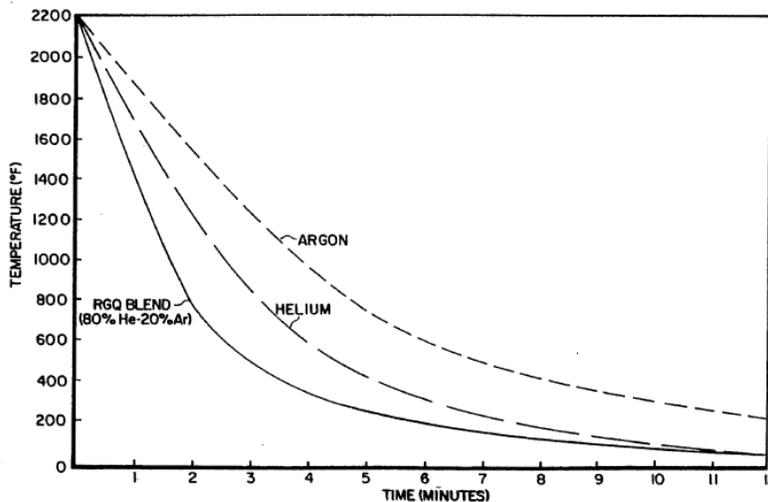
Research shows that a gas mixture of helium and argon or, helium and nitrogen has a greater cooling power than pure helium alone, as shown in Figure 2 [2]. This behavior is a result of the combined effect of thermal conductivity and gas density on the heat transfer coefficient. The use of helium-argon or helium-nitrogen mixture reduces the amount of helium needed for quenching, while providing a cooling power better than 100% helium.



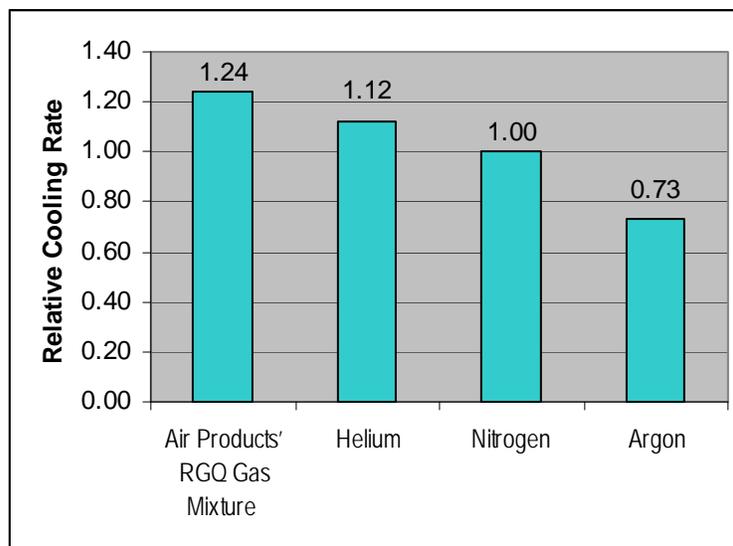
**Figure 2.** Heat transfer coefficient vs. percent helium in argon [2]

Air Products ran a series of tests in a 5-bar turbo treater furnace using a 10,000 cubic feet per minute blower capacity, with a furnace hot zone 48” diameter by 60” deep. For each test the load weighed about 1844 pounds and was made up of 1” diameter by 4” long steel cylinders located in three baskets. Ten thermocouples were placed in various locations in the load and the load was heated to 2200F in vacuum and then quenched with 100% argon, 100% helium, or helium and argon mixture (He-20% Ar).

Figure 3 is a plot of temperature vs. time for the tests. It is apparent that an 80% helium-20% argon mixture provides the fastest cooling rate. Figure 4 shows a comparison of the relative cooling ability of the Air Product’ RGQ mixture with three inert gases commonly used in vacuum furnace gas quenching. The cooling capacity improves about 10% with the helium and argon mixture over 100% helium.



**Figure 3.** Cooling curves showing Air Products’ RGQ mixture (80%He-20%Ar) exhibits a greater cooling capacity than pure helium



**Figure 4.** The cooling capacity of Air Products’ RGQ mixture is about 10% greater than 100% helium

With Air Products' RGQ gas mixture, vacuum heat treaters can increase production, reduce operating cost, improve metallurgical properties and increase furnace flexibility to handle other materials and larger loads.

## Summary

Safety and environmental considerations make gas quenching an attractive alternative to liquid quenching. The advantages of gas quenching include cleaner product, minimum distortion, and elimination of environmental problems associated with gas quenching. However, gas quenching has not been widely used because of limited cooling rate. Air Products' RGQ gas mixture increases the gas cooling rate over 100% helium at a given gas pressure and velocity.

## References

1. F. Kreith, "Principles of Heat Transfer", International textbook Co., 1958.
2. W.J. Baxter, P. T. Kilhefner, and C. E. Baukal, Jr., "Rapid Gas Quenching Process," US Patent 5173124, 1992.

## For More Information

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