Activated plasma carburising
Revolutionary technology

Air Products’ patented cold plasma technology has been designed to eliminate the internal oxidation defects that traditionally occur during atmospheric pressure carburising.

The composition, function and control of a furnace atmosphere is of critical importance for all heat treatment processes. When applied in carburising and neutral hardening or annealing operations, an oxygen-free, nitrogen-hydrocarbon heat treating atmosphere delivers a number of advantages, including improved part quality, when compared with conventional methods.

Our novel system injects a cold plasma-activated nitrogen-hydrocarbon gas blend to eliminate inter-granular oxidation, resulting in improved part quality with additional cost benefits, compared to conventional processes.
Easy to install, the cold plasma system offers minimised atmosphere toxicity, environmental impact and accurate control of the carburising process. It also features an instant turn-on/turn-off capability.

Carburising and neutral hardening or annealing of carbon steels are achieved by injecting a low-energy cold plasma-activated blend of nitrogen/hydrocarbon gas, such as methane or propane. The hydrocarbon concentration will vary between 0.1 and 5 vol.%. Since no oxygen containing gases, such as carbon monoxide or carbon dioxide are introduced, inter-granular and surface oxidation is prevented. The surface hardness of the treated steel is superior to that seen from traditional endothermic atmosphere processing as diffusion and loss of alloying elements, such as manganese or chrome, is minimised. (See Figure 1).

An externally attached, compact plasma gas injector is used to introduce the pre-blended nitrogen/hydrocarbon gas mix to the furnace. The plasma discharge acts as a catalyst for the reaction between the gases and the steel being treated, increasing the surface carburising speed compared to traditional atmosphere processes. The amount of gas and hydrocarbon introduced is controlled by an in-situ carbon-flux sensor and intelligent carbon diffusion modelling software.

![Figure 1](image)

No intergranular oxidation defects (IGO) form in tight, air-free atmospheric furnaces. In integral-quench furnaces that aspirate as much as 5% of ambient air into the atmosphere, the formed IGO are reduced to less than a negligible 3-micrometer depth.
High-voltage/low-amperage plasmas (also known as non-equilibrium plasmas, corona, glow, and/or gliding arc discharges) can enhance chemical reactions between gas molecules without excessive heating. The ionizing gas of a non-equilibrium plasma electrodes have a longer lifespan than that of thermal arcs and plasmas. This means an increase in combustion efficiency, stability and control.

Various cold and warm, non-equilibrium plasma discharges are simultaneously generated in the injector due to pressure differentials inside the gas vortices formed. The gas crosses the discharges along the path of an external and then reversed or internal vortex. Molecules of premixed reactant gases are subject to a dynamically controlled ionization, resulting in chemical reactions and products including radicals, atoms, and vibrationally excited molecules. The product stream is electrically neutral.

An iron wire resistance sensor is used to measure dissolved carbon, which enables direct monitoring of the mass-flux of carbon entering the metal. Integrated over the carburising treatment time, the mass-flux is balanced against the diffusion into the metal core to predict the carbon concentration profile and in real time. The Protherm controller compares the results, according to the set specification, and regulates the flow valves of the plasma injector for optimal use.

*Process-electronic GmbH is a member of United Process Controls*
Figure 3: Carburising Furnace – Simplified mass balance

The process control method, developed jointly by Air Products and Process-electronic, predicts the carbon profile under the steel surface from the mass of the carbon entering the metal and not by the commonly used measurements of the carburising gas concentration in the furnace atmosphere. The accuracy of this predictive method is high because it is not affected by the unreacted gases, typically present in carburising furnaces (see Figure 3). The intelligent system can also generate the process documentation required to comply with industry quality standards.