Experimental Method

Setup

The experimental setup for measuring impurities at the actual point of use (outlet of the weld torch) is shown in Fig. 1. All process lines were made of Type 304 stainless steel with ¼-in. Swagelok compression fittings. A special part, shown in Fig. 3, was fabricated to fit on the ceramic cup of the weld torch. This part enabled testing of the gas at the weld torch. All gas sampling lines were made of flexible stainless steel, Type 316.

Figure 4 shows the permeation test apparatus. Flow rates were calibrated with a wet test meter and a bubble meter. Flow meters commonly used in the welding industry, such as rotameters, can have a flow measurement error of 10–25%. A wet test meter has a maximum measurement error of less than 5%, a bubble meter error of less than 2%. Appropriate correction factors for the vapor pressure of water and the barometric pressure were used to precisely measure the flow rates.

Equipment

A moisture analyzer, Ametek Model 5700 (previously known as the DuPont 5700), was used to measure moisture levels in the sampled gas. This instrument is often used in the semiconductor industry for measuring low levels of moisture; detection limits are about 0.02–0.05 ppm moisture. The unit has a vibrating piezo-electric crystal coated with a hygroscopic polymer. Moisture in the gas is adsorbed on the polymer, changing the mass of the crystal and, thereby, its vibration frequency. The change in the vibration frequency is correlated to the moisture content of the gas (Ref. 10).

Oxygen levels were measured with a Delta F Trace oxygen analyzer; this instrument has a lower detection limit, about 0.05 ppm oxygen. The meter consists of an electrolytic cell containing potassium hydroxide solution. Oxygen in the gas forms electrons in the cell; the generated current is a measure of the oxygen concentration in the gas.

Such oxygen and moisture meters will give accurate readings in the low ppm range only if a very clean gas is used to "zero" the instrument, accomplished here with four-way switching valves and smaller gas purifiers — Figs. 1, 4. A constant purge of purified argon kept the gas sampling lines and the instruments free of moisture and oxygen. Flow from vent lines was sent to oil-filled bubblers to prevent any back diffusion of atmospheric air. Such precautions are necessary; otherwise, the instruments may take a very long time to give accurate readings. Measurement of low ppm levels of moisture in gases is a difficult task because moisture tends to coat on the walls of the tubing, slowly desorbing over time (Ref 10). Such a coating may take hours, even days of purging for complete removal.

Conclusions

Permeation of atmospheric moisture and oxygen in rubber or plastic hoses/tubing can significantly degrade gas quality. At a flow rate of 20 ft^3/h, a 30-ft rubber hose or clear Tygon tubing can easily add 35 ppm moisture to the shielding gas, and a 30-ft PVC hose can easily add 20 ppm moisture.

If a purifier cannot be installed at the weld torch, use a gas purifier at the immediate outlet of the power source. This will provide insurance against shield gas contamination from the entire delivery system upstream of the purifier.

To minimize recontamination of the purified gas by atmospheric oxygen and moisture permeation through the weld torch hose, keep hose and tubing lengths as short as possible. If a welder is working with small parts, a tubing length of 10–15 ft (3–4.5 m) to the weld torch, rather than 30 ft, should be considered. Better still, replace materials such as rubber or PVC with plastics, such as polypropylene or polyethylene, having good resistance to moisture permeation. High density polyethylene or polypropylene tubing is strongly recommended for very low flow rate applications, such as flow to the plasma in plasma welding applications.

Butyl rubber gloves are recommended when welding is done inside a glove box or inert atmosphere chamber. Glove boxes should be built of metal with Plexiglas or Lexan windows/viewing ports. Glass and Lexan are preferable over Plexiglas.

Pressure regulators with stainless steel diaphragms are recommended; regulators with rubber diaphragms should be avoided.

Most importantly, take care while designing a gas delivery system. All its components can contribute contaminants, resulting in a significant reduction in gas quality at the final point of use — the welding torch. ◆

Acknowledgement

The author deeply appreciates the contribution of Kenneth F. Krysiak, principal engineer, Hercules Inc., for his help in the preparation and testing of aluminum welds.

Trademarks

Kel-F is a trademark of 3M Corp.
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