at 30 lb/in.². Assume the argon/helium blend contains 20 ppm oxygen, 10 ppm moisture and 100 ppm nitrogen. Assume the air outside the hose is at 75°F (23.8°C) at 70% relative humidity. Atmospheric air contains about 78% nitrogen, 20.9% oxygen, 1% argon and 5 ppm helium. At 75°F, the vapor pressure of water is about 22 mm Hg (Ref. 9). Thus, the concentration of moisture in air (outside the hose) is determined to be

$$70\% \times (22 \text{ mm Hg} / 760 \text{ mm Hg}) \times 1{,}000{,}000 \text{ ppm} = 20{,}300 \text{ ppm}.$$

Table 4 shows the driving force (difference in partial pressures) of each individual component of the gas mixture, inside and outside the hose, for the above case. The unmistakable conclusion is that there are large driving forces for permeation of argon and helium from inside the hose to the atmosphere. But large driving forces exist for permeation of oxygen, moisture and nitrogen from the atmosphere into the hose.

Permeation Tests

Table 5 gives results of permeation tests conducted with 8-ft (2.4-m) hose sections of different plastics. These results show that shielding gas quality can be significantly degraded with commonly used materials of construction, such as rubber or PVC. For a standard 30-ft (9-m) weld torch hose, moisture permeation will be almost four times higher than reported in Table 5 — as much as 35 ppm with rubber or 20 ppm with PVC. Note these tests were done in an atmosphere of approximately 50% relative humidity. On hot, humid, summer days, moisture contamination by atmospheric permeation is likely to be higher.

With the Teflon hose, moisture permeation was one-tenth the value for PVC (Table 5). However, the low moisture permeability of Teflon, Kel-F and other plastics is usually at the expense of flexibility. These plastic hoses can be used for connecting gas cylinders or tanks to the delivery manifold, but they are too rigid to be used for a weld torch hose.

A further search revealed that high-density polyethylene (HDPE) and polypropylene (PP) offered sufficient flexibility along with excellent moisture barrier properties. Results indicated that permeation of atmospheric moisture with a PP tubing was less than one-tenth that with a PVC hose. In actual weld tests with a thin-walled polypropylene weld torch tubing, the welder did not experience any significant discomfort or inconvenience.

Pressure Regulators

Inexpensive pressure regulators, common in the welding industry, often use rubber diaphragms instead of the stainless steel ones used on more expensive models. Because of rubber's extremely high moisture permeability, regulators with rubber diaphragms are not recommended for critical welding applications.

The Misguided Popularity of Clear Tygon Tubing

Over the last several years, many users have switched from black PVC tubing to clear Tygon tubing, a tubing perceived to be cleaner. But, Tygon is actually similar to PVC in chemical composition. A few tests were done to evaluate the effectiveness of this clear tubing. Oxygen and moisture permeation results for 8-ft tubes are given in Tables 6–8. The results clearly indicate that the clear Tygon tubing hose is inferior to the black PVC tubing, which has black fillers to reduce permeation. Tables 7 and 8 show the characteristic trend for permeation — a doubling of the flow rate halved the permeate concentration.

The clear Tygon tubing contributed more than 1 ppm moisture for every 1 ft (30.48 cm) of tubing. Indeed, 30 ft of clear Tygon tubing could contribute 35 ppm moisture.

Table 6 — Experimental Results, Comparison of Permeation through Clear Tygon Tubing and Black PVC Tubing

Hose Material	Oxygen Permeation through 8-ft tubing ppm	Moisture Permeation through 8-ft tubing ppm
Clear Tygon	0.7	9
Black PVC Hose	0.1[a]	5.5

Flow Rate= 20 ft³/h, Operating Pressure = ~30 lb/in.²
(a) Value may be slightly higher; a different oxygen meter was used.

Table 7 — Experimental Results, Permeation of Atmospheric Moisture through Clear Tygon Tubing

Relative Humidity %	Flow Rate ft³/h	Moisture Permeation through 8-ft hose length ppm
52	20	9
53	15	13
55	10	18
56	5	34
57	2	95
~35	0.2	465

Operating pressure = ~30 lb/in.²

Table 8 — Experimental Results, Permeation of Atmospheric Moisture through Clear Tygon Tubing

Flow Rate ft³/h	Oxygen Permeation through 8-ft hose length, ppm
20	~0.7
15	~0.9
10	~1.3
5	~2.7

Operating pressure = ~30 lb/in.²

Plasma Welding Applications

In plasma welding applications, a separate gas stream at a very low flow rate, usually 0.5–5 ft³/h (0.15–1.5 m³/h), is sent to the plasma. At such low flow rates, the effects of moisture permeation can be huge (Table 7). Although oxygen permeation is usually not significant at flow rates of 20 ft³/h and higher for most plastics, it can become significant at very low flow rates, such as flow rates to a plasma torch (Table 8).

Test Welds

When impurities in shielding gas are removed with a purifier, and recontamination minimized by using a low-permeability hose, the results can be dramatic. GTA test welds were made with ¼-in. (6.35-mm) beveled aluminum plates at a weld speed of 6–8 in./min (15.24–20.32 cm/mm), at 210–250 A and 24–28 V. Even with a shielding gas containing as much as 200 ppm moisture, weld porosity was completely eliminated when the gas was purified with a resin-based purifier and the gas quality maintained with a polypropylene hose to the weld torch. Welds made with gas purification also showed a significant improvement in ductility, with fewer microcracks, as determined by bending tests.