Shielding Gas Purification Improves Weld Quality

Purification of argon shielding gas and backing gas improves impact toughness for two stainless steels

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Since the development of gas shielded arc welding processes, a variety of shielding gases and gas mixtures have been introduced, ranging from highly oxidizing to inert. The primary reason for using a shielding and backing gas is to protect 1) the melted portion of the welding wire, 2) the nonconsumable electrode (when used), 3) the weld pool, and 4) the weld bead (up to a point) from atmospheric contamination. Depending on the material being welded, gas contaminants can cause cracking, varying degrees of porosity, weld bead oxidation, arc instability, and degradation of mechanical and corrosion properties (Refs. 1–5). Other reasons to use a particular gas or mixture might be for 1) enhanced arc stability, 2) a particular mode of weld metal transfer, 3) enhanced penetration or bead profile, 4) availability or 5) easier arc ignition.

Certainly, there is no question that quality welds require quality shielding. This requires obtaining clean gas and maintaining gas quality at the point of use. From a practical point, some factors that have been identified as relating to "bad gas" and welding problems are:

- Contaminated gas cylinders (by moisture/air).
- Contaminated and/or leaking gas manifold systems.
- Damaged, defective or loose shielding/backing gas line fittings.
- Intrusion of contaminants when mixing gases.

Achieving gas quality at the point of use can be a challenge. Welding problems can show up with a single cylinder of gas or a series of cylinders. A manifold system can be particularly difficult to deal with because of the usual long length from the liquid tank or gas cylinder to the numerous welding stations served. As a result of poor gas quality, 1) defects are produced that require costly repair, 2) job completion can be delayed, and 3) job quality may be compromised.

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It is clear that a portable cost-effective system to remove contaminants from the shielding and backing gas would be useful, not only when working in the shop, but also in the field. A system has been developed using Nanochem® resin, a material that removes impurities from various gases. To prove the benefits of purification, alloys Ferralium 255 and E-Brite 26-1 were selected for a weld study because of their known sensitivity to contaminants and the effect these contaminants have on fracture toughness.

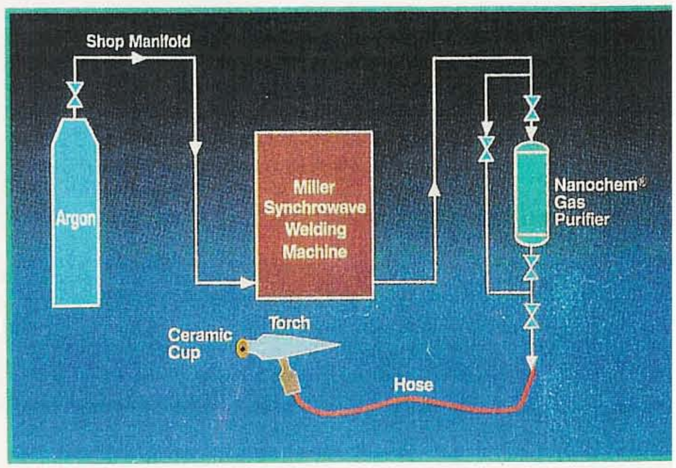

Fig. 1 — Schematic of welding process.

Welding Tests

Welding tests on Ferralium 255 (duplex) and E-Brite 26-1 (ferritic) stainless steels were conducted at the Hercules Research Center's weld shop. Initial welds were made using the gas tungsten arc welding (GTAW) process with argon shielding and backing gas containing 40 to 42 ppm moisture and 18 to 20 ppm oxygen. Additional welds were then made using the same argon, but cleaned with a gas purification system installed between the welding unit and the torch. The system removed the moisture and oxygen impurities to less than 10 ppb at the purifier outlet. A schematic of this setup is shown in Fig. 1.

Test plates were beveled to provide a 75-deg included angle and assembled as shown in Fig. 2. Prior to welding, the plates and welding wire were solvent degreased with Freon 113. Freon 113 is a reliable degreasing agent that is commonly

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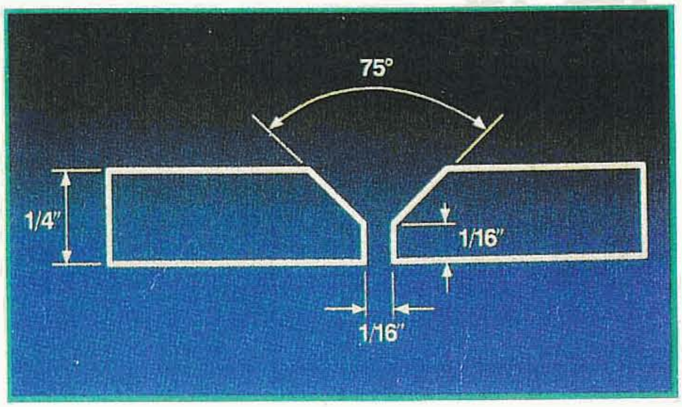

Fig. 2 — Schematic of weld joint.

used in high-purity cleaning applications.

The gas manifold to the weld torch was purged for about 1 h at a flow rate of approximately 50 ft^3/h (23.6 L/min) to minimize contamination by atmospheric air or moisture absorbed on the interior walls of the gas delivery system. By closing the weld area, wind drafts such as those caused by opening or closing of doors were eliminated during this test.

Tacking and welding were performed using argon shielding and backing gas. Shielding and backing gas impurity levels and gas tungsten arc welding parameters are listed in Table 1.

The filler metal for each alloy was a matching composition. Ferralium 255 filler did not contain nickel enrichment. Autogenous welding was avoided. The filler metal was used throughout the weld joint with care taken to protect the molten weld pool by using both a postpurge as well as a prepurge to sweep out any air/moisture that may have filtered in during shut down. Care was taken to keep the melted end of the welding wire within the shielding gas envelope.

Weld starts and stops were accomplished with a foot-operated current control. A high-frequency start was used to avoid scratching the workpiece with the tungsten electrode. Power was supplied by a Miller Syncrowave 300-A machine.

During welding, it was observed that when using the new resin purifier, the surface of the molten weld pool was absolutely clean. Without purification, the surface of the molten weld pool contained particulates (oxides) moving wildly about.

Wetting appeared to be improved with purification. Improved wetting suggests a reduction in the viscosity and/or surface energy (surface tension) due to impurity removal from the weld pool.

Weld joints were completed in three to four weld passes from one side. Penetration was complete with the backside bead contour slightly convex.

Weld Evaluation

Upon completion, the welds were examined visually. The backsides of the welds were bright and shiny with no evidence of heat tint or oxidation. Each weld was radiographed and found to be free of any apparent internal weld defects. Because the two alloys tested are sensitive to interstitial contamination, the welds were evaluated with the Charpy V-notch impact test. In this particular test the specimens were one-quarter size. Test results are summarized in Figs. 3 and 4.

The Charpy V-notch data also included mils lateral expansion, the ability of the material to flow under dynamic loading conditions, and the percent shear fracture for each impact specimen at the various test temperatures. These properties behaved in the same manner as the impact energy absorbed, as shown in Figs. 3 and 4. Gas purification significantly improved the mils lateral expansion and percent ductile shear fracture.

In these tests, the levels of contamination in the shielding

Table 1—Welding Process Conditions

Material	E-Brite 26-1	Ferralium 255
Plate Size (in.)	¼ × 12 × 6	¼ × 12 × 6
Welding wire addition	yes	yes
Shielding gas	argon	argon
Impurity level, ppm		
H_2O	40	40
O_2	20	20
Flow rate, ft^3/h	60	60
Voltage	14	14
Current (A) (DCSP)	150	150
Travel speed (in./min)	3.5–6	3.5–6

Shielding gas flow rates reflect the use of a large ceramic nozzle with a ¾-in. ID and gas lens collet body.

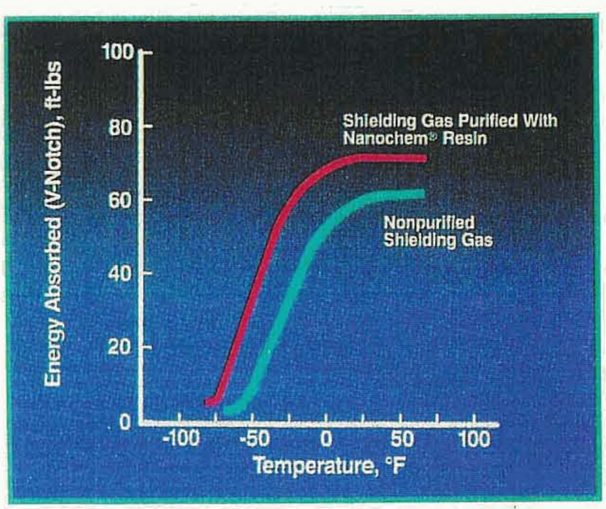

Fig. 3 — Charpy impact results of GTAW E-Brite 26-1 welds.

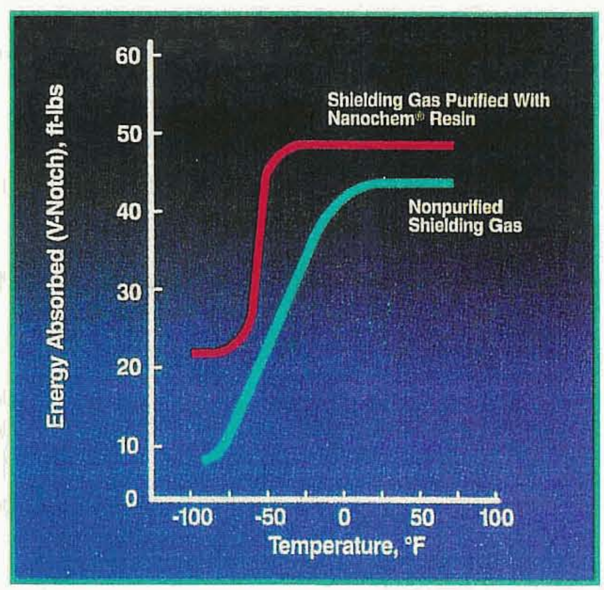

Fig. 4 — Charpy impact results on GTAW Ferralium 255 welds.

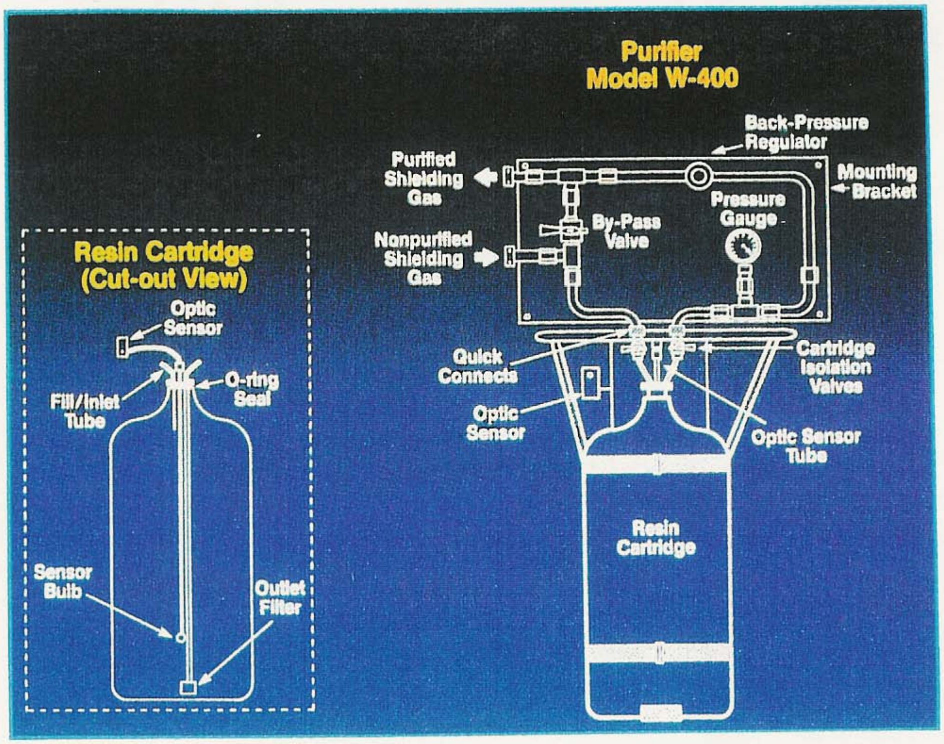

Fig. 5 — Nanochem gas purification system for welding.

and backing gases were not very great. In fact, the impurity level was only slightly higher than the normal specification of welding-grade argon, which is 50 ppm or 99.995% argon. If the level of oxygen and moisture in the cylinder had been higher, which is not uncommon, the impact toughness of those welds made without purification would have been even more inferior.

Purification

The new resin can provide effective removal of a variety of impurities to less than 10 ppb — the limit of sensitivity of our test equipment. The purifiers are simple to use, have low energy requirements and operate at room temperature.

The purifiers are most frequently used to remove moisture, oxygen, hydrocarbons (such as oils from compressors) and carbon dioxide from welding gases such as argon and helium. The efficiency of impurity removal with a purifier system is independent of the level of impurities in the gas stream. Impurity surges as high as 50,000 ppm are completely and irreversibly removed from the gas.

The gas purification system (Fig. 5) can be mounted on the wall or on the welding power supply unit. The system consists of two major components: a gas manifold and a refillable aluminum cartridge that holds 4 L of active resin.

Operation

The gas purifier system is installed in the shielding/backing gas lines between the welding power supply and the torch. Hose lengths between the purifier and torch should be kept as short as possible to obtain the highest quality gas at the torch. Short hose lengths minimize permeation of airborne moisture and oxygen through the hose walls.

The system can handle flow rates up to 60 ft^3/h (28.3 L/min). The lifetime of a 4-L (20.34 ft^3) system operating around the clock at 30 ft^3/h (14.2 L/min) with an impurity level of 10 ppm is approximately one year. Intermittent use will, of course, result in proportionally longer service life. No external heating or cooling is required to operate or control the system. A built-in fiber-optic sensor signals when the resin is spent. The probe measures the inherent color change of the resin as it goes from the active to inactive state. The sensor output is a red-light-emitting diode (LED) that illuminates as the resin approaches inactivity. The resin should be replaced within two weeks after the LED shows red.

Conclusions

The quality of welds made by GTAW will depend on the purity of the welding gas as well as the welding practices used. Purification at the point of use ensures consistency. Purification of argon shielding gas and backing gas improves impact toughness of Ferralium 255 duplex stainless steel and E-Brite 26-1 ultrahigh-purity ferritic stainless steel.

Regardless of the alloy system being welded, a purification system incorporated in the welding process will ensure that the best possible gas is delivered consistently to the weld environment. Variability in shielding and backing gas quality due to cylinder-to-cylinder variations, manifold cross-contamination problems, and/or minute piping leaks, will be essentially eliminated.

The ability of purifiers to handle impurity surges will provide insurance against major system upsets. Downtime (due to system upsets), as well as costly repairs (for rework of defective welds), should be minimized also with the use of purifiers. ♦

References

1. Krysiak, K. F. 1986. Welding behavior of ferritic stainless steels — an overview. *Welding Journal* 65(4):37–41.

2. *Metals Handbook* Vol. 13. ASM International, pp. 351, 355–361.

3. Morgan-Warren, E. J. 1978. Atmosphere control criteria for welding titanium. *Advances in Welding Process,* Vol. 1, published by The Welding Institute, Abington Hall, Abington, Cambridge, U.K.

4. Psares, G. G. The effects of the moisture contents of shielding gases on the formation of pores when aluminum is welded. *Automat. Weld.* (Journal — USSR) 32:(10)6–8.

5. Northcote, D. 1984. The gas tungsten arc welding processes — electrodes and shielding gases — criteria for optimum weld quality. *Aust. Weld. J.* 29:(1)18–20.