Wallpapering sheet lining with nickel-chromium-molybdenum alloys guidelines

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WALLPAPERING SHEET LINING WITH NICKEL-CHROMIUM-MOLYBDENUM ALLOYS

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This document is made available by the Nickel Development Institute to assist Contractors and Fabricators concerned with the design and manufacture of flue gas desulfurization/process equipment. It is intended as a guide for the wallpapering or sheet lining of carbon steel or alloy vessels, ductwork or chimney liners (stacks) where resistance to corrosion by an aggressive environment such as that encountered in flue gas desulfurization systems is necessary.

Those interested in wallpapering or sheet lining should also refer to NACE Standard Recommended Practice RP0292-98, "Installation of Thin Metallic Wallpapering Lining in Air Pollution Control and Other Process Equipment."

February 2000
INTRODUCTION

The practice of wallpapering, or sheet lining, of carbon steel or alloy structures such as process vessels, water boxes, ducting, chimney liners, etc. is well established with extensive experience in the chemical and process industries and more recently with flue gas desulfurization, FGD, equipment.

This document is concerned with the most widely employed procedure utilizing thin, typically 1.6 mm (0.062 in.), sheet which is applied to carbon steel or alloy substrates so that the sheets overlap. See Figure 1. This procedure ensures that the seam welds which are exposed to the corrosive environment are all fillet welds made between the overlapping sheets, providing full weld integrity and performance.

This document provides guidelines for the procedures employed in wallpapering carbon steel or alloy substrates with high nickel alloys such as UNS N10276 (Alloy C-276). The practices also are applicable to a wide range of lower alloyed nickel-containing materials where appropriate.

Figure 1  Lining Technique

Wallpapering with Ni-Cr-Mo alloys • Page 1
**DESIGN CONSIDERATIONS AND PLANNING**

Wallpapering (sheet lining) is generally more cost effective than the use of solid high nickel alloys or nickel-alloy clad carbon steel.

**SHEET THICKNESS AND SIZE**
The most widely used thickness is 1.6 mm (0.062 in.) although thicknesses up to 3.2 mm (0.124 in.) have been used. Welding becomes more difficult in thinner gauges and there is greater risk of mechanical damage. However, 1.6 mm (0.062 in.) thick sheet offers flexibility for ready fit-up to the substrate material in the fabricated structure.

Optimum sheet size is influenced by the geometry of the surfaces to be covered. In lining large uniform surfaces such as chimneys or stacks, wide sheets up to 2.4 m (8 ft.) may be used with considerable savings of weld metal, welding inspection and other costs. Normally 1.2 m (4 ft.) wide sheets in lengths of 2.4 m (8 ft.), 3.0 m (10 ft.), and 3.7 m (12 ft.) are used.

**LAYOUT PLANNING**

The pre-planning of handling procedures, optimum sheet size, lining layout and detail design around supports and corners is important.

**Location of fabrication**

As much fabrication as is practical should be completed in a work-shop or at ground level. Whenever possible, welding should be in the flat position. Pre-fabrication of sections reduces on-site welding time.

**Material handling procedures**

Simple, well designed equipment, for example the “picture-frame”, should be considered to safely and efficiently move sheets into place without damage.

The lining sheet should be protected against contact with carbon steel tools, clamps and other potentially contaminating surfaces. (Also see Sheet handling).

**Sheet lining layout**

Plans should be developed in advance. Usually it is preferred to start lining at the top of a unit and work down. In ducts where there

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**Figure 2 Sheet lining sequence**

Sheet 1 is tack welded to the substrate

Sheet 2 is tack welded with approximately 25mm/1 in. overlap over the first sheet. Note, the lining sheet to lining sheet tack welds should be as small as practical to minimize sheet contact problems at the overlap.

Sheet 3 overlaps the first and second sheets.

Spot or plug welds, if used, should be appropriately spaced, typically on 0.61m/2 ft. centers. Continuous seam welding of lining sheet to lining sheet follows.

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*Wallpapering with Ni-Cr-Mo alloys*
are roofs, sides and floors the sequence is frequently roof, sides, then the floor. Each lining sheet is completely tack welded in position and spot or plug welds are made prior to seal welding to an overlapping sheet. Continuous welds may be made attaching a sheet to the substrate, to provide means of monitoring local conditions such as the presence of a leak.

Sheets should be staggered to avoid the possibility of four corners coming together at one point. (See Figure 2).

**Structural support attachments and inlets**

When feasible, it is preferable to avoid internal structural supports in favor of external reinforcement. When internal supports are necessary, “windows” should be provided in the sheet lining so that the supports can be welded directly to the steel substrate rather than applying stress to the lining. Once any structural attachments are secured, the “window” area is covered, using preformed or fabricated alloy sections. Similar arrangements may be made for inlets such as pipework or manways.

**Corners**

It is recommended that sheets be attached to the carbon steel substrate with a gap of about 25 mm (1 in.) from a change in section, say, from horizontal to vertical planes, and in particular in corners. Suggested procedures are illustrated in Figures 3 and 4.

Small pre-fabricated sections about 100 mm x 100 mm (4 in. x 4 in.) can be employed to advantage. These facilitate seam welding, inspection and reduce the need for preparation of the fillet welds in the carbon steel substrate and avoid the need to pre-form the edges of large sheets.

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**Figure 3 Example of a preformed edge section**

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**PREPARATION FOR WELDING**

**CLEANING**

The substrate surface must be cleaned and free of oxide, corrosion products, oil, grease and other foreign matter. In retrofit lining, abrasive blasting with clean abrasives, such as Garnet or Fused Alumina, is preferred for surface cleaning and removing corrosion pits. Abrasive blasting should follow the treatment of corroded areas with an alkaline solution to neutralize acidic corrosion products, followed by water washing. A rust preventative should be applied after cleaning when rerusting is likely. A number of commercial compounds and weld-through paints (primers) are available that prevent rusting and do not cause problems in welding.

Care should be taken to avoid any contamination of the nickel alloy lining sheets.

**SUBSTRATE PREPARATION**

The substrate surface should be relatively smooth and free of protrusions or depressions such as pits, to allow close contact with the lining sheet for tack and spot welding.

Grinding and/or welding and grinding should be employed as needed. As far as possible, substrate preparation should be completed prior to installation of nickel alloy sheets.
SHEET HANDLING
Care in handling nickel alloy sheets is necessary. Rough handling can cause mechanical damage to the relatively thin lining materials. (Also see Material handling procedures).

Cutting nickel alloy sheets
Acceptable cutting methods include:
- mechanical shearing
- plasma arc cutting with inert gas protection
- abrasive cutting or grinding with dedicated uncontaminated discs
- punching (mechanical)
- drilling
Thermal cuts should be ground back as necessary to remove dross.

Carbon/arc cutting has caused severe corrosion problems as a result of carbon pickup and the process must not be used.

FORMING
The nickel alloys are generally stiffer than the austenitic stainless steels, requiring more effort for the cold forming of sections. Also, the alloys tend to work harden more readily than austenitic stainless steels so that allowance for greater "spring back" may be required.

The forming of simple bends on brake presses will seldom require the use of a lubricant. However, should more complex forms require the use of a lubricant, care must be taken to completely degrease the work after forming.

Care must be taken to ensure all tools are clean and free from contamination which may detrimentally influence the performance of the nickel alloy, such as iron pick-up from tools previously used for cutting and forming carbon constructional steel.

Advice should be sought of nickel alloy suppliers for specific recommendations on forming practices.

ANTI-SPATTER
Judicious use of anti-spatter compounds will minimize the need for post weld clean-up procedures. Care should be taken with application close to the weld joint as out-gassing of trapped compound may cause the formation of severe weld porosity.

WELDING PROCEDURES
The welding parameters cited in Tables 1 to 3 (found at the back of this paper) are for guidance purposes only, as optimum settings will vary with local conditions and characteristics of the equipment employed. The welding operators must be qualified to an agreed standard (for example, ASME Section IX) and will require specialized training.

ATTACHMENT WELDING
Tack welds should be sequenced so that there is close contact between the lining and substrate. A suitable tacking procedure should be employed to avoid distortion such as "wrinkling." Tack welds may be made by gas metal arc welding (GMAW) with the pulsed arc mode as used for the seal welds (Table 1) or alternatively by TIG (GTAW) (Table 3.)

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Figure 4 Example of a preformed corner section

![Diagram of a preformed corner section](image)
Guides for tack welds are:

**Liner to substrate**
These tacks provide the structural strength of the liner so they must be adequate. The tack welds should be flush with the sheet liner surface to facilitate contact by the covering sheet and avoid any necessity for grinding back.

**Seal weld tacks**
Close tacking is required to control distortion and burn through. Tacks should be as small as possible.

### SEAL WELDS
Table 1 details suggested welding procedures for gas metal arc welding (GMAW) - pulsed arc mode. Seal welds are made with a single pass only.

Gas tungsten arc welding (GTAW) also has been used for seal welds and repair welds. Suggested welding parameters are shown in Table 2.

Shielded metal arc welding (SMAW) should not be employed unless absolutely necessary because of risk of entrapped slag and other defects.

The addition of spot or plug welds to the sheet may be required to resist stresses generated by pressure variation, vibration or thermal expansion.

The various spot or plug welding procedures used are as follows:

### SPOT WELDS
A spot weld, in this context, is defined as melt through of the lining sheet by the welding process without need for pre-formed holes. For suggested welding procedure: see Table 3. The pre-programmed, automatic spot weld is cost-effective, fast and simple.

### PLUG WELDS
A plug weld, in this context, is defined as the fillet welding around the periphery of a pre-cut or prepunched hole. A gap may be left in the periphery weld to allow for the escape of hot air during the capping of the weld. The holes may be 9.5 mm (0.375 in.) to 16 mm (0.629 in.) in diameter or elongated slots 25 to 50 mm (1 to 2 in.) long.

Subsequent capping of this plug weld is necessary to prevent the risk of reduced corrosion resistance by iron dilution. The cap in matching alloy material, larger than the hole, is seal welded in place in accordance with Table 1. Care should be taken to avoid porosity due to air entrapment.

### REPAIR WELDING
Defects should be repaired using tungsten inert gas welding (GTAW) procedures once the area has been thoroughly cleaned and dried. Suggested welding parameters are shown in Table 2.

### POST WELD CLEANING
By use of appropriate welding procedures and anti-spatter compounds, post weld cleaning should be minimal and not require anything other than detergent and water washing methods.
INSPECTION AND TESTING

All weld joints must be critically inspected for defects that might allow leakage to the backing material.

Following preliminary visual inspection and repair of obvious defects (see Repair welding), weld seams and spot or plug welds must be tested for soundness using such methods as the vacuum box test (ASTM E515) or similarly effective tests such as API procedures, supplemented as necessary by dye penetrant checks in inaccessible areas.

WELD ACCEPTANCE CRITERIA

The following criteria are offered for consideration:

“A” Reinforcement of the alloy lining seal weld must be minimal to avoid the possibility of scale buildup in service which may influence corrosion resistance. Commonly accepted U.S. limitation is 4.8 mm (3/16 in.) maximum. European limitation is 0.5 of liner thickness maximum. (Term reinforcement does not imply any addition to strength of weld joint).

“B” Undercut of seal welds is a significant matter. Commonly accepted U.S. limitation is 0.25 mm (0.010 in.) maximum. European limitation is 0.1 mm (0.004 in.) maximum. Undercut is defined as a groove melted into the base metal adjacent to the toe or root of a weld and left unfilled by weld metal.

“C” As the sheet being attached to the substrate by the tack weld is to be covered by a second sheet, preferably no reinforcement is acceptable, to avoid necessity of dressing. Therefore, a tolerance of +0 - 0.4 mm (+0 - 1/64 in.) is suggested.

“D” As undercut in carbon steel is not a corrosion concern a limit of 0.25t in accordance with ANSI/AWS D9-1 is acceptable.


ANSI/AWS D1- 1 - Structural welding code - steel.

Tightest limit is 0.25 mm (0.10 in.) max in 4.8 mm (3/16 in.) to 15.88 mm (5/8 in.) thick material in primary stress members when the weld is transverse to tensile stress under any load condition. Other welds may have up to 0.79 mm (1/32 in.) undercut.
**Table 1** Suggested Welding Procedure, Gas Metal Arc Welding (GMAW) - Pulsed Arc Mode  
Wallpapering - Sheet Lining (Seal welds, intermittent tack welds and plug welds)

Sheet Materials: UNS N10276 (Alloy C-276) or other high-nickel alloys may be used

Filler Materials:  
- Welding Wire 0.8 mm, 1 mm, or 1.2 mm Diameter  
- AWS A5.14: ERNiCrMo-4  
- (Alloy C-276 filler metal)  
- UNS N10276, 56Ni, 16Mo, 16Cr, 5Fe, 3.5W  
- Other filler compositions are available.

Positions: All

Preheat: Not normally required, in low temperature conditions preheat may be necessary to prevent moisture condensation in weld area.

Shielding Gas: 75% Helium - 25% Argon. Lower Helium content mixtures are being used in Europe because of reduced cost. (see note)

Electrical Characteristics: Polarity: DCRP (electrode positive)

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<td>about 2.0</td>
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<tr>
<td>Base Amps (A)</td>
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<td>20 - 30</td>
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</tr>
<tr>
<td>Mean Volts (V)</td>
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<td>24</td>
<td>20</td>
</tr>
</tbody>
</table>

Travel Speed:  
- Up to 0.5 m/min for manual operation.  
- Up to 1.5 m/min automatic with increasing arc energy.

These figures are to be used as a guide only, conditions will vary with equipment used and location (eg. shop or site)

NOTE: Other gas mixtures may be applicable. With recent development of electronically controlled power sources, indications are that welds can be made in all positions utilizing 100 % Argon. However, addition of Helium is stated to improve weld quality at lower levels of operator skills. Present work indicates that a very small addition of active gas (less than 0.5 %) stabilizes the arc and aids wet-out.
### Table 2  Suggested Welding Procedure for Gas Tungsten Arc Welding (GTAW), Wallpapering - Sheet Lining (Seal welds, intermittent tack welds and plug welds)

<table>
<thead>
<tr>
<th>Sheet Materials:</th>
<th>UNS N10276 (Alloy C-276) or other high-nickel alloys may be used</th>
</tr>
</thead>
</table>
| Filler Material: | Welding Filler 1.2 - 1.6 mm Dia  
|                  | AWS A5.14 ERNiCrMo - 4  
|                  | (Alloy C-276 filler metal)  
|                  | UNS N10276, 56Ni, 16Mo, 16Cr, 5Fe, 3.5W |
|                  | Other filler compositions are available. |
| Positions:       | All |
| Preheat:         | In low temperature conditions preheat may be necessary to prevent moisture condensation in weld area. |
| Shielding Gas:   | 100% Argon  
|                  | Use of gas lens attachment to the welding torch provides better gas protection to the weld metal. |
| Electrical       | Polarity: DCSP (electrode negative)  
| Characteristics: | Pointed Tungsten electrode diameter:  
|                  | 1.6mm (1/16 in.) or 2.4mm (3/32 in.)  
|                  | (2% Thorium preferred for longer life)  
| Amperage:        | 40 - 60 amps* |
| Voltage:         | 10 - 13 volts |
| Travel speed:    | Manual 100 - 150 mm/min*   
|                  | Automatic 400 - 1000 mm/min |

*Amperage and travel speed are starting guides. Depending on joint conditions, acceptable welds can be made outside indicated ranges.

**NOTE:** For guidance purposes only - conditions will vary with equipment used and location (eg. shop or site)

### Table 3  Suggested Welding Procedure, Gas Metal Arc Welding (GMAW) - Pulsed Arc Mode, (Arc spot welding for plug and tack welds)

<table>
<thead>
<tr>
<th>Sheet Materials:</th>
<th>UNS N10276 (Alloy C-276) or other high-nickel alloys may be used</th>
</tr>
</thead>
</table>
| Filler Metal:    | AWS A5.14 ERNiCrMo - 4  
|                  | (Alloy C-276 filler metal)  
|                  | 1.6 mm Diameter  
|                  | UNS N10276, 56Ni, 16Mo, 16Cr, 5Fe, 3.5W GMA spot welds may also be made in  
|                  | 1.6 mm thick alloy sheet with 1.2 mm Diameter wires.  
|                  | Other filler compositions available. |
| Positions:       | All |
| Preheat:         | In low temperature conditions preheat may be necessary to prevent moisture condensation in weld area. |
| Shielding Gas:   | 100% Argon or Argon-Helium mixtures |
| Electrical       | Polarity: DCSP (electrode positive)  
| Characteristics: | Amperage: 300 amps  
|                  | Voltage: 28 volts  
|                  | Arc time: 0.5 seconds to 1.0 second |

**NOTE:** For guidance purposes only - conditions will vary with equipment used and location (eg. shop or site)
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