Practical Guidelines for Fabrication of SS409M

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Guidelines for the Fabrication of SS409M

(INDIAN RAILWAY SPECIFICATION IRSM44 IS SIMILAR TO SS409M in respect of Fabrication Characteristics)

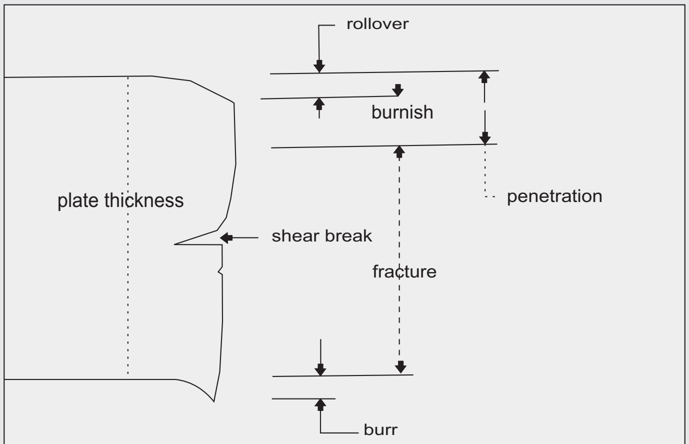
CUTTING

Cutting of 409M using the oxyacetylene or oxy-hydrogen processes is not practical:

Cutting is subdivided into:

Guillotining

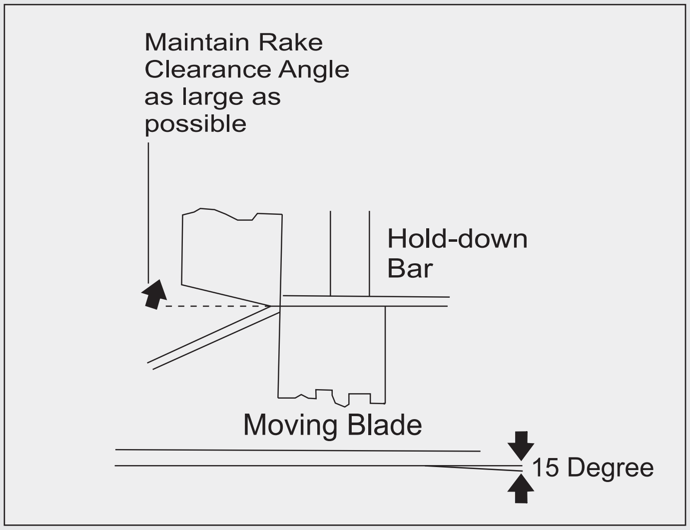
The guillotine is normally used for cutting steel up to 16mm thick. The maximum capacity of the guillotine (for mild steel shearing) should be downgraded by 30-40% for cutting 409M because of 409M's greater shear strength, e.g., if maximum shearing capacity is 16mm (mild steel) then the maximum shearing capacity will be 11mm for 409M. “Shear breaks” on the cut edge can be prevented by using well sharpened, correctly aligned and set blades, especially for plate heavier than 8mm.



Goometric leatures of sheared edge.

Burnish and burr heights increase with increasing blade blundness and blade gap. Rollover tends to be excessive.

Shear break or splitting should not be confused with laminations as the former is a result of the shearing process parameters, while the latter is a material defect. Shear break is caused by excessive cutting speeds, blade clearance etc.



The most suitable shear blades for cutting 409M and stainless steel are made of high carbon – high chromium tool steel. The blades must be kept sharp – a good test is to cut a piece of paper.

Good practice is to wipe the blade and hold down pads free of adherent mild steel particles prior to cutting 409M. This will avoid mild steel contamination.

Where possible, shearing speeds should be reduced by up to 20%. This will prevent shear break of thick plates.

Plasma cutting

Due to the high chromium content of 409M, it cannot be cut with the conventional oxy-acetylene torch. Plasma cutting and profiling of 409M is the fastest and most economic thermal cutting speeds together with a clean smooth surface finish can be achieved. Due to the fast cutting speeds, the heat affected zone is very narrow, minimizing the effect on the properties of the material. Thin plates can be stackcut. Any discoloration of the cut edge can easily be removed by grinding or by using a stainless steel wire brush. If no subsequent welding is undertaken, edge discoloration must be removed, followed by passivation.

The following guillotine clearance settings are recommended.

Plate Thickness (mm)	3	6	10	12	16	20	22	25
Clearance Settings (mm)	0.1	0.15	0.25	0.3	0.4	0.45	0.5	0.6

Cutting Gases

Today, there are many makes of portable plasma cutting machines which are able to cut up to 25mm thick plate. These portable units make use of compressed air, (300-500 KPa) rather than mixed plasma gases. These machines are light, (weighing not more than an oxy-acetylene set) economical and efficient. Consumable item is the torch tip.

For gauges in excess of 25mm, heavier mixed gas plasma cutting machines will have to be used. Oxygen-free nitrogen is the most economical cutting gas. Other gases which can be used include mixtures of argon and hydrogen or nitrogen and hydrogen. The secondary shielding gas can be one of numerous gases such as welding grade carbon dioxide which is inexpensive. Argon or argon hydrogen mixtures are often used where a better, cleaner cut is required, although these mixtures are more expensive.

Laser Cutting could be practiced for thinner sheets. Water Jet Cutting will be cost effective for thicker plates.

FORMING

Bending

Despite the fact that 409M does not work harden appreciably, more power is required to bend this steel due to its higher proof strength. The maximum capacity of the bending press is reduced by 40% for bending. 409M generally exhibits greater spring back than mild steel during bending. This should be compensated for by slight over bending e.g. + or – 5% on a 90° bend. Use of hydraulically operated press brakes is recommended for bending 409M.

The minimum inner bend radius recommended for 409M is twice the plate thickness. Cracking problems can be prevented during bending of heavy (12mm +) sections by preheating the bend area to around 150° C. Reverse bending at ambient temperatures is not recommended. Severe bends should be carried out transverse to the rolling direction.

It is also recommended that severe bending on thicker plate sections be carryout before welding to avoid the possibility of heat affected zone cracking. Edge cracks can be avoided by placing the cut face on the outside radius of the bend and the sheared face on the inside. This type of cracking can also be prevented by grinding the outside radius point of bending into a rounded profile, thus eliminating the natural stress concentration point.

409M could be formed with greater accuracy in Hydro Folding Machines. Longer sections could be made by cold roll forming.

Abrasive Cut-off Wheels

Abrasive disc cutting is acceptable for limited lengths of cut. Only dedicated discs should be used and suitable control of the storage of these must be exercised. Excessive overheating must be avoided. Use can be made of water soluble oil for cooling / lubrication.

Aluminium oxide discs of the vitrified or resinoid bonded types are suitable. Zirconia and silicon carbide discs are not recommended.

Arc-Air Gouging

Arc-Air gouging is a suitable method of cutting provided the recommended settings are adhered to in order to produce acceptable cuts. All cut edges must be ground back (using dedicated grinding discs) to a depth of approximately 2mm to remove the heat affected zone before further fabrication. Areas not subsequently welded must be descaled and passivated.

Power Cutting

Ferrite powder injected into an oxy-acetylene flame can be used to cut 409M, but the unsightly edges produced must be ground back approximately 2-4 mm using dedicated discs before further fabrication, to ensure that the plate edge is of an acceptable quality. Areas not subsequently welded must be descaled and passivated.

WELDING PROCESS

Both Manual Metal Arc (MMA) and Metal Inert Gas (MIG) welding processes have been used extensively with great success on 409M. Tungsten Inert Gas (TIG) welding is usually used to weld the thinner plate thicknesses e.g. 1.0 – 3.0 mm. The use of combined processes, e.g., TIG root followed by MIG filler and cap can be considered as a means of improving both quality and productivity.

The Submerged Arc Welding (SAW) process has been used in very few instances and only after extensive procedure testing. The high heat input and slow cooling rate associated with the process can cause excessive loss of toughness in the heat-affected zone, so that, great care is essential during design and fabrication to avoid serious service failures. The process therefore should be carefully controlled.

Flux Cored Arc Welding (FCAW) has also been used successfully particularly for fillet welds where full penetration is required.

Spot welding and friction welding have also been successfully used to join 409M provided joint crevice effects are considered.

MANUAL METAL ARC WELDING (MMA)

Electrical Characteristics:- AC/DC, D.C.E.P. (Direct Current Electrode Positive).

Consumables:

Electrodes having acid-rutile, neutral or basic flux coatings are generally preferred as they reduce the likelihood of slag inclusions. The recommended grade of electrode is the AWS E309L type although E308L and E316L can also be used.

Synthetic electrodes are suitable and provide a cost effective filler material. The electrode pre-heat and storage requirements recommended by the electrode manufacturer) must be strictly adhered to.

Typical Suggested Voltages and Currents for Different Types and Diameters of Electrodes (Horizontal welding)*

ELECTRODE		VOLTAGE	CURRENT
Type	Dia (mm)	(V)	(A)
Rutile	1.6	19-21	30-40
AC/DC	2.0	20-22	40-55
	2.5	20-22	60-75
	3.25	21-23	95-115
	4.0	21-23	120-140
Basic	1.6	24-30	35-45
DC+	2.0	24-30	45-60
	2.5	24-30	65-80
	3.25	24-30	100-120
	4.0	24-30	130-150

*Adjust for positional welding

In all cases the manufacturer's recommendations should also be followed.

METAL INERT GAS WELDING (MIG)

MIG welding is very versatile, in that a wide range of material thicknesses and positions can be accommodated. Weld quality and weld speeds that can be achieved are both high with MIG welding. Lack of side wall fusion problems commonly associated with this process must be guarded against.

Electrical Characteristics is D.C.E.P. (Direct Current Electrode Positive)

Very high heat inputs are associated with the spray arc process. It is recommended that the mechanical properties achieved by welding with this process be carefully evaluated in terms of the joint requirements. The welding should in any case be carried out in accordance with an approved welding procedure.

Consumables :

a) Filler Wire :

The austenitic stainless steel consumable wires are recommended e.g.

AWS - ER309L, (308L) ER312, and ER316L or equivalent.

“High Silicon“ Wires to the above compositions can improve penetration, Reduce spatter and Improve weld appearance.

Note : The use of filler materials other than those listed (including the “ so called” matching consumables) require procedure testing before being approved & are better avoided.

b) Gas :

The shielding gas should be an Argon -1 to 2% Oxygen mixture or Helium Argon mixtures. Argon based gases with CO_2, can also be used for the flux cored arc welding process.

Gas flow rate under shielded welding conditions must be at least 14 L/min. Higher gas flow rates will be required if welding is being carried out in draughty or exposed conditions.

TYPICAL WELDING PARAMETERS FOR MIG SHORT ARC & SPRAY ARC WELDING

Type of Arc	Position	Wire Diameter (mm)	Current (A)	Voltage (V)	Speed (mm/sec)
Short Arc	Flat	0.8	130-140	22-24	3.0-4.5
	Vertical	0.8	110-130	20-22	3.0-4.5
Spray Arc	Flat	1.2	180-280	24-28	3.0-4.5
Spray Arc	Flat	1.6	325-375	25-28	3.0-4.5

TUNGSTEN INERT GAS WELDING (TIG)

This process is generally limited to sheet up to 2.5mm, TIG welding is also used for fusion of the root run on heavy gauge weldments. In order to ensure adequate ductility in the weld, a suitable austenitic filler wire should be used.

Electrical Characteristics is D.C.E.N. (Direct Current Electrode Negative).

Electrode is 1-2% thoriated tungsten using a 30-60 degree vortex angle (pointed tip) for optimum welding penetration for the least current used.

Consumables :

a) Filler Wire is "AWS - ER309L, ER308L and ER316L or equivalent.

b) Pure argon must be used as the shielding gas. Typical flow rates are between 8 and 14 L/min.

Tungsten inclusions occur most commonly at striking and the use of striker pads is recommended.

A closed edge butt joint must be used for autogenous welding. The use of an inner gas shield (purging gas) may be an advantage, especially in pipe welding. Argon is generally used for this purpose, although cheaper gases such as nitrogen or a gas mixture consisting of 92% nitrogen and 8% hydrogen may be employed. The additional gas shielding at the rear of the groove enables a fine, oxide-free root surface to be more easily achieved. This is of particular advantage when the root surface is not accessible for grinding as it provides a root wetting action which ensures the integrity of the root. Because of the low welding speed and high heat input associated with this process special attention must be paid to distortion control, e.g. use of chill bars and jigs.

Note : The use of filler materials other than those listed (including the "so called" matching consumables) require procedure testing before being approved and are better avoided.

PLASMA ARC WELDING (PAW)

This is a development of the TIG welding process. Plasma welding has become increasingly common as a fully automatic process for the welding of components such as 409M piping. The Plasma-MIG variation of the process is essentially the same except that filler wire is used during the welding process.

Electrical Characteristics is D.C.E.N. (Direct Current Electrode Negative).

Electrode:

1-2% thoriated tungsten.

Consumables:

a) Filler Wire :

AWS-ER309L, ER312 and ER316L or equivalent.

b) Gas:

Both plasma gas and shielding gas must be high purity argon or argon-hydrogen mixtures to ensure that electrode contamination does not occur. Typical flow rates are 3.7- 4.7 L/min for the plasma gas and 9-20 L/min for the shielding gas.

Note : The use of filler materials other than those listed (including the "so-called" matching consumables) require procedure testing before being approved.

409M WELDED TO OTHER MATERIALS

409M can be welded to other materials. e.g., carbon steel and stainless steels, using the above mentioned processes.

AWS – 309L/308L/316L welding consumables are recommended.

The filler materials used in the welding of dissimilar metals to 409M should be selected to be compatible with both materials and may require procedure testing. Note that "matching" electrodes are unacceptable for all cases where 409M is welded to other materials, e.g. carbon steel and stainless steel.

JOINT DESIGN & PREPARATION

The quality and integrity of welds is an important feature of any fabrication. Strength requirements of the joints must be calculated and incorporated in joint design.

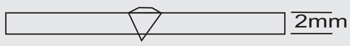
BUTT JOINTS

The load carrying capacity of a welded butt joint is influenced by the degree of penetration. Loading conditions should be analysed and a suitable weld size computed and specified on design drawings. Partial penetration welds should be used only where static weld strength is required. It is strongly recommended that the crevice formed by partial penetration weld joint be sealed if they are to be exposed to a corrosive environment as crevice corrosion may occur.

For full penetration welds, back grinding or gouging is necessary before welding on the reverse side. In general, the joint preparations shown represent the optimum joint configurations for minimum weld metal deposition and optimal cost economy for the various thicknesses of material.

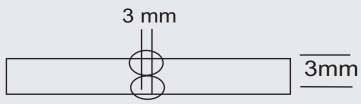
weld joint Desjgn

closed Square Butt



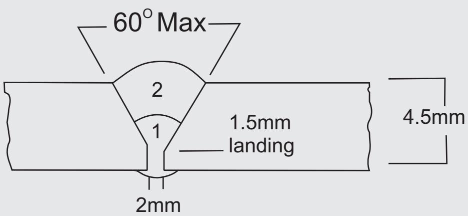
Comments: Up to 2mm max thickness.
1 pass

open Square Butt

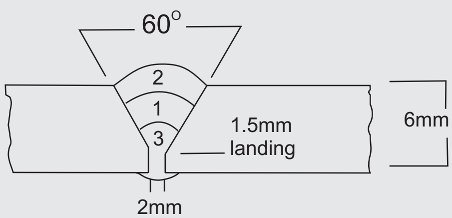


Comments: 3 - 4.5mm max (Plate thickness)
Backgrind root and reweld.
2 passes.

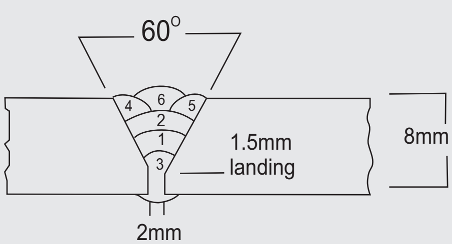
Typical Single vee Butt Joints



Comments : Alternative design to open square butt.
Back grind root and reweld.
2 passes



Comments : Back grind root and reweld.
3 passes



Comments : Back grind root and reweld.
6 passes

Fillet Joints

The specific size of a fillet weld is usually dictated by the thickness of the thinnest plate to be joined. In many instances the purpose of the weld is to attach stiffeners and brackets where full strength is not required, thus allowing the use of smaller welds. In all cases, the designer should minimize the size of the fillet weld, because, the volume, weight and cost of the weld metal required and the resultant distortion increase by the square of the fillet leg length. For corrosive applications, crevices formed by partial penetration joints must be sealed.

MINIMUM FILLET WELD SIZES

(For Static Strength Applications)

Base Metal Thickness (mm)	Minimum Weld Size (leg Length) (mm)
up to 6	3
6 – 12	5

Control of Distortion

409M behaves similarly to mild steel as far as distortion is concerned. Where practical, all welds must be deposited in a sequence that will balance the applied heat of welding so that distortion can be minimized.

ASSEMBLY

Tack Welding :

409M should be assembled and tack welded in a similar fashion to austenitic stainless steels. Tack welds should be spaced about 300 – 500 mm apart, and should not be more than 30mm in length.

It is important to use the same filler material for tack welding as that to be used for completing the weldment. Tacking should always commence from the centre out towards the unrestricted ends. Removal of cleats or dogs should be undertaken by grinding, rather than by striking with hammers, etc.

Heat Treatment

1. Preheating

   No preheating is recommended for 409M prior to welding, except to bring the temperature of the material upto 25°C (removal of cold chill).

2. Post weld heat treatment

   This is generally not required except in certain cases where annealing may be required. (e.g. vibrating equipment).

General Welding Procedure

1. Surfaces to be welded and surfaces adjacent to a weld must be free from loose or thick scale, slag, rust, moisture, grease and other foreign material that would prevent production of acceptable quality welds. This can be achieved in part by thorough degreasing of the weld joint.

2. Surfaces and edges to be joined must be smooth, uniform, and free from fins, tears, cracks and other discontinuities which would adversely affect the quality or strength of the weld.

3. Good welding practice to avoid craters, burn through and excess penetration will ensure that premature failures do not occur in service.

4. The work must be positioned for flat position welding whenever possible.

5. Before tack welding, ensure that the joint geometry is correct e.g. fit up, root opening, edge preparations, etc.

6. The classification and size of electrode, voltage, amperage and weld speed must be adjusted to suit the thickness of material, type of weld joint, welding position and other circumstances at the time of welding.

7. Current settings should be at the lower to medium end of the range recommended by the electrode/filler wire manufacturer.

8. Where basic coated electrodes are used they should be baked in an oven at a temperature of 150 - 200° C for one hour or as recommended by the manufacturer. These electrodes should be used within 30 minutes of their removal from the oven.

9. Striking the arc must be performed with caution to prevent arc strikes outside of the weld joint. Arc strikes are hard spots which can affect both the mechanical properties and corrosion resistance of the steel.

10. Avoid weaving and back stepping, to reduce heat input.

11. Back grinding or gouging to sound metal on the reverse side of the weld will be necessary for full penetration welds on plate thicker than 3 mm.

12. When doing multi-pass runs, interpass temperatures should not exceed 100°C.

13. Before welding over previously deposited metal, all slag should be removed and the weld and adjacent base metal should be brushed clean using a stainless steel wire brush. This requirement applies not only to successive layers but also to successive beads and to the crater area when welding is resumed after any interruption.

14. Post weld cleaning in the form of removal of scale (mechanically and/or chemically) followed by passivation is required to remove the discoloration from welding and to restore optimum corrosion resistance to the weldment.

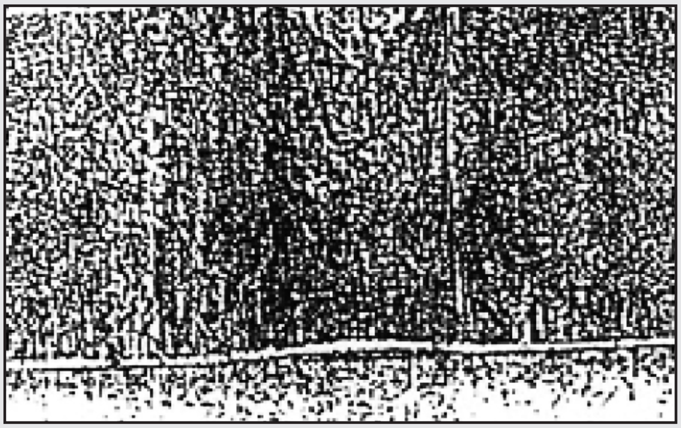
WELD REPAIRS

The removal of weld metal or portions of the base metal may be undertaken by machining, grinding, chipping or gouging. It should be performed in such a manner that the remaining weld metal or base metal is not nicked or undercut.

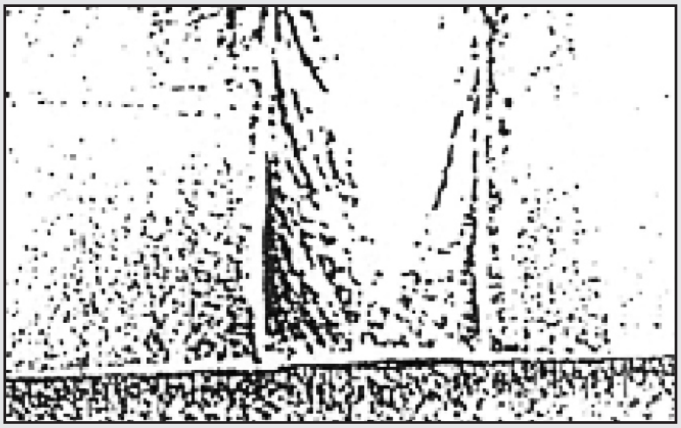
Unacceptable portions of the weld (e.g. weld beads) should be removed without substantial removal of the base metal. It is recommended that a smaller electrode than that used to make the original weld be used to make up for any over grinding, undercut etc. The surfaces should be cleaned thoroughly before welding. Careful attention must be exercised to avoid / reduce distortion.

POST WELD CLEANING

AS WELDED



AS PICKLED



The heat generated during welding stainless steels affects the naturally passive oxide film adjacent to the weld. To restore maximum corrosion resistance, post weld cleaning must be considered.

All welding processes give rise to a zone of discoloration in the weld area. This discoloration consists of a layer of thermally-formed oxides and particles from the protective flux. In corrosive atmospheres or environments, an electro-chemical cell can be set up between this oxide layer and the underlying metal which can promote localized corrosion.

To prevent such corrosion it is necessary to remove all traces of discolouration from the weld area. In abrasive applications the weld discolouration will be removed by wear mechanisms and post-weld cleaning may not be necessary.

If 409M is to be used in contact with aqueous solutions it is essential the post-weld cleaning and passivation be undertaken, so that adequate service life can be ensured.

Mechanical Cleaning

1. Wire Brushing: It is often possible to remove a substantial amount of discoloration from weld areas by vigorous brushing with stainless steel wire brushes. Brushes must not previously have been used on materials other than stainless steel or 409M itself.

2. Grinding: Dressing of weld and removal of discoloration can be carried out by grinding. Only dedicated grinding wheels and discs should be used. The presence of iron, iron oxides and other undesirable materials in the grinding medium will adversely affect 409M's appearance and corrosion resistance.

3. Flapper Wheel Abrasives: These are often used for cleaning weldments, aluminium oxide abrasive being the preferred medium.

4. Abrasive Blast Cleaning: The abrasive should be stainless steel shot, copper slag (Angrit) or alumina free of metallic iron, iron oxides or chlorides.

   a. Grit Blasting

   b. Sand Blasting

   c. Glass Bead Blasting

4a. Grit Blasting: Grit Blasting is generally unsatisfactory because grit is seldom clean, and even if it is initially, it soon becomes contaminated with abraded material. Grit blasting leaves a rough profile that makes the 409M prone to crevice corrosion whether or not the surface is free of iron. Grit blasting should be avoided unless the steel is to be painted.

4b. Sand Blasting: This method is generally unsatisfactory. However, for a severely contaminated surface sand blasting can be used as a last resort. New clean sand will remove debris and heavy iron-contamination from the surface.

4c. Glass-Bead Blasting: Good results have been obtained with clean glass beads. Before applying this method, a test should be made to determine that it will remove the surface contamination. Also periodically test, to see how much re-use of the beads can be tolerated before they begin to re-contaminate the surface.

Chemical Cleaning

1. **Pickling:**

   Pickling formulations based on Nitric and Hydrofluoric acids are available and are suitable for post-weld cleaning of 409M. It is important to follow manufacturer's recommendations. Thorough washing with copious quantities of clean cold water is required after pickling to remove all traces of the acids used.

2. **Passivation:**

   In most cases pickling suffices, but in arduous conditions involving exposure to aggressive chemical environments, passivation should be considered.

   409M relies on a chromium rich surface oxide film (passive film) to resist corrosion. Post-weld cleaning removes this protective film and unless it is restored some localized staining may result.

   Passivation with an oxidizing acid restores the passive film.

Passivation Method

1. Passivation of 409M should be carried out within as short a period as possible after post-weld cleaning.

2. A solution made up of 10 to 20% Nitric acid balance H_2O is suitable for passivating 409M.

   The temperature of the passivating solution should not exceed 30°C.

Proprietary passivation solutions are available for 409M and manufacturer's recommendations should be followed.

Thorough washing with clean, cold water after passivation is necessary to remove all traces of the acid used.

Note: Pickling is normally undertaken using formulations based on acids which are harmful if ingested or allowed to come into contact with the skin. Suitable precautions (e.g. protective face masks, rubber gloves, availability of first aid, etc,) must be observed. Disposal of pickling formulations should be carefully controlled.

COATING SYSTEMS

Coating of 409M

Laboratory assessments indicate that the paint systems listed below can be applied to 409M (in the No.1 finish) without having to resort to primers and undercoats. The 409M surface should however be clean and degreased with a water dispensable degreasing agent.

The following systems are recommended for No.1 finish only. Two coats of the paint system as per the manufacturers' specifications should be applied.

409M (Mill Finish)	409 (Weathered)
*Alkyd Enamel	*Alkyd Enamel
Chlorinated Rubber Enamel	Chlorinated Rubber Enamel
Vinyl Enamel	Exterior Acrylic Emulsion
Exterior Acrylic Emulsion	

Note : Paint manufacturers should be contacted regarding suitability of their paint systems under different environments and they must recommend the primer and finishing coat systems which are compatible with each other as well as being suitable for the environment.

Zinc chromate etch primer is the preferred primer coat for 409M in case of 2D & 2B finish. This may be followed by enamel coat of desired color.

(Prepared by ISSDA in consultation with Sri K R Ananthanarayanan, Stainless Steel Consultant, Bangalore (Formerly with SAIL, Salem Steel Plant).

The Indian Stainless Steel Development Association (ISSDA) was founded in 1989 by Primary Producers of Stainless Steel in India. The primary object of the Association is to provide free and authentic technical information on the appropriate grade selection and fabrication of stainless steel.

These are specifically addressed to engineers, architects, builders, rail and road transportation companies, water industry and fabrication units. It conducts conferences and in-house workshops for end user sectors to become aware of the benefits of stainless steels.

ISSDA will be celebrating its 20th anniversary in 2009. *(for details: check www.stainlessindia.org)*

ISSDA publishes a quarterly magazine 'Stainless India', devoted to new applications of stainless steel. This magazine is distributed free of charge. To obtain a copy send your postal address, contact details and nature of profession/business to nissda@gmail.com. Currently over 7,000 copies of this magazine are distributed across India

The Association currently has over 150 member companies consisting of primary producers and downstream processors of stainless steel and end user sectors.

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