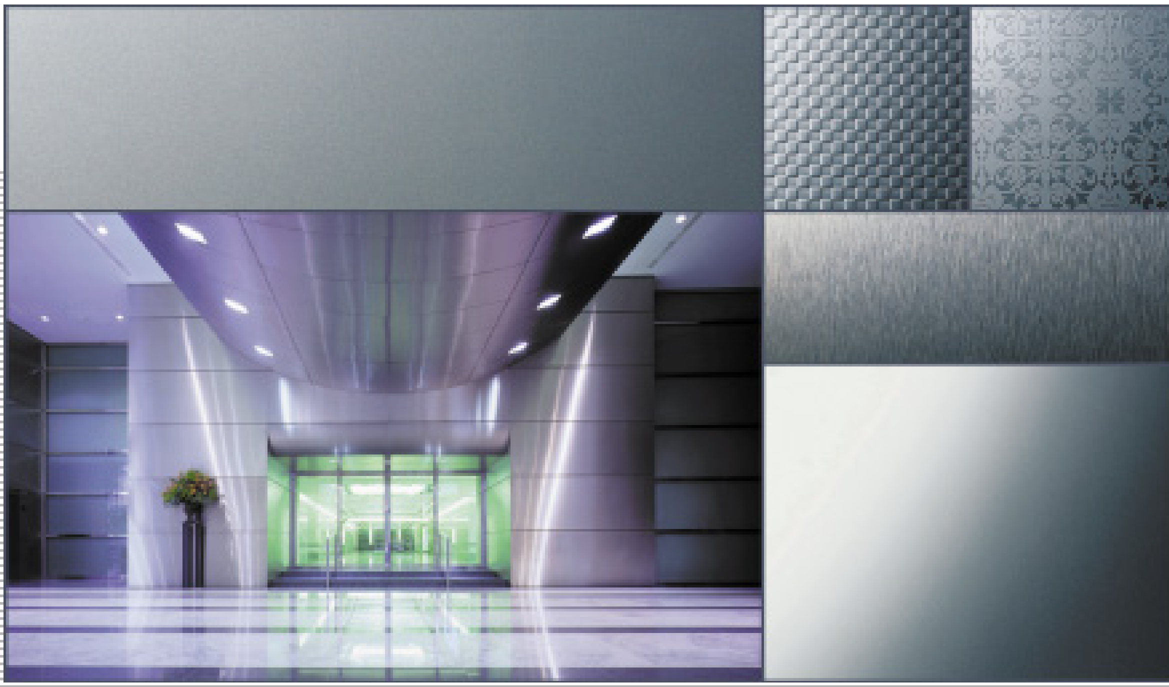
Guide to Stainless Steel Finishes



Building Series, Volume 1

Euro Inox

Euro Inox is the European market development association for Stainless Steel.
The members of Euro Inox include:
- European stainless steel producers
- National stainless steel development associations
- Development associations of the alloying element industries.

A prime objective of Euro Inox is to create awareness of the unique properties of stainless steels and to further their use in existing applications and in new markets. To assist this purpose, Euro Inox organises conferences and seminars, and issues guidance in printed form, and electronic format, to enable architects, designers, specifiers, fabricators, and end users, to become more familiar with the material. Euro Inox also supports technical and market research.

Editorial

Guide to Stainless Steel Finishes
Second Edition 2002 (Building Series, Vol. 1)
ISBN 2-87997-013-X

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www.edelstahl-rostfrei.de

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Acknowledgements

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Introduction

Stainless steels are a family of materials with a unique set of properties. Protected by a chromium oxide film at the surface which is formed by a reaction of the chromium in the steel and the oxygen in the atmosphere, stainless steels require no added surface protection against corrosion. In the event of the surface becoming damaged, the film immediately self repairs in the presence of oxygen. As illustrated later in this brochure this protective layer can be modified by chemical process to produce permanent metallic colours.

Stainless steels are ideally suited to building applications. They are readily formable and weldable and further information on their physical properties is given in the European Standard EN 10088 Part 1.

The columns at Amstelveen bus station in the Netherlands were clad with a pattern rolled stainless steel; an ideal surface for active pedestrian areas.

In the Eurostar International Railway Station at Ashford, England, stainless steel panels were extensively used for the control desks and refreshment area.

Standard mill finishes and mechanically treated surface finishes of appropriate hot and cold rolled stainless steels are given in EN 10088 Part 2 in which the designations for surface finishes are given by number, for example, 1 for hot rolled, 2 for cold rolled, and classified by a combination of number and letter as 2J. This system provides basic information on process route and description, but not on practical application.

The purpose of this guide therefore is to :

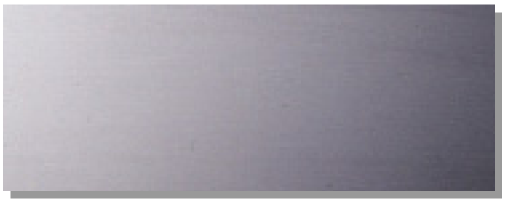
- show to the architect and designer the wide range of possible surfaces at his/her disposal
- provide more detail on the processes involved
- provide basic technical advice on their application

Mill Finishes

Mill finishes, whether hot or cold rolled, are the basic supply condition for all stainless steel flat products. They are used universally for standard building components but are also the basis for subsequent finishing processes that alter the surface to meet more demanding architectural requirements.
Four particular surface designations are important for architectural and building applications. These are: 1D, 2D, 2B and 2R.

To maximise resistance to corrosion in the as-supplied condition, mill finish surfaces are acid cleaned (pickled) to remove scale formed during the hot rolling and annealing process.

1D
Hot rolled and annealed, and with the mill scale removed, this surface condition is classified as a 1D finish. This surface, which is found on thicker sheets and plate, is slightly coarse with very low reflectivity. It is primarily used for non-decorative purposes where the visual appearance is less relevant, for example, in unexposed support systems, and structural applications.



2D
This is a more refined surface than 1D and is achieved by cold rolling, heat treating and pickling. The low reflective matt surface appearance is suitable for industrial and engineering needs but, architecturally, is suitable for less critical aesthetic applications.

2B
This is produced as 2D, but a final light rolling using highly polished rolls gives the surface a smooth, reflective, grey sheen. This is the most widely used surface finish in use today and forms the basis for most polished and brushed finishes.

2R
By bright annealing under Oxygen-free atmospheric conditions following cold rolling using polished rolls, a highly reflective finish, that will reflect clear images, is obtained. This ultra-smooth surface is less likely to harbour airborne contaminants or moisture than any other mill finish, and it is easy to clean.

Mechanically Polished and Brushed Finishes

The number of additional finishing processes can be minimised by selecting, as the starting point, the closest mill finish to the desired end result.

Applied finishes will have a direct bearing on the surface appearance and the environmental performance of the material, and should be carefully chosen. Mechanically polished and brushed finishes involve the use of abrasive materials that effectively cut the surface of the steel to some degree.

A wide choice of uni-directional finishes is available, depending on the original stainless surface, type and texture of the belts and brushes, and the nature of the polishing process used.

To achieve a consistent surface quality, it is advisable to agree with the contractor a polishing specification which can include a surface roughness R_a, and inspection criteria. Reference samples should be prepared to the agreed standard and held by each party.

Metro stations on the new line 14 in Paris, France, use stainless steel extensively.

Mechanically applied finishes may involve wet (oil faced emery) or dry (grit faced belts or fibre brushes) which claim to provide a high lustre, low roughness, and silk sheen finish respectively. Wet finishes are smoother and may be more consistent from batch to batch than their dry counterparts. The cost is slightly higher, however, and there may be a minimum supply requirement. Manufacturers' sample panels are available which show the range of finishes available.

The visual appearance of ground surfaces is dependent upon the material and roughness of the grinding belts; 180 grit (above) and 240 grit (below).

2G

A uniform uni-directional surface that has low reflectivity. The coarse finish restricts it to internal applications.

The profiled stainless steel sheet clad counters of this Bank in Flensburg, Germany, were ground to provide a lively contrast to the smooth wooden surfaces.

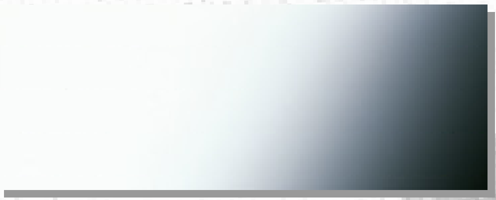
2J

This surface is achieved by polishing belts or brushes. It is uni-directional, non-reflective, and suitable for internal architectural applications.

2K

This smooth reflective surface makes it particularly suitable for most architectural applications, especially exteriors where atmospheric performance is critical. The finish is obtained by the use of finer grit belts or brushes which give a clean cut finish with a roughness of R_a = 0.5 microns maximum.

The impressive polished canopy of the Belgacom Tower in Brussels, Belgium, leads visitors into a large entrance hall which is part clad with stainless steel panels.



2P

A highly reflective ultra-smooth mirror finish which is achieved by polishing and buffing with soft cloth mops and special polishing compounds. This surface reflects a clear distinct image.

Background:
The 6.433 triangles used for the exterior cladding of La Géode at Parc de la Villette, in Paris, were given a mirror polished finish which clearly reflects the surroundings and their colours.

Designed for adaptability, durability, and low maintenance, the bus shelters for Elche, Spain, used mirror polished stainless steel to present a high quality image.

Erected in 1929, the mirror polished stainless steel sign of this famous London Hotel, has been exposed to the elements for 70 years. This recent photograph shows that the sign has not lost any of its lustre.

Patterned Finishes

Proprietary pattern-rolled finishes are achieved by pressing or by rolling with patterned rolls which can effectively stiffen the sheet permitting thinner gauge cladding and a subsequent possible cost saving and overall weight reduction.

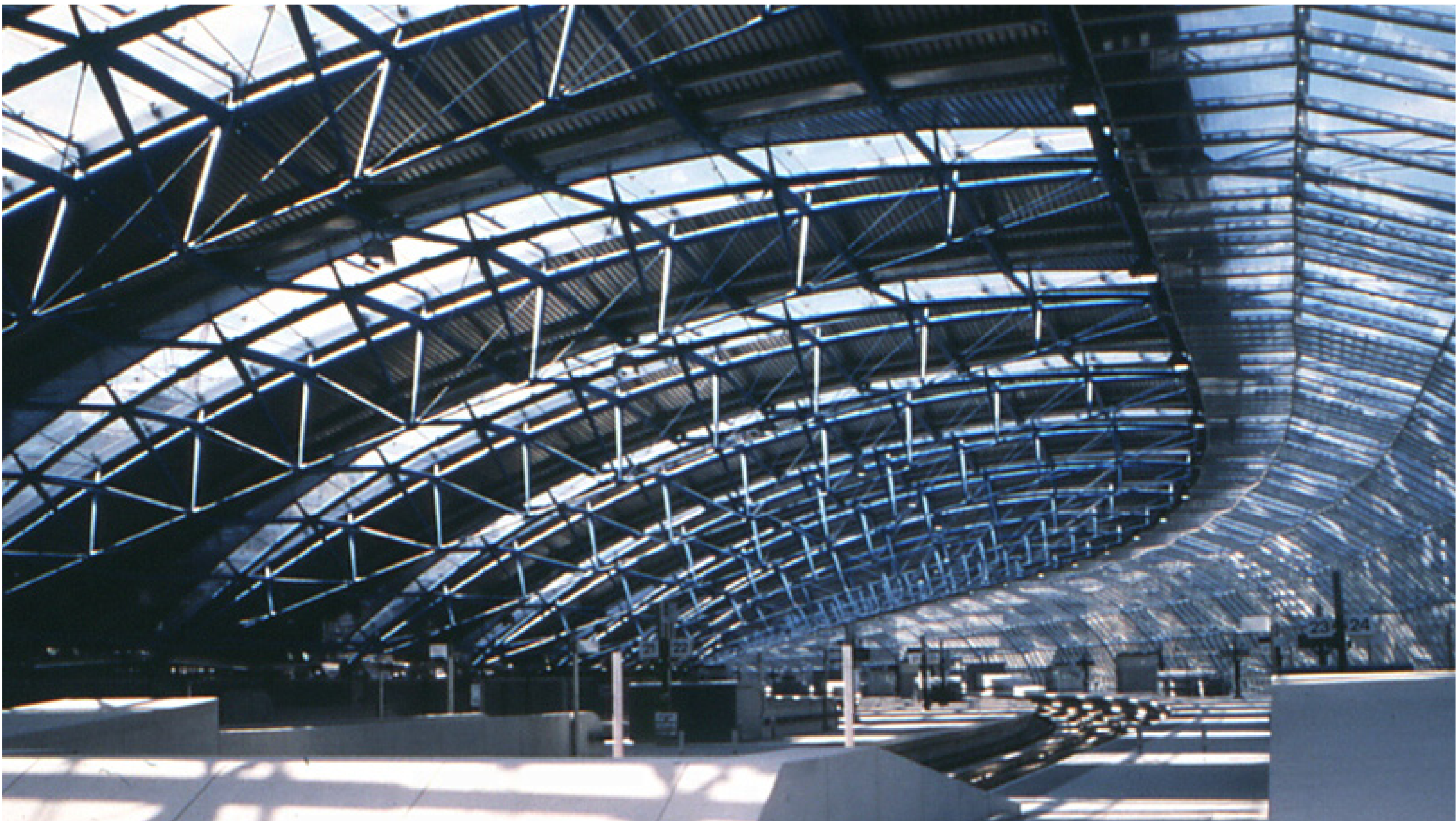
They are particularly suitable for large flat areas such as cladding, where visual surface optical distortions known as 'oil canning' are considerably reduced.

There are two main types of rolled pattern: 1-sided pattern, where the reverse side is plain – classified as 2M, and 2-sided pattern where the pattern is imprinted through to the reverse side – classified as 2W.

2F

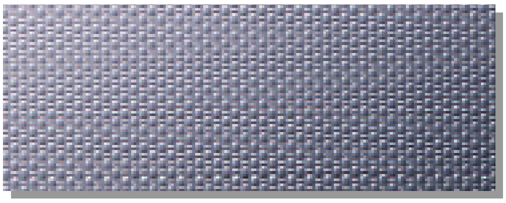
Classified as a 2F finish, this low-reflective dull finish was required on both sides of the sheet. The material has been annealed, pickled and skin passed on bead blasted rolls.

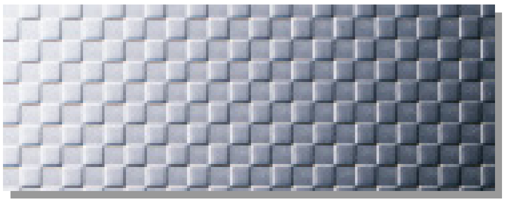
At the Waterloo International Rail Terminal, London, the surface of the stainless steel roof required a low-reflective finish.



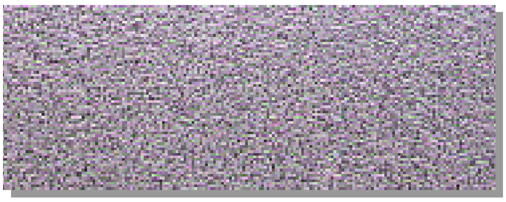
In areas of high public usage such as building entrances, lift cages and airport terminals, where surfaces are susceptible to accidental knocks and scratches, patterned surfaces are less likely to show the damage effects.

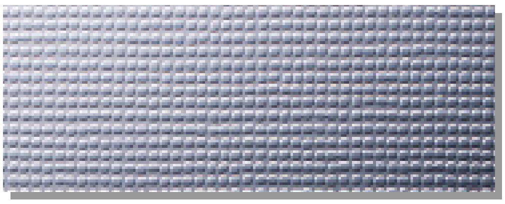
The low reflectivity of the linen finish adopted for the stainless steel walls, ceiling and counter areas, reflect the colour chosen for the floor, to provide a warm and welcoming effect.





These few examples illustrate the use of sheets patterned on one side only, classified as 2M. A wide variety of patterns are available.





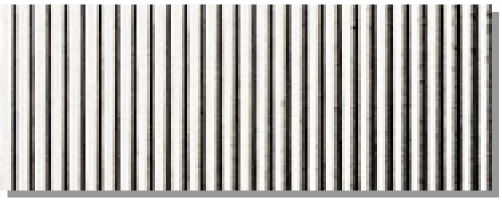
2M

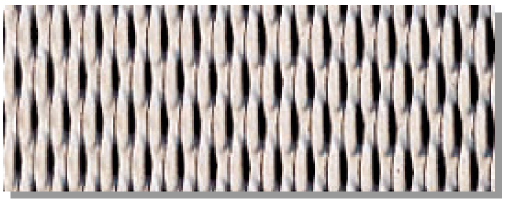
Visually attractive surfaces, textured on one side only, are designed for many architectural applications.

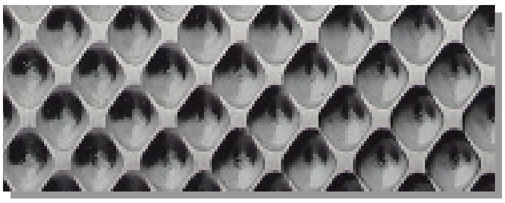
The exhibition pavillons of the 'Meteorit' museum park at Essen are clad with an embossed patterned stainless steel.

Embossed pattern rolled finishes such as those used for the ticket counters at Waterloo International Rail Terminal, are particularly ideal for 'hiding' knocks and scratches.

A wide range of 2-sided patterns is available and a few examples are shown below.





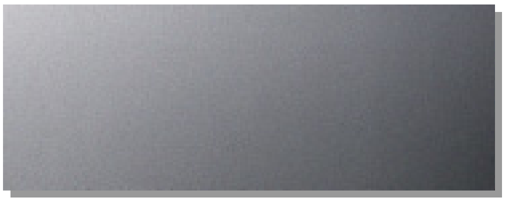


2W

The rolled or pressed patterns are produced on male and female rolls and dies.

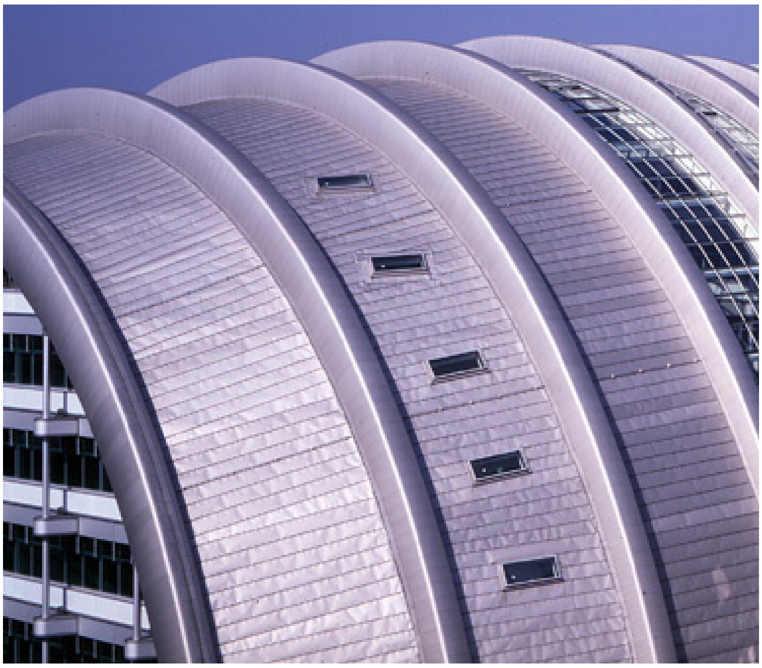
Bead Blasted Finishes

Bead Blasting provides uniform, non-directional, low-reflective surfaces that contrast well, visually, with high polished finishes. Materials used for blasting include stainless steel particles, ceramic beads, aluminium oxide, shredded nut shells, and glass, each of which add to the variety of surface finish available. On no account should conventional iron or carbon steel shot be used as this will severely contaminate the surface of the stainless steel, while sand can contain ferrous materials that may contaminate the surface and is not generally recommended for use on stainless steel.
The surface of austenitic grades of stainless steel will work harden during the blasting process. The process, however, can induce or relieve stress within the sheet or manufactured component. In some cases blasting on both sides may be necessary to equalise the stresses. Advice and information are available from specialist finishing companies.



The appearance can be altered by different blasting materials, eg glass bead (above) or shredded glass (below).

In this new annex to an existing villa in Munich, Germany, the entire balcony was bead blasted to blend with both buildings.



Ludwig-Erhard-Haus in Berlin is characterized by an extremely dull finish produced by blasting with shredded glass.

Electro-Polished Finishes

This electro-chemical process is suited to both sheet and intricately shaped components. The process is used to improve the surface of the material by removing the ‘peaks and troughs’ of the irregular surface to leave a smoother surface and an enhanced reflectivity. The degree of smoothness, and reflectivity that results from this process, will depend upon the roughness of the initial material and it should be noted that it may not produce the mirror reflectivity achieved by mechanical polishing process. Non-metallic surface inclusions can be removed by this process.

Improved corrosion resistance results from the smoother surface which is also less susceptible to harbouring of contaminants and is also easier to clean and maintain.

The external surfaces of the stainless steel component were electro-polished to enhance their appearance and facilitate ease of maintenance in this industrial atmosphere.

Coloured Finishes

Electrolytically Coloured Finishes

The inert chromium oxide layer at the surface of stainless steel provides the corrosion resistant properties of the material and, if damaged, is self repairing in the presence of oxygen. The layer can also be given colour by chemical process which is then hardened by electrolytic process.

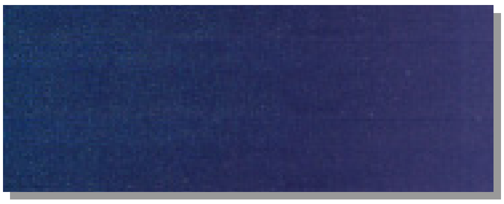
Austenitic stainless steel is particularly suited to this process. Time dependent, during immersion of the steel in the acid solution, the surface film is built-up and through the physical effect of light interference, ie the superimposing of the incoming and reflected light, intense colour effects are produced. The specific range of colour that the film passes through is: bronze, gold, red, purple, blue and green, corresponding to an increase in the film thickness from 0.02 microns to 0.36 microns.

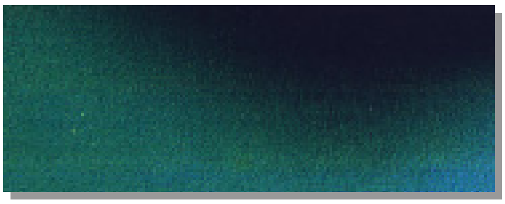
The initial chromium oxide layer, being colourless, is not susceptible to bleaching by ultraviolet light, and, as the colouring process does not involve pigments, fabrication can be carried out after treatment without film cracking. In bending, for example, the inert film will stretch at the bend although thinning will marginally reduce the depth of colour.

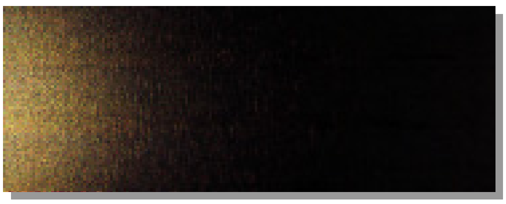
As the inert surface film is transparent, the substrate will influence the final appearance, ie a dull finish will result in a dull colour, and a mirror polish will result in a highly reflective coloured appearance.

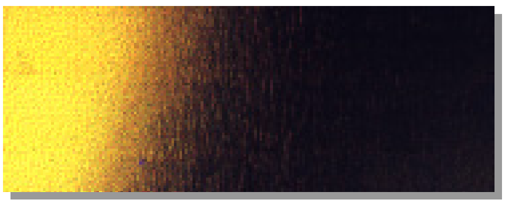
This process results in a permanent colour that requires no restoration, (unlike painted surfaces) therefore care should be taken to ensure that the surface is not damaged as these cannot be readily repaired. Stainless steel coloured by this process cannot be welded without destroying the coloured surface.

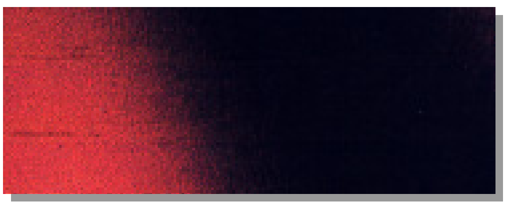
The logo of a confectionary company, at Agrate Brianza (Milan), Italy, is supported by a 22 m high tower clad with electrolytically coloured stainless steel.











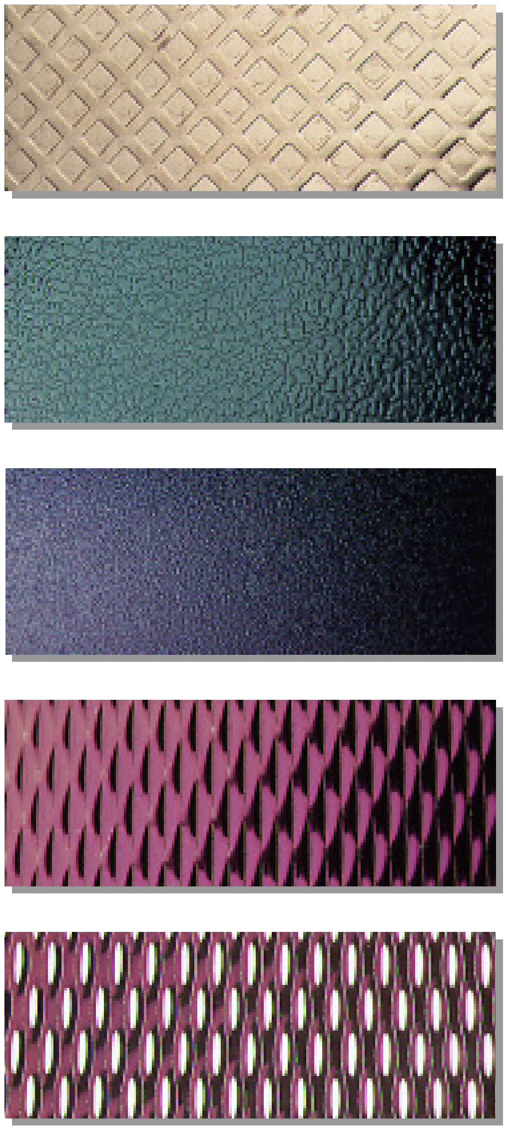
This is only a selection of the colour effects that can be produced by electrolytically colouring stainless steel.

Stainless steel can also be coloured black using a solution involving sodium dichromate. Care must be exercised when cleaning coloured stainless steel. Wire wool and other abrasives which will permanently damage the surface should not be used and chloride bearing cleaning agents should also be avoided.

Electrolytically Coloured and Patterned Finishes

By texturing the stainless steel prior to applying chemical colour, many attractive designs can be created. These designs can be further enhanced by lightly grinding off the pattern 'high points' to expose the stainless self-colour, leaving the applied colour in the recess and less susceptible to damage.

Euro Disney, near Paris, France, makes extensive use of coloured and textured stainless steel eg column cladding and roofing.



By polishing or grinding the high points of coloured and patterned finishes, the stainless self- colour is exposed to provide an attractive contrast with the colour.

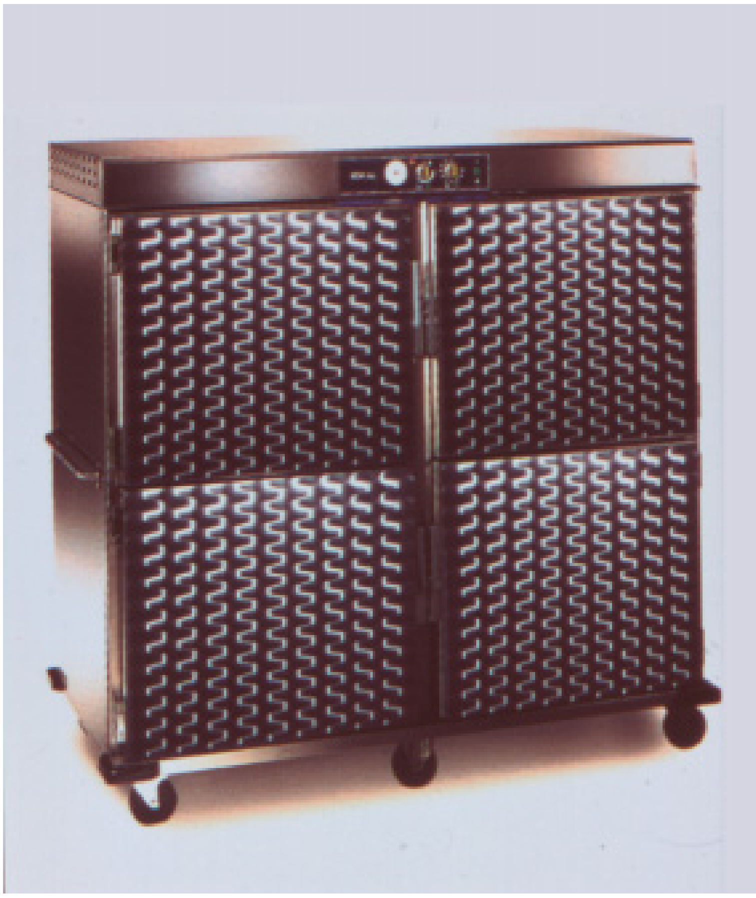
Organic Coatings

Organic coatings are available on flat rolled stainless steel either as primers, or, primer plus top coat in PVF2 and Acrylic. Specialist pre-treatment and coatings processes provide the basis for maximum adherence and stable service life for the coating.
Developed originally for roofing and cladding applications, organic coated stainless steel is available in a wide range of colours to international standards.
Organic coated stainless steel for roof sheeting can be seam welded by a process that involves the inclusion of stainless steel powder at the material to be joined.
Primer coatings, applied to the reverse side of polished or patterned stainless sheets, can facilitate bonding to other materials to form, for example, composite panels.

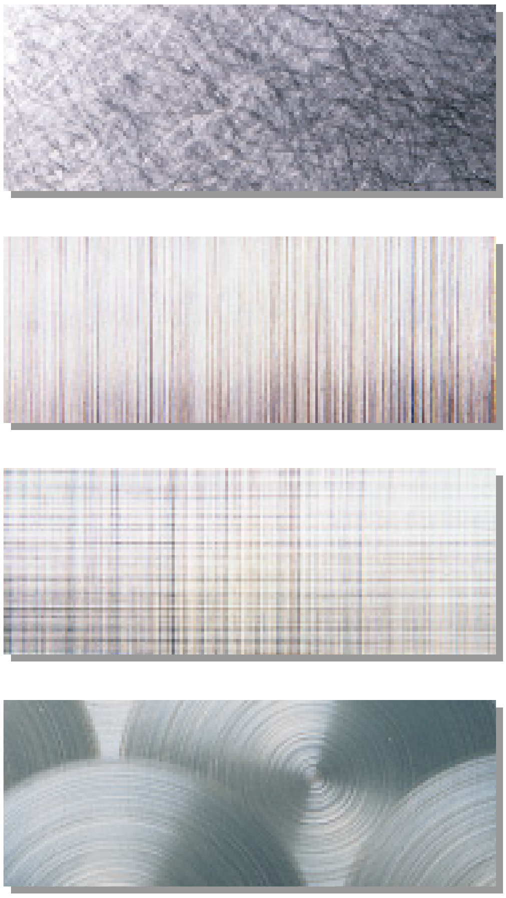
The roof of the Hermitage Museum and Art Gallery in St. Petersburg, Russia, was replaced with PVF2 coated stainless steel.

Specialist Decorative Finishes

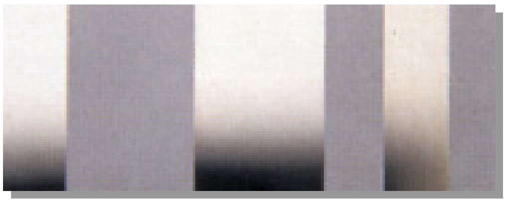
Modern techniques and processes provide the means to create exciting and dynamic graphic designs. The processes include: Photoresist, acid etched, shot blasted, coloured, patterned, ground and polished.
Individually or in combination these processes are carried out by specialist companies, and an infinite number of surface patterns and effects can be achieved. Masking is used to protect the surface during, for example, grinding or shot blasting.
Some patterns are illustrated to demonstrate the capabilities of the specialist finisher.



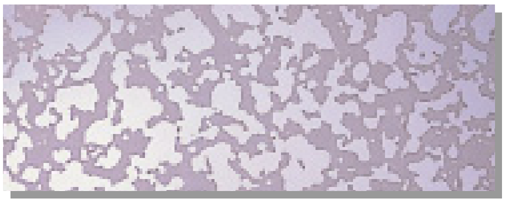
Stainless steel can be abraded to create unique and individual patterns as shown by this intermittent 'wave' design.



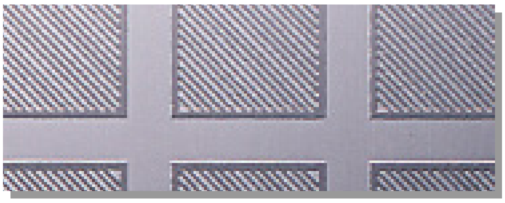
Special grinding and polishing techniques are used to give stainless steel a variety of finishes, for example, random-ground finish, hair line finish, tartan and engine turned.



Example of patterned and bead blasted finishes.

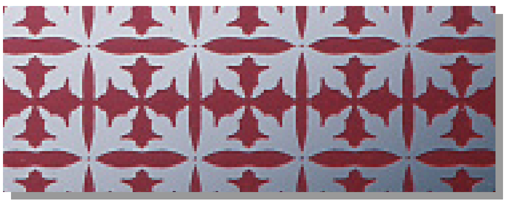


The depth of etching is controlled by the length of time that the stainless steel is exposed to the acid.



Silk screen and photoresist processes have been developed to transfer any pattern onto stainless steel, the surface of which is then acid etched to reveal the pattern.
Acid etching is a process which removes a small amount of surface material. Etched surfaces have a dull and slightly coarse appearance which contrast well with polished or satin finished un-etched surfaces. Electro-chemical colour can be given to etched surfaces before or after etching.

These examples are: Chemically coloured blue before etching (above) and etching, followed by red painting of the recessed pattern (below).



The use of alternating stripes of matt and mirror polished finishes contrast well to provide a striking overall translucent effect to these elevator doors at a bank in Potsdam, Germany.

Annex A. Technical and Practical Aspects

Stainless steel can provide a long life, low maintenance and corrosion resistant building material provided that the correct grade, and appropriate surface finish are used, together with good design detailing and an adequate maintenance schedule. Detailed guidance on important aspects of material selection, fabrication, welding, and maintenance are available from the stainless steel producers and related associations. In this section useful pointers are given to guide the architect to good practice.

Selection of material grade

Chromium provides the basic corrosion resistance of stainless steel while Nickel specifically improves formability, weldability and corrosion resistance in specific environments. The addition of Molybdenum increases resistance to surface pitting in aggressive environments. Austenitic stainless steel grade 1.4401 (316) includes these elements which make it eminently suitable for long life in external applications. It is appropriate for coastal or heavy industrial exposed sites, while the non-molybdenum containing grade 1.4301 (304), is suitable for less demanding exterior environments. Ferritic stainless steels, which contain only chromium, are better suited to internal or cosmetic applications, while some enhanced ferritic grades can be satisfactory, externally, under certain circumstances. Duplex stainless steels combine the strength of ferritics with the corrosion resistance and formability of austenitics and are increasingly being specified for structural members.

Workability

Stainless steels are readily fabricated by the normal processes, including roll form, press brake, guillotine, drill, punch, and weld. A characteristic of the austenitic grades is that they work harden, and in bending, for example, approximately 50% more power is required compared to a carbon steel of similar thickness. Austenitic grades are also subject to 'spring back' and must be overbent by about 5^{o} to compensate. All tools used with stainless steel should be dedicated 'stainless only' to avoid contamination of the surface by carbon steel particles.

When drilling, sharp drills should be used together with the correct speed and feed to avoid 'bluing' or work hardening the material.

Joining

Stainless steel can be attached, or joined, to other materials using standard jointing techniques such as welding, brazing, mechanical connections, and adhesive bonding. Selection of the appropriate means will be dependent upon the application, the working environment, strength required, and the finish of the stainless steel.

Mechanical connections

There is a wide variety of stainless steel fasteners available, in various grades, to suit most applications where mechanical joining is the preferred jointing system. These include: studs, screws, bolts, washers, rivets, and dowels. Where the connection is subject to moist or humid conditions, it is recommended that the grade of fastener be at least equivalent in grade to that of the adjoining stainless steel.

Other fastener materials, if used, should be separated from the stainless steel by non-metallic washers and bushes. Studs, welded to the back of the sheet, are often used for attaching stainless steel panels to a sub-frame. This type of connection can be used where the sheet is at least 1 mm in thickness. Stud welding requires no weld clean-up and will not 'show through' to the front face, however, care should be taken with thin gauge material to ensure that the connections butt to the sub-frame as over-tightening can lead to 'pull through' visual distortions on the front face.

Adhesive bonding

Stainless steel can be successfully bonded to other materials using adhesives such as epoxy resin, acrylic, and polyurethane resin. Selection of the appropriate adhesive will depend upon a number of factors including; the material to be bonded to the stainless steel, the working environment of the composite construction, and the type of loading to be resisted.

Adhesive manufacturers should be consulted in all cases, but it is important also to consult with the stainless steel manufacturer so that the appropriate finish can be provided. In general, a coarse finish to the stainless steel will provide a key for the adhesive but a pre-bonding treatment may also be necessary, although modern adhesives are more tolerant of surface films and moisture. The pre-treatment of the stainless steel may involve degreasing, use of abrasives, or chemical priming.

Weldability

While choice of weld process will depend upon a number of factors, stainless steel is readily welded to stainless steel or to carbon steel. Cognisance of the higher thermal expansion and lower thermal conductivity values of stainless steel compared to carbon steel, should be taken into account during fabrication to minimise distortions. Competent fabricators are familiar with these characteristics.

TIG (tungsten inert gas), Plasma arc, MIG (metal inert gas), SMAW (shielded metal arc welding) and Resistance welding processes are particularly suited to stainless steel. Stud welding using capacitor discharge is a popular joining method for the attachment of panels and eliminates weld clean-up and surface marking. The choice of surface finish should be taken into account when selecting the fabrication process and post weld clean-up to avoid damaging any mechanical finish. Restoration of directional finishes, for example, need to be considered at welded junctions.

Cleanability

Rainwater is beneficial to the cleaning of stainless steel and patterned or directional external finishes should therefore run vertically to facilitate water run-off. Crevices and horizontal 'lines' where airborne contaminants can accumulate should be avoided where possible. Routine washing of stainless steel with soap and water followed by a clean water rinse and wiping with a dry cloth is generally sufficient to maintain the aesthetic appearance of stainless steel. Frequency of washing depends upon the site and exposure conditions as well as the particular aesthetic demands for the building.

On no account should carbon steel abrasives, such as wire wool, or materials containing chlorides, be used to clean stainless steel. If abrasive cleaning is necessary, proprietary liquid cleaners can be used, alternatively, specialist cleaning contractors should be consulted. It is advisable to include an appropriate cleaning process and regime in the design specification.

Avoidance of galvanic corrosion

If other metals are used in conjunction with stainless steel externally, the differing materials must be separated by a non-metallic barrier, neoprene or nylon, for example, to avoid the possibility of galvanic corrosion. Stainless steel is more noble than galvanised or uncoated carbon steel, zinc, and aluminium and unless electrically separated, in the presence of rainwater or moisture, will cause the less noble material to corrode. Where the area of stainless steel is large, compared to the less noble material, as in a cladding/fixing application, there will be an acceleration in the rate of corrosion of the non-stainless fixing. This can lead to corrosion staining and loss of area of the fixing. Stainless steel fixings should be used with stainless steel cladding.

Uniformity of finish

Where large areas of sheeting are used in a single elevation or installation, care should be taken to ensure that the coils are from the same production batch. This helps to control colour consistency which can vary from batch to batch. If necessary, the rolling or finishing process direction should also be taken into consideration during fabrication and erection, as mixed directionality may display a contrasting appearance under certain lighting conditions. Arrangements can be made with the supplier to indicate the rolling or processing direction on the underside of the sheets or on the packaging.

Annex B. EN 10088/2

Type of process route and surface finish of sheet, plate and strip [1]

	Abbreviation[2]	Type of process route	Surface finish	Notes
Hot rolled	1U	Hot rolled, not heat treated, not descaled	Covered with the rolling scale	Suitable for products which are to be further worked e.g. strip for rerolling.
	1C	Hot rolled, heat treated, not descaled	Covered with the rolling scale	Suitable for parts which will be descaled or machined in subsequent production or for certain heat-resisting applications.
	1E	Hot rolled, heat treated, mechanically descaled	Free of scale	The type of mechanical descaling, e.g.coarse grinding or shot blasting, depends on the steel grade and the product, and is left to the manufacturer´s discretion, unless otherwise agreed.
	1D	Hot rolled, heat treated, pickled	Free of scale	Usually standard for the most steel types to ensure good corrosion resistance; also common finish for further processing. It is permissible for grinding marks to be present. Not as smooth as 2D or 2B.

	Abbreviation[2]	Type of process route	Surface finish	Notes
Cold rolled	2H	Work hardened	Bright	Cold worked to obtain higher strength level.
	2C	Cold rolled, heat treated, not descaled	Smooth with scale from heat treatment	Suitable for parts which will be descaled or machined in subsequent production or for certain heat-resisting applications.
	2E	Cold rolled, heat treated, mechanically descaled	Rough and dull	Usually applied to steels with a scale which is very resistant to pickling solutions. May be followed by pickling.
	2D	Cold rolled, heat treated, pickled	Smooth	Finish for good ductility, but not as smooth as 2B or 2R.
	2B	Cold rolled, heat treated, pickled, skin passed	Smoother than 2D	Most common finish for most steel types to ensure good corrosion resistance, smoothness and flatness. Also common finish for further processing. Skin passing may be complemented by tension levelling.
	2R	Cold rolled, bright annealed [3]	Smooth, bright, reflective	Smoother and brighter than 2B. Also common finish for further processing.
	2Q	Cold rolled, hardened and tempered, scale free	Free of scale	Either hardened and tempered in a protective atmosphere or descaled after heat treatment.
Special finishes	1G or 2G	Ground [4]	See footnote 5	Grade of grit or surface roughness can be specified. Unidirectional texture, not very reflective.
	1J or 2J	Brushed [4] or dull polished [4]	Smoother than ground. See footnote 5	Grade of brush or polishing belt or surface roughness can be specified. Unidirectional texture, not very reflective.
	1K or 2K	Satin polish [4]	See footnote 5	Additional specific requirements to a 'J'-type finish, in order to achieve adequate corrosion resistance for marine and external architectural applications. Transverse R_a<0,5 μm with clean cut surface finish.
	1P or 2P	Bright polished [4]	See footnote 5	Mechanical polishing. Process or surface roughness can be specified. Non-directional finish, reflective with high degree of image clarity.
	2F	Cold rolled, heat treated, skin passed on roughened rolls	Uniform non-reflective matt surface	Heat treatment by bright annealing or by annealing and pickling
	1M	Patterned	Design to be agreed; 2nd surface flat	Chequer plates used for floors
	2M			A fine texture finish mainly used for architectural applications
	2W	Corrugated	Design to be agreed	Used to increase strength and/or for cosmetic effect
	2L	Coloured [4]	Colour to be agreed	
	1S or 2S	Surface coated [4]		Coated with e.g. tin, aluminium, titanium.

1 Not all process routes and surface finishes are available for all steels.
2 First digit, 1 = hot rolled, 2 = cold rolled.
3 May be skin passed.
4 One surface only, unless specifically agreed at the time of enquiry and order.
5 Within each finish description, the surface characteristics can vary, and more specific requirements may need to be agreed between manufacturer and purchaser (e.g. grade of grit or surface roughness).

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The European Stainless Steel Development Association

ISBN 2-87997-013-X

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