HASTELLOY® and HAYNES®

PIPE AND TUBULAR PRODUCTS

HAYNES
International

PRINCIPAL FEATURES

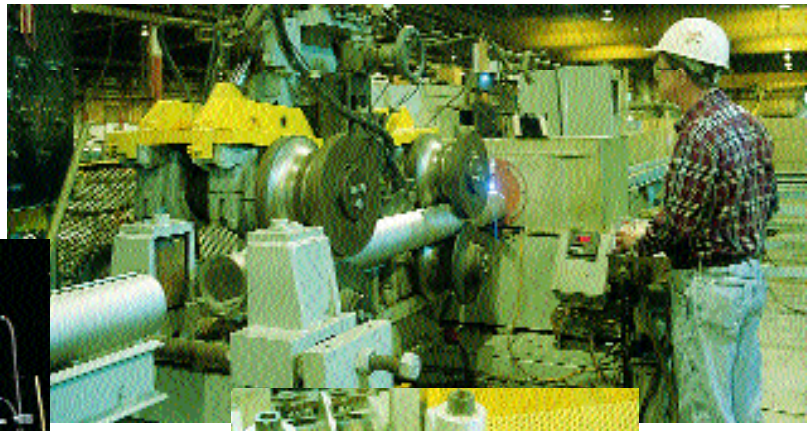
Facilities

Haynes International Tubular Products Facility, located in Arcadia, Louisiana, is devoted exclusively to the production of high-quality tubulars. A 125,000 square foot building houses a complete range of pilgering, welding and drawing equipment designed especially for the manufacture of seamless and welded products in specialty metals and alloys. Supportive equipment is also available for black annealing, vacuum annealing, pickling, straightening, chemical milling, polishing, and non-destructive testing.

Single Source for Tubular and Fitting Products and Alloys

Haynes International is unique in that it not only is a leading supplier of a complete line of welded and seamless tubulars, but also is a leading producer of nickel alloys, high performance alloys, titanium, and titanium alloys. This combination provides single source responsibility for the quality of both tubular products and alloys.

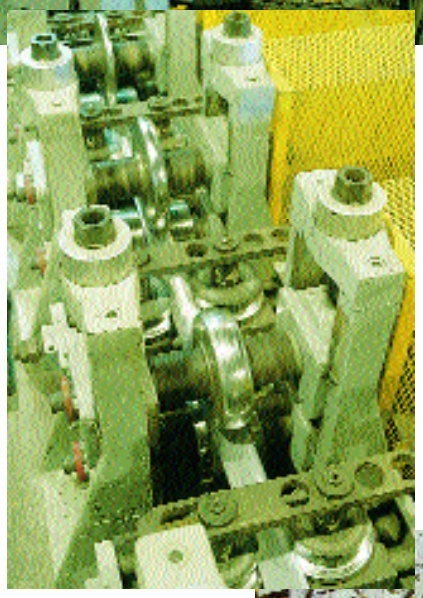
Contents

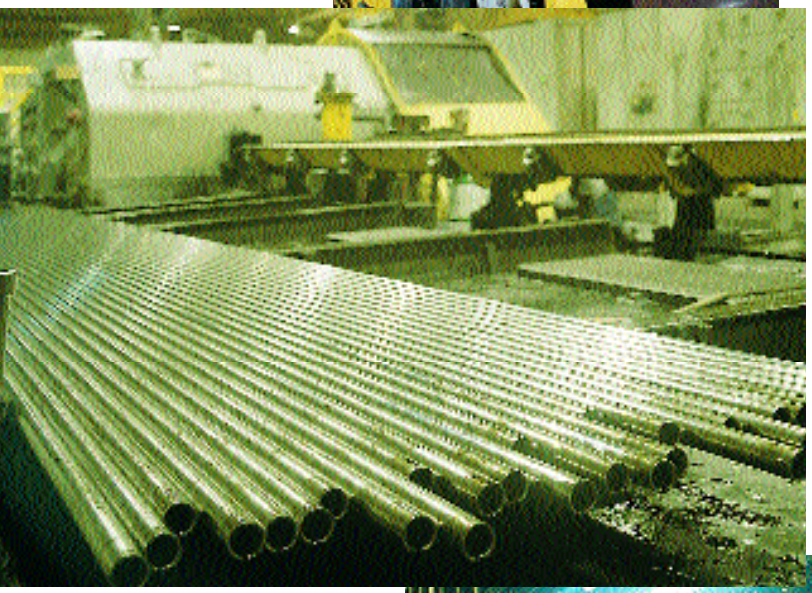


Pipe seam welding

Black annealing furnace

Continuous strip welding





Pilger mill

Straightening

Polishing and finishing

Signing our name . . .

for a perfect finish.

QUALITY CONTROL

Quality Systems

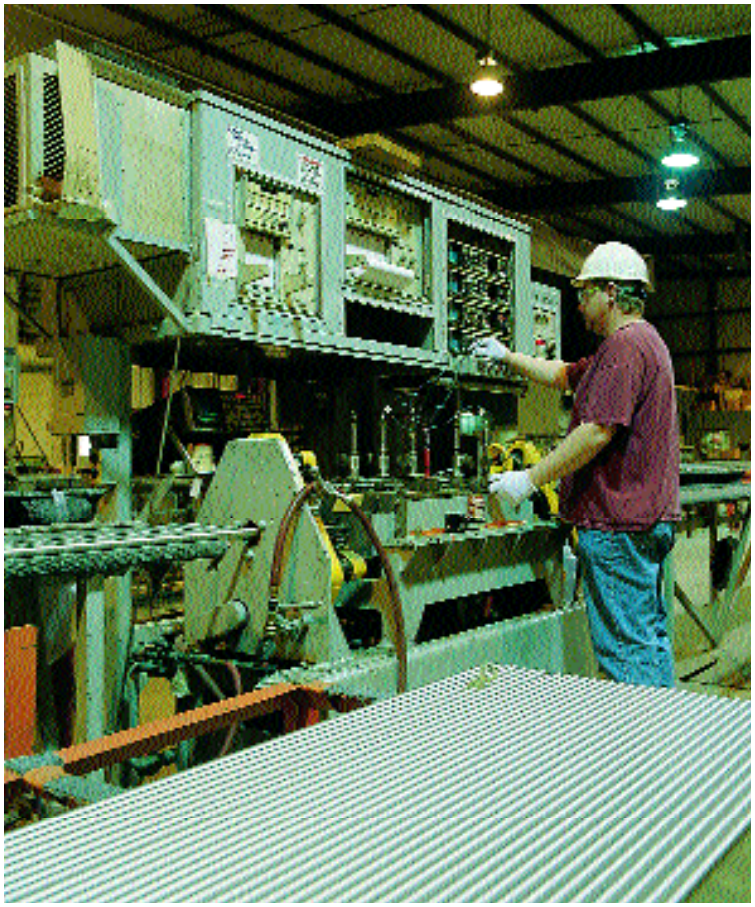
Haynes Tubular Products Facility maintains a fully documented quality management system in compliance with the ISO 9000 series of international quality management standards.

Strict Quality Control

State-of-the-art inspection equipment and methods are used at the Haynes International Tubular Products Facility to provide process control and ensure product integrity. Samples are tested for conformance to the chemical composition requirements of the applicable specification. Radiographic, ultrasonic, hydrostatic, dye penetrant, pneumatic, eddy current inspections, corrosion testing, and metallographic examinations can be performed as required. Tubular products are routinely inspected visually and dimensionally. In addition, samples are given tensile, flattening, flange and/or bend tests for conformance to mechanical property requirements of the applicable specification.

High-Temperature and Corrosion Technology

Haynes International engineers and metallurgists are continually studying and developing improved alloys for longer service under increasingly severe conditions. Mathematical models and computer techniques are used to improve alloy properties by optimizing various processing methods. Both manufacturing and quality control rely largely on technological input to consistently produce uniformly high-quality products.



AVAILABLE ALLOYS AND FORMS

ALLOYS	UNS No.	Available Forms* Production	Available Forms* Development	Available Forms* Oil Country Tubulars	Specifications** SEAMLESS Pipe & Tubing	Specifications** WELDED Pipe & Tubing
Corrosion-Resistant Alloys						
HASTELLOY® B-2 alloy	N10665	W/D/S			SB622/B622	SB619/B619 SB626/B626
HASTELLOY B-3® alloy	N10675	W/D/S			SB622/B622	SB619/B619 SB626/B626
HASTELLOY C-4 alloy	N06455	W/D				SB619/B619 SB626/B626
HASTELLOY C-2000® alloy	N06200	W/D/S			SB622/B622	SB619/B619 SB626/B626
HASTELLOY C-22® alloy	N06022	W/D/S			SB622/B622	SB619/B619 SB626/B626
HASTELLOY C-276 alloy	N10276	W/D/S		SEAMLESS	SB622/B622	SB619/B619 SB626/B626
HASTELLOY G-30® alloy	N06030	W/D/S			SB622/B622	SB619/B619 SB626/B626
HASTELLOY G-50® alloy	N06950			SEAMLESS		
HASTELLOY G-3 alloy	N06985	W/D/S		SEAMLESS	SB622/B622	SB619/B619 SB626/B626
Heat-Resistant Alloys						
HASTELLOY X alloy	N06002	W/D				SB619/B619 SB626/B626 AMS 5588
HAYNES® HR-160® alloy	N12160		W/D/S		SB622/B622	SB619/B619 SB626/B626
HAYNES 214™ alloy	N07214		S		B622	
HAYNES 230® alloy	N06230	W/D	S		B622	SB619/B619 SB626/B626
HAYNES 242™ alloy	——		W/D/S		Code Case 2319	Code Case 2319
HAYNES 263 alloy	N07263		W/D			SB619/B619
HAYNES 625 alloy	N06625	W/D/S			SB444/B444 AMS 5581	SB704/B704 SB705/B705
HAYNES 718 alloy	N07718	W/D/S			AMS 5589/AMS 5590	
HAYNES 188 alloy	R30188	W/D				AMS 5588
HAYNES 25 alloy	R30605	W/D				
HAYNES 556™ alloy	R30556	W/D				SB619/B619 SB626/B626
HAYNES HR-120® alloy	N08120		W/D/S		B407	B514/B515
Titanium Alloys						
HAYNES Ti-3Al-2.5V	R56320	S			B338/B861 AMS 4943 AMS 4944/AMS 4945 SGT-325	

* W=Welded
* D=Drawn
* S=Seamless

** B = ASTM Specifications
** SB = ASME Boiler and Pressure Vessel Code Specifications
** AMS = SAE Specifications
** Code Case = ASME Specifications
** SGT = High-Sports Grade

WELDED AND SEAMLESS TUBING

Welded tubing is available in sizes ranging from 1/4 in. to 3 in. (6.4 to 76.2 mm) outside diameters with wall thicknesses from .035 to 0.148 in. (0.89 to 3.8 mm) and in lengths up to 50 ft. (15.2 m).

Tubing is made from strip by forming, welding, sizing or cold working, solution heat-treating, and testing in accordance with the applicable specification(s).

The classes of welded tubing available from Haynes International as described in ASTM B626 are as follows:

Class IA

Welded, sized, solution heat-treated, and nondestructively tested. Each tube is subjected to the pneumatic test, hydrostatic test, or the eddy current test at Haynes' option.

Class IIA

Welded, cold-worked, solution heat-treated, and nondestructively tested. Each finished tube is subjected to the pneumatic test, the hydrostatic test, or the eddy current test at Haynes' option.

Class III

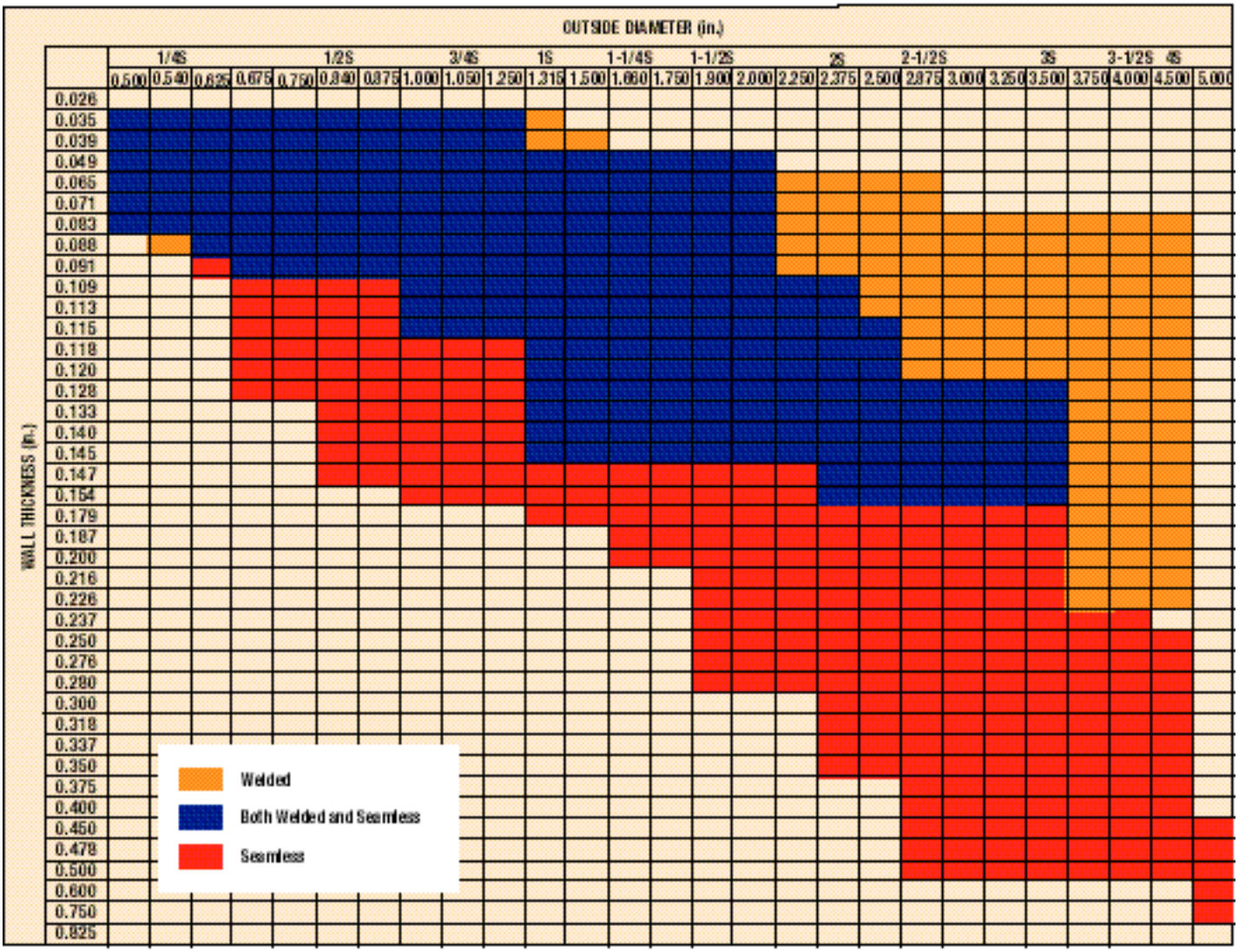
Welded, cold-worked, solution heat-treated, and nondestructively tested. Each finished tube is subjected to the pneumatic test and eddy current test. In lieu of the pneumatic test, tubes larger than 1-1/2 in. (38.1 mm) in outside diameter are hydrostatically tested .

Class IIA and III shall be cold-worked either in both weld and base metal or in welded metal only prior to final heat treatment (solution anneal). Within ASTM B626 there are two additional classes of tubing, IB and IIB, which can also be applied upon request

Seamless Tubing

Cold worked seamless tubing is produced from billets by either trepanning or extrusion followed by pilgering and/or drawing.

COMMON WELDED AND SEAMLESS TUBING SIZES*



* Metric and non-standard sizes are available depending on the quantity required.
Standard lengths range from 5 feet to 50 feet. Longer lengths are available on special order.

WELDED TUBING, STANDARD O.D. AND WALL THICKNESS TOLERANCES

Specified Outside Diameter , in. (mm)	Tolerance	
	Diameter, in. (mm)	Wall Thickness, %
Under 1.000 (25.4), incl.	+0.004 / -0.005 (+0.12 / -0.13)	±12.5
Over 1.000 (25.4) to 1.500 (38.1), incl.	+0.006 / -0.006 (+0.15 / -0.15)	±12.5
Over 1.500 (38.1) to 2.000 (50.8), incl.	+0.008 / -0.008 (+0.20 / -0.20)	±12.5
Over 2.000 (50.8) to 3.500 (38.1)	+0.010 / -0.010 (+0.25 / -0.25)	±12.5

SEAMLESS TUBING, DIMENSIONAL TOLERANCES

Nominal Outside Diameter, In. (mm)	Outside Diameter Tolerance in.	mm	Wall Thickness Tolerance, Percent Average Wall	Minimum Wall
0.500 (12.7) to 0.625 (15.8), incl.	±0.005	±0.130	±12.5	+25.0/-0
Over 0.625 (15.8) to 1.500 (38.1), incl.	±0.0075	±0.190	±10.0	+20.0/-0
Over 1.500 (38.1) to 3.500 (88.9), incl.	±0.010	±0.254	±10.0	+22.0/-0
Over 3.500 (88.9) to 4.500 (114.0), incl.	±0.015	±0.380	±10.0	+22.0/-0
Over 4.500 (114.0) to 6.000 (152.0), incl.	±0.020	±0.510	±12.5	+28.0/-0

WELDED AND SEAMLESS TUBING — NOMINAL WEIGHT, POUNDS PER FOOT*

Wall Thickness, Inches	0.035	0.042	0.049	0.058	0.065	0.072	0.083	0.095	0.109	0.120	0.134	0.148
GAUGE	20		18		16		14		12		10	
O.D., in.												
1/4	0.091	0.106	-	-	-	-	-	-	-	-	-	-
5/16	0.118	0.138	0.157	-	-	-	-	-	-	-	-	-
3/8	0.144	0.170	0.194	0.223	0.224	-	-	-	-	-	-	-
7/16	0.171	0.202	0.231	0.267	0.294	-	-	-	-	-	-	-
1/2	0.197	0.233	0.268	0.311	0.343	-	-	-	-	-	-	-
5/8	0.250	0.297	0.342	0.398	0.441	0.482	-	-	-	-	-	-
3/4	0.303	0.360	0.416	0.486	0.539	0.591	0.670	-	-	-	-	-
7/8	0.356	0.424	0.490	0.574	0.637	0.700	0.796	-	-	-	-	-
1	0.409	0.487	0.564	0.661	0.736	0.809	0.921	1.04	1.18	-	-	-
1-1/4	0.515	0.614	0.712	0.837	0.932	1.03	1.17	1.33	1.51	1.64	1.81	-
1-1/2	0.621	0.741	0.861	1.12	1.13	1.24	1.42	1.62	1.84	2.00	2.22	-
1-3/4	-	-	1.01	1.19	1.33	1.46	1.68	1.91	2.17	2.37	2.62	-
2	-	-	1.16	1.45	1.54	1.68	1.93	2.19	2.49	2.73	3.03	3.32
2-1/4	-	-	1.31	1.54	1.72	1.90	2.18	2.48	2.82	3.09	3.43	3.77
2-3/8	-	-	1.38	1.63	1.82	2.01	2.30	2.62	2.99	3.27	3.63	3.99

*HASTELLOY® C-276 alloy. To obtain the weight-per-foot for other alloys multiply the value shown in the table for HASTELLOY C-276 alloy by the factor shown below:

Alloy	Weight Per Foot Factor
HASTELLOY® B-2 alloy	1.037
HASTELLOY B-3® alloy	1.037
HASTELLOY C-4 alloy	0.972
HASTELLOY C-2000® alloy	0.956
HASTELLOY C-22® alloy	0.972
HASTELLOY G-30® alloy	0.925
HASTELLOY G-50® alloy	0.938
HASTELLOY G-3 alloy	0.935
HASTELLOY X alloy	0.925
HAYNES® HR-160® alloy	0.910
HAYNES 214™ alloy	0.906
HAYNES 230® alloy	1.010
HAYNES 242™ alloy	1.019
HAYNES 263 alloy	0.941
HAYNES 625 alloy	0.950
HAYNES 718 alloy	0.925
HAYNES 188 alloy	1.009
HAYNES 25 alloy	1.028
HAYNES 556™ alloy	0.925
HAYNES HR-120® alloy	0.906

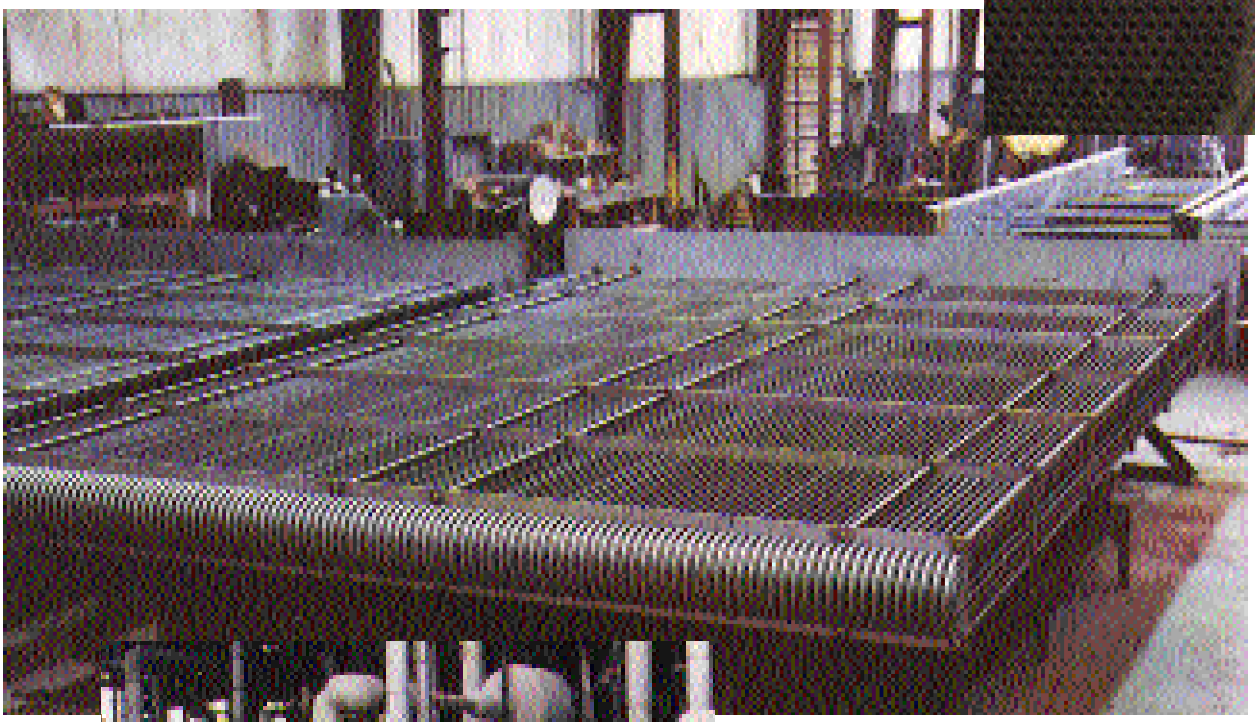
APPLICATIONS

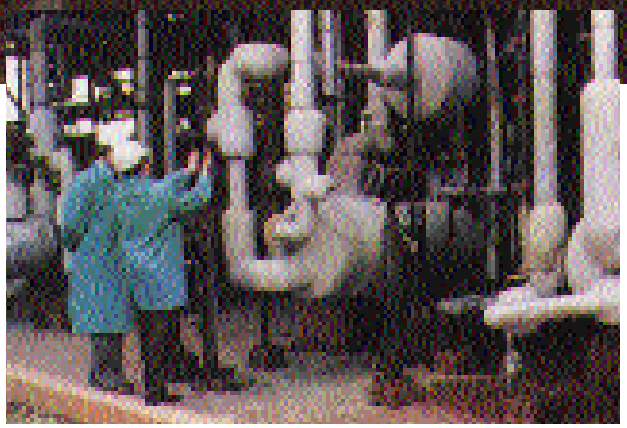
Haynes International Tubular Products supplies highly reliable tubular products to the exacting requirements of the oil and gas, refining, chemical process, agricultural, pulp and paper, marine, power, pollution control, aerospace, gas turbine, and other industries.

Welded-and-drawn pipe and tubing of HASTELLOY® alloys have wide application for heat exchangers, spargers, and process lines involving aggressive corrosives. Seamless pipe fabricated from materials such as HASTELLOY C-276 and G-50 alloys plays a vital role as tubulars in deep sour gas wells. At depths of 20,000 feet (6100 m) or more, high-temperature, corrosive atmospheres and high pressures rapidly degrade carbon and stainless steels.

HAYNES® and HASTELLOY high-temperature alloy pipe and tubing find broad application in gas turbines as flame holders and crossover tubes, as well as in chemical processing plants in equipment such as muffles and retorts, radiant heating tubes, thermocouple protection tubes, and furnace tubes.

CORROSION APPLICATIONS





WELDED AND SEAMLESS PIPE

Welded pipe is made from slit strip through 2 in., Schedule 40, and is available up to 50 feet (15.2 m) long. Larger sizes are made from sheared strip or abrasive-cut plate in lengths up to 19 feet (5.8 m). Welded pipe is formed, welded, solution heat-treated, and tested in accordance with the appropriate specification(s) such as ASTM B619.

Seamless pipe is covered under ASTM B622.

COMMON WELDED AND SEAMLESS PIPE SIZES*

Nominal Wall Thickness			Schedule									
Pipe Size Inches	Nominal O.D., in.	mm	5 in.	mm	10 in.	mm	40 in.	mm.	80 in.	mm.	160 in.	mm.
1/4	0.540	13.72	-	-	0.065	1.65	0.088	2.24	0.119	3.02	-	-
3/8	0.675	17.15	-	-	0.065	1.65	0.091	2.31	0.126	3.20	-	-
1/2	0.840	21.34	0.065	1.65	0.083	2.11	0.109	2.77	0.147	3.73	0.187	4.75
3/4	1.050	26.67	0.065	1.65	0.083	2.11	0.113	2.87	0.154	3.91	0.218	5.54
1	1.315	33.40	0.065	1.65	0.109	2.77	0.133	3.38	0.179	4.55	0.250	6.35
1-1/4	1.660	42.16	0.065	1.65	0.109	2.77	0.140	3.56	0.191	4.85	0.250	6.35
1-1/2	1.900	48.26	0.065	1.65	0.109	2.77	0.145	3.68	0.200	5.08	0.281	7.14
2	2.375	60.33	0.065	1.65	0.109	2.77	0.154	3.91	0.218	5.54	0.343	8.71
2-1/2	2.875	73.03	0.083	2.11	0.120	3.05	0.203	5.16	0.276	7.01	0.375	9.53
3	3.500	88.90	0.083	2.11	0.120	3.05	0.216	5.49	0.300	7.62	0.438	11.13
3-1/2	4.000	101.60	0.083	2.11	0.120	3.05	0.226	5.74	0.318	8.08		
4	4.500	114.30	0.083	2.11	0.120	3.05	0.237	6.02	0.337	8.56	0.531	13.49
5	5.563	141.30	0.109	2.77	0.134	3.40	0.258	6.55	0.375	9.52	0.625	15.88
6	6.625	168.28	0.109	2.77	0.134	3.40	0.280	7.11	0.432	10.97	0.719	18.26
8	8.625	219.08	0.109	2.77	0.148	3.76	0.322	8.18	0.500	12.70	0.906	23.01

*Not all sizes are available in all alloys.

WELDED PIPE, STANDARD OUTSIDE DIAMETER TOLERANCES

Nominal Pipe Size, in.	Nominal Outside Diameter, in.	mm	Outside Diameter Tolerance, in.*	mm*
1/4	0.540	13.72	+0.003 - 0.008	+0.08 - 0.20
3/8	0.675	17.15	+0.004 - 0.008	+0.08 - 0.20
1/2	0.840	21.34	+0.004 - 0.010	+0.10 - 0.25
3/4	1.050	26.67	+0.005 - 0.012	+0.13 - 0.30
1	1.315	33.41	+0.005 - 0.012	+0.13 - 0.30
1-1/4	1.660	42.16	+0.005 - 0.012	+0.13 - 0.30
1-1/2	1.900	48.26	+0.008 - 0.015	+0.20 - 0.38
2	2.375	60.03	+0.010 - 0.016	+0.25 - 0.41
2-1/2	2.875	73.03	+0.010 - 0.016	+0.25 - 0.41
3	3.500	89.90	+0.012 - 0.018	+0.30 - 0.46
3-1/2	4.000	101.60	+0.012 - 0.018	+0.30 - 0.46
4	4.500	114.30	+0.014 - 0.020	+0.36 - 0.51
5	5.563	141.30	+0.063 - 0.031	+1.60 - 0.79
6	6.625	168.28	+0.063 - 0.031	+1.60 - 0.79
8	8.625	219.18	+0.063 - 0.031	+1.60 - 0.79

*Includes ovality tolerance

Wall Thickness Tolerance—The wall thickness tolerance for welded pipe is ± 12.5% of the specified nominal wall thickness.

SEAMLESS PIPE, DIMENSIONAL TOLERANCES

Nominal Outside Diameter, In. (mm)	Outside Diameter Tolerance in.	mm	Wall Thickness Tolerance, Percent Average Wall	Minimum Wall
0.500 (12.7) to 0.625 (15.8), incl.	±0.005	±0.130	±12.5	+25.0/-0
Over 0.625 (15.8) to 1.500 (38.1), incl.	±0.0075	±0.190	±10.0	+20.0/-0
Over 1.500 (38.1) to 3.500 (88.9), incl.	±0.010	±0.254	±10.0	+22.0/-0
Over 3.500 (88.9) to 4.500 (114.0), incl.	±0.015	±0.380	±10.0	+22.0/-0
Over 4.500 (114.0) to 6.000 (152.0), incl.	±0.020	±0.510	±12.5	+28.0/-0

HAYNES® Ti-3Al-2.5V alloy

Developed in the late 1950s, Ti-3Al-2.5V alloy became a widely-accepted seamless tubing material for the aircraft industry, primarily because of its high strength-to-weight ratio. This ratio proved to be a major design advantage when used for hydraulic tubing lines, providing adequate strength levels, but more importantly, reducing weight by as much as 43% when compared to stainless steel. This material now is considered an industry standard for aerospace hydraulic lines. More recent applications in the sports industry have taken advantage of the unique properties offered by Ti-3Al-2.5V, such as bicycle frames, tennis racket frames, and lacrosse sticks.

Product Development

In the initial examination of titanium alloys for specific aircraft/aerospace applications, commercially pure titanium was alloyed with selected elements to improve the performance characteristics and to obtain high strength levels. Certain alloying additions, notably aluminum, raise the temperature at which the alloy transforms completely to the beta phase, referred to as the beta transus temperature. The addition of vanadium, on the other hand, lowers the temperature of transformation of the alpha to beta phases.

Titanium - 6% Aluminum - 4% Vanadium (Ti-6Al-4V) was chosen as an ideal aircraft/aerospace alloy because of its good strength-to-weight ratio as annealed, good resistance to cracking during forging, fair to good weldability, and heat-treatable to higher strengths.

But, because Ti-6Al-4V did not have good cold forming characteristics, the Titanium - 3% Aluminum - 2.5% Vanadium (Ti-3Al-2.5V) was developed for tubing and foil applications. This alloy is intermediate in strength between commercially pure titanium and Ti-6Al-4V. Mechanical properties range 30-50 percent higher than pure titanium, but more importantly, it has the excellent cold formability needed to make seamless tubing.

Heat Treatment

HAYNES Ti-3Al-2.5V seamless tubing is normally supplied in either the solution-annealed or cold-worked and stress-relieved condition. Annealing temperatures used generally range from 700˚F to 1450˚F (371˚C to 790˚C) depending on the desired degree of recrystallization or stress relief that is required for a given application.

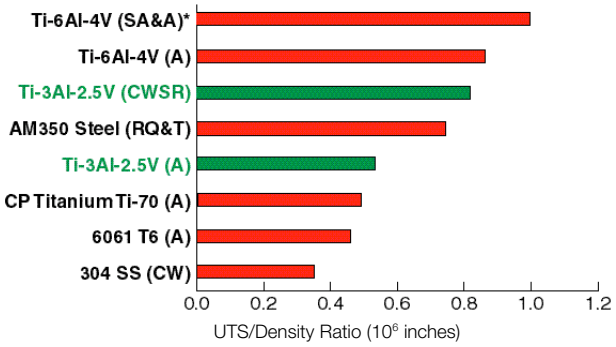
Strict Quality Controls

To provide maximum product integrity, the latest in quality control equipment is available at Haynes International, Inc. Tubing lots are 100 percent visually, dimensionally, and ultrasonically tested. Samples also are examined metallographically as well as tested for conformance to the chemical composition and mechanical property requirements of the applicable specification.

Applications

Seamless tubing of HAYNES Ti-3Al-2.5V alloy was developed for aircraft hydraulic and fuel systems transmission lines. Its performance has been proven in the most technologically advanced military aircraft, spacecraft, and commercial aircraft. Sports grade applications range from high-end bicycle frames to octagonal-shaped tubing for lacrosse sticks. A recent application advancement relying on the corrosion resistance characteristics of HAYNES Ti-3Al-2.5V alloy seamless tubing is providing corrosion resistance to fluid flow monitoring devices in a multitude of various process streams in the chemical processing industry.

Ultimate Tensile Strength Comparison Aerospace Tubing Materials



*SA&A: Solution annealed and aged
A: Annealed
CWSR: Cold Worked Stress Relieved
RQ&T: Rapid Quench/Tempering
CW: Cold Worked

HAYNES® Ti-3Al-2.5V COMMON SEAMLESS SIZES

WALL THICKNESS (in.) \ OUTSIDE DIAMETER (in.)	0.250	0.313	0.375	0.500	0.625	0.750	0.875	1.000	1.250	1.500
0.016	■	■								
0.018	■	■								
0.019	■	■	■							
0.020	■	■	■	■	■	■		■		
0.021	■	■	■	■	■	■		■		
0.022	■	■	■	■	■	■		■		
0.023	■	■	■	■	■	■		■		
0.024	■	■	■	■	■	■		■		
0.025	■	■	■	■	■	■		■		
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0.028	■	■	■	■	■	■	■	■	■	■
0.032		■	■	■	■	■	■	■	■	■
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0.044				■	■	■	■	■	■	■
0.045				■	■	■	■	■	■	■
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0.055				■	■	■	■	■	■	■
0.056				■	■	■	■	■	■	■
0.057				■	■	■	■	■	■	■
0.061				■	■	■	■	■	■	■
0.065					■	■		■	■	■
0.066					■	■		■	■	■
0.070					■	■		■	■	■
0.071					■	■		■	■	■
0.072						■		■	■	■
0.073						■		■	■	■
0.083						■		■	■	■
0.087						■		■	■	
0.088						■		■	■	
0.096						■		■	■	
0.125								■	■	
0.140								■		

TYPICAL SEAMLESS TUBING OUTER DIMENSIONAL TOLERANCES

Nominal Outside Diameter, in. (mm)	Diameter Tolerance, in. (mm)
Over 0.093 (2.4) to 0.187 (4.7), incl	+0.002 (0.05) / -0.000 (0.00)
Over 0.187 (4.7) to 0.499 (12.7), incl	+0.003 (0.08) / -0.000 (0.00)
Over 0.499 (12.7) to 0.749 (19.0), incl	+0.004 (0.10) / -0.000 (0.00)
Over 0.749 (19.0) to 0.999 (25.4), incl	+0.004 (0.10) / -0.001 (0.03)
Over 0.999 (25.4) to 1.499 (38.1), incl	+0.004 (0.10) / -0.002 (0.05)
Over 1.499 (38.1) to 1.999 (50.8), incl	+0.005 (0.13) / -0.002 (0.05)
Wall Thickness Tolerance	+10% / -5% of the nominal wall thickness.

TYPICAL SEAMLESS TUBING INNER DIMENSIONAL TOLERANCES

Nominal Inner Diameter, in. (mm)	Diameter Tolerance, in. (mm)
Up to 0.338 (8.6), incl	±0.0015 (0.04)
Over 0.338 (8.6) to 0.449 (11.4), incl	±0.0020 (0.05)
Over 0.449 (11.4) to 0.673 (17.1), incl	±0.0025 (0.06)
Over 0.673 (17.1) to 0.900 (22.9), incl	±0.0030 (0.08)
Over 0.900 (22.9) and above	±0.0040 (0.10)
Wall Thickness Tolerance	+10% / -5% of the nominal wall thickness.

APPLICATIONS

BEAD WORK vs. COLD REDUCED

Severely corrosive environments are handled safely by specifying the right material for the service. Corrosion will occur if the environment/material interaction is one where the metal will favor dissolution into the corrosive media. This will happen if the material is not noble enough to protect itself against the mechanisms of corrosion or if the right material has been selected, but it is not in the optimum condition for the service. The latter point occurs quite frequently, mainly due to the aspects associated with fabricating material into engineered components.

In the case of welded tubular products, most highly alloyed nickel-based materials are manufactured to specification ASTM B626 Class III. The Class III designation covers cold worked and solution annealed tubing. Within this class designation, the method of cold working or the amount of cold working is not specified and is left up to the buyer.

Production practices will vary among different tubing manufacturers and the result to the market place is a distinct product quality range. "Bead Working" or "Bead Rolling" will impart a degree of cold work into the weld bead by applying an external force to the weld bead after weld-up. The amount of cold working received by the seam weld will depend on the thickness of the tube wall, weld bead profile, and ID mandrel support. These variables can be difficult to control and the result will be a variation of cold working along the weld bead which produces product inconsistency.

After "Bead Working", the tubing is given a full solution anneal. From the chemistry standpoint, the cast dendritic structure associated with the weld is highly segregated and to improve its resistance to corrosion it must be homogenized. During the anneal cycle, the benefit of any amount of cold work is realized by recrystallizing the cold worked structure, adding to the homogenization of weld metal deposit. The recrystallization and diffusion that occur during the anneal cycle work to break-up the dendritic structure associated with the weld.

Specialty tube mills like Haynes International Tubular Products offer an additional product which is also classified by the Class III designation. Haynes' "Fully Cold Reduced" welded tubing is first welded up to a larger weld-up size than the ordered finished size, then processed exactly as stated above for the bead worked product. After the solution anneal cycle, the tubing is then cold reduced to the finished size either by "cold drawing" or "cold pilgering". This complete reduction in tube size imparts a minimum of 20 percent cold work across the entire tube, base material, and weld seam, after which the tube is given a second solution anneal. This process assures complete recrystallization of the weld zone and base metal, and the second solution anneal promotes greater homogenization of the weld metal through diffusion processes which is important for highly alloyed materials like the HASTELLOY® alloy grades. A "Fully Cold Reduced" tube will provide a seam weld approaching the corrosion resistance performance of a wrought seamless microstructure.

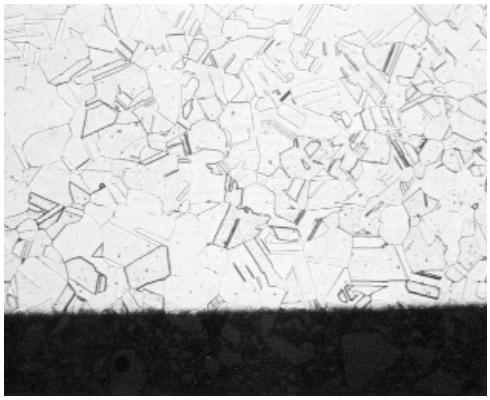


Figure 1: Fully recrystallized weld (ID)

The "Bead Worked" and "Fully Cold Reduced" tubular products are both covered by the same Classes (IIA, IIB, and III) ASTM B626 specification. To some purchasing personnel, the only difference between both types of tubing appears to be in the pricing. Due to the increased manufacturing time for "Fully Cold Reduced" tubing, the pricing will be greater than the "Bead Worked" tubing. The additional cost will provide a more consistent tubing product with a more homogenized weld zone for greater protection against corrosive attack.

If a given chemical process stream is expected to be aggressive even to highly alloyed materials like the HASTELLOY alloy grades, to benefit from a more homogenized weld seam, a "Fully Cold Reduced" tube with 20 percent minimum cold reduction must be specified when calling out ASTM B626 Class III tubing.

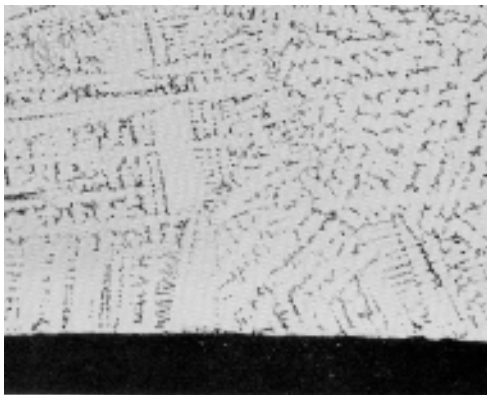
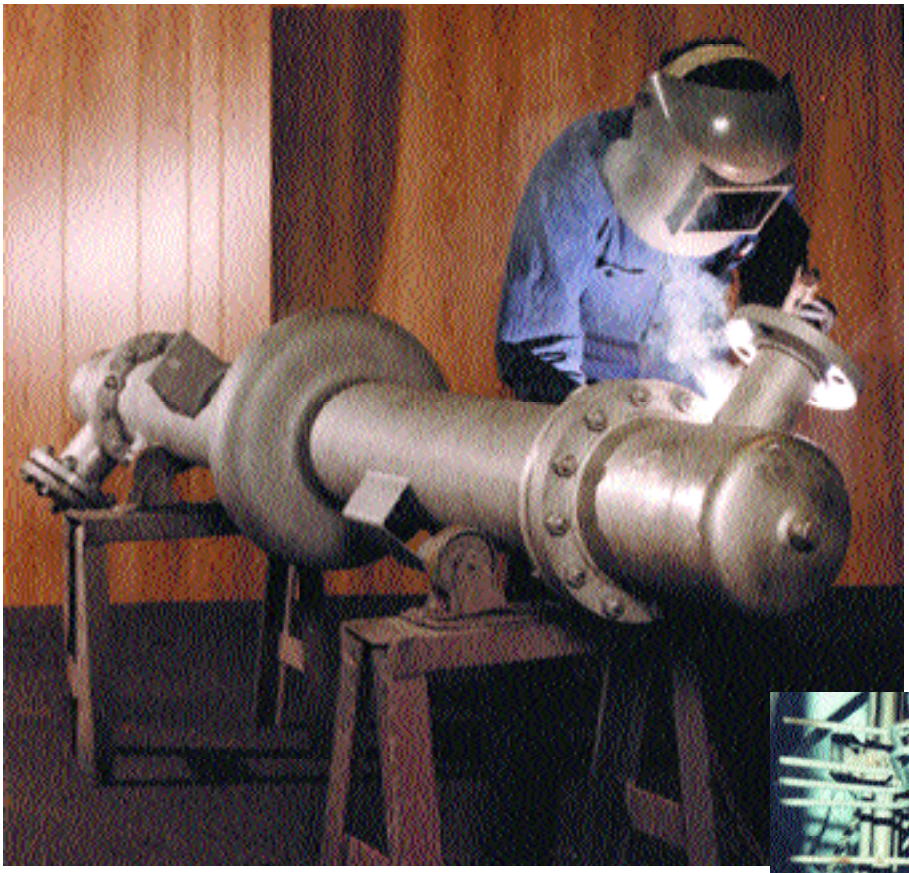
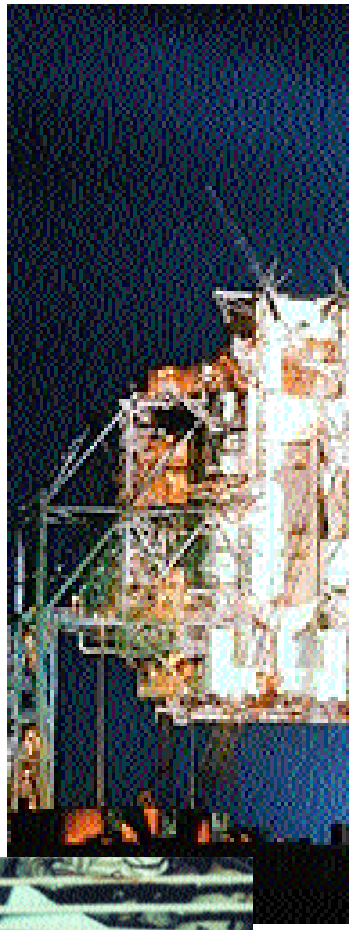


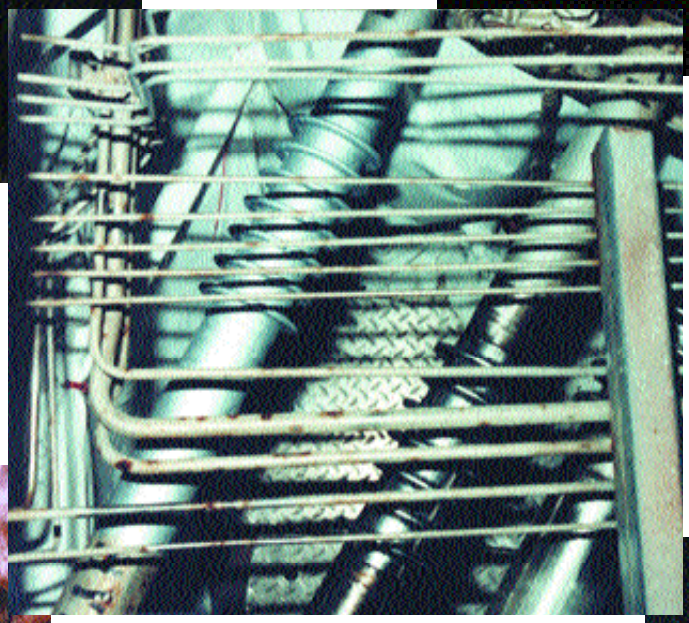
Figure 2: Unrecrystallized ID surface

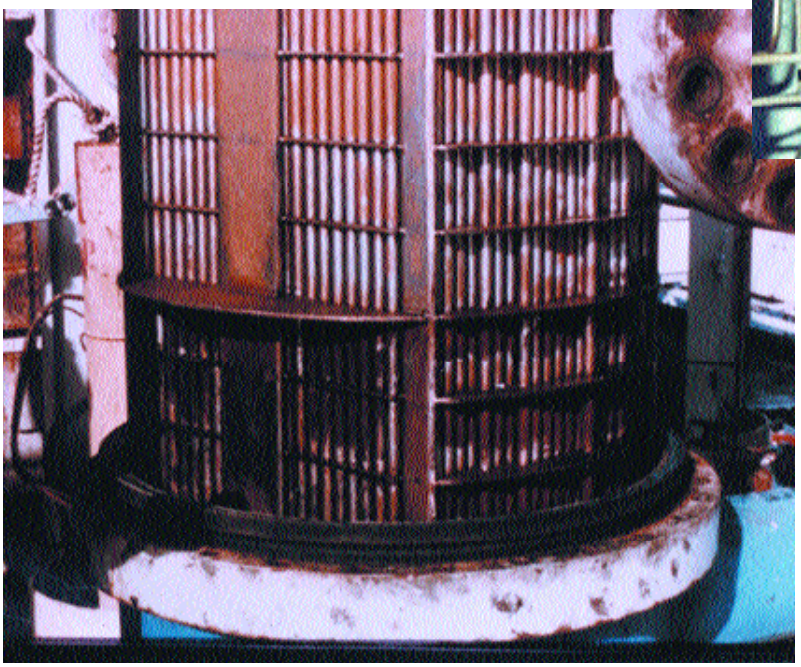
Even though HASTELLOY tubular products are highly alloyed with chromium and molybdenum, to withstand aggressive chemical environments, they need to be in an "optimum" metallurgical condition (Figure 1) in order to provide the anticipated resistance to corrosion. When high nickel alloys are supplied in the "non-optimum" conditions, such as the case of "partially" recrystallized and "non-fully" homogenized weld seam (Figure 2), corrosive attack at the weld has a greater chance for the initiation of corrosion.

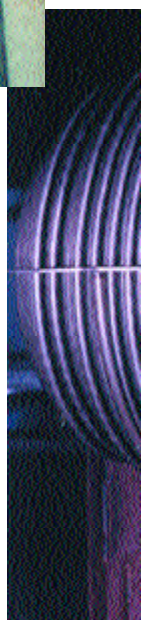
APPLICATIONS

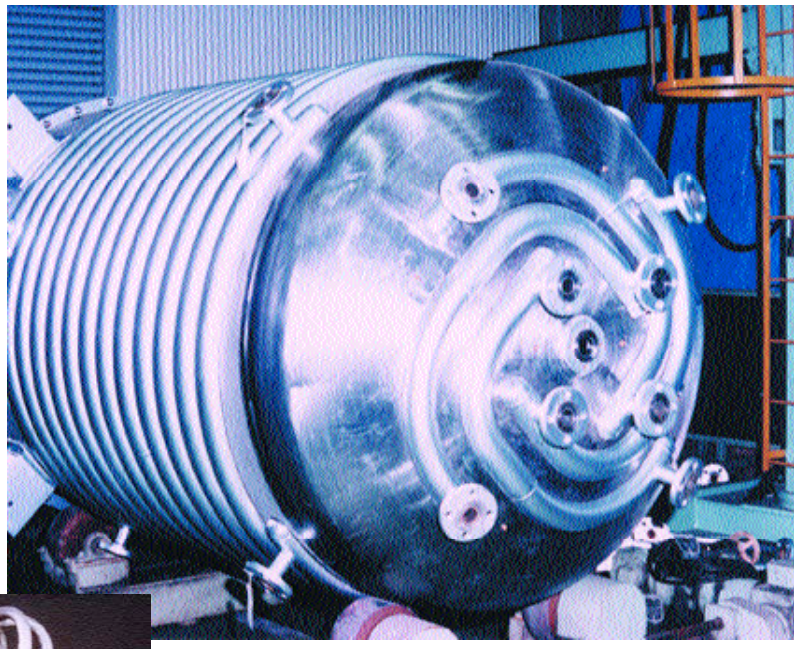


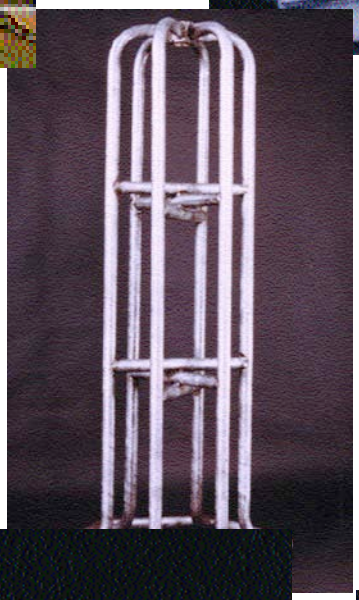


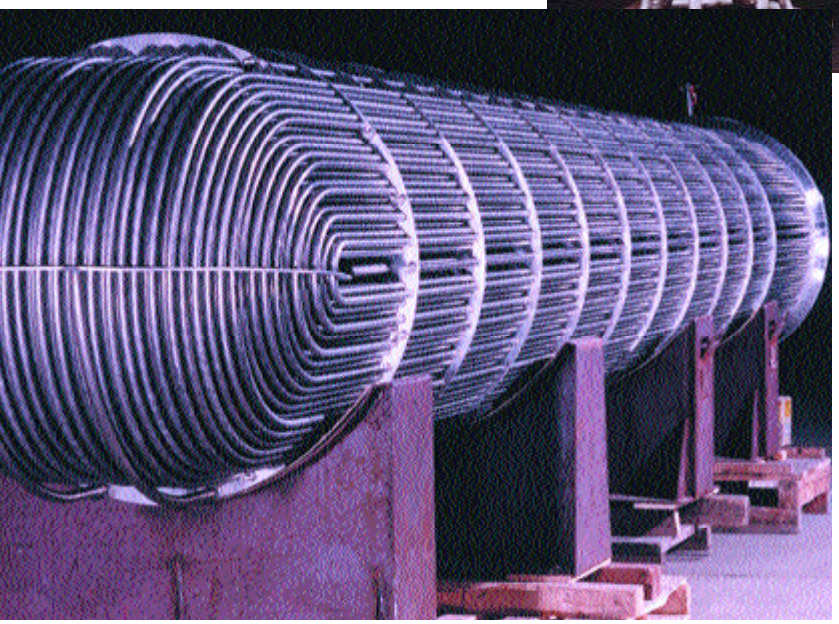


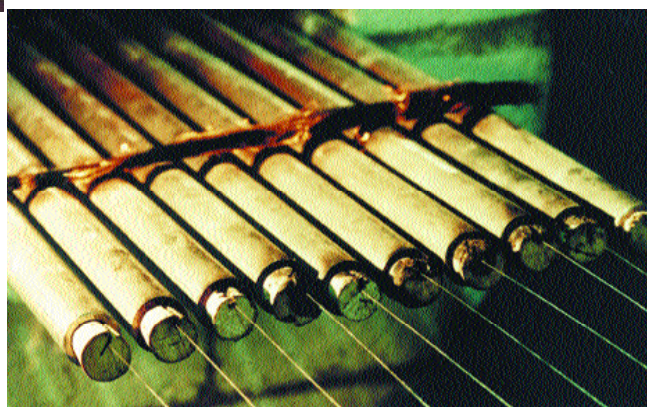


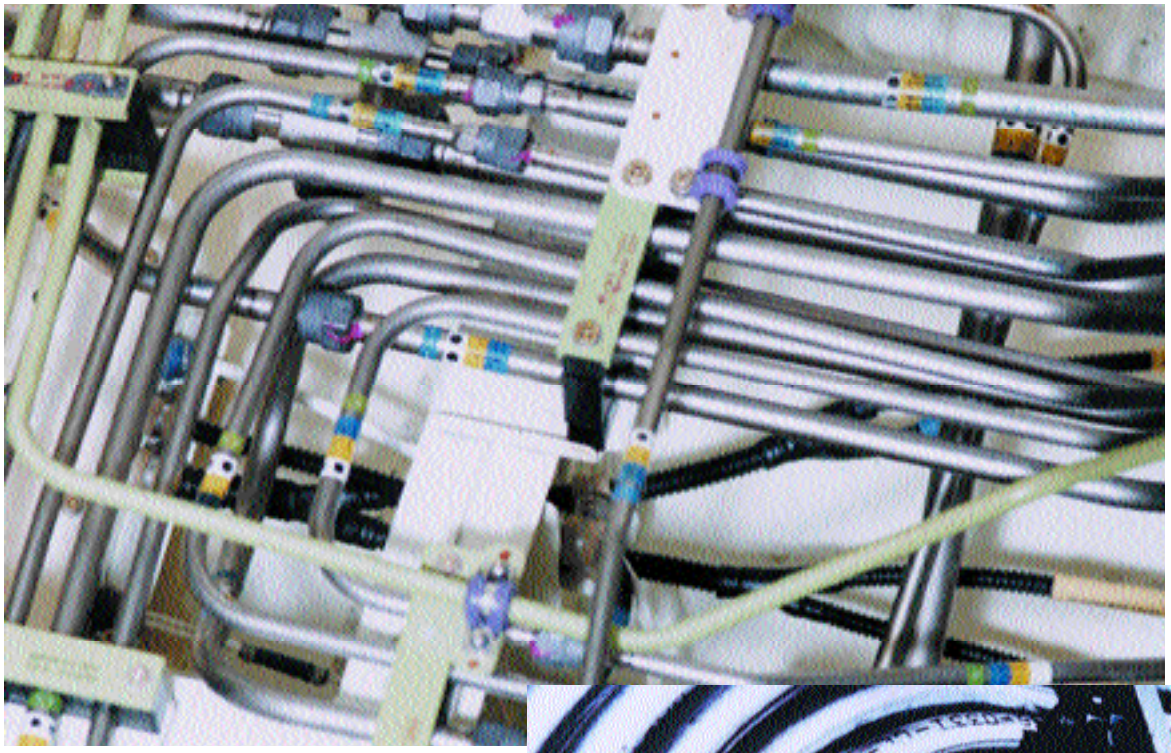


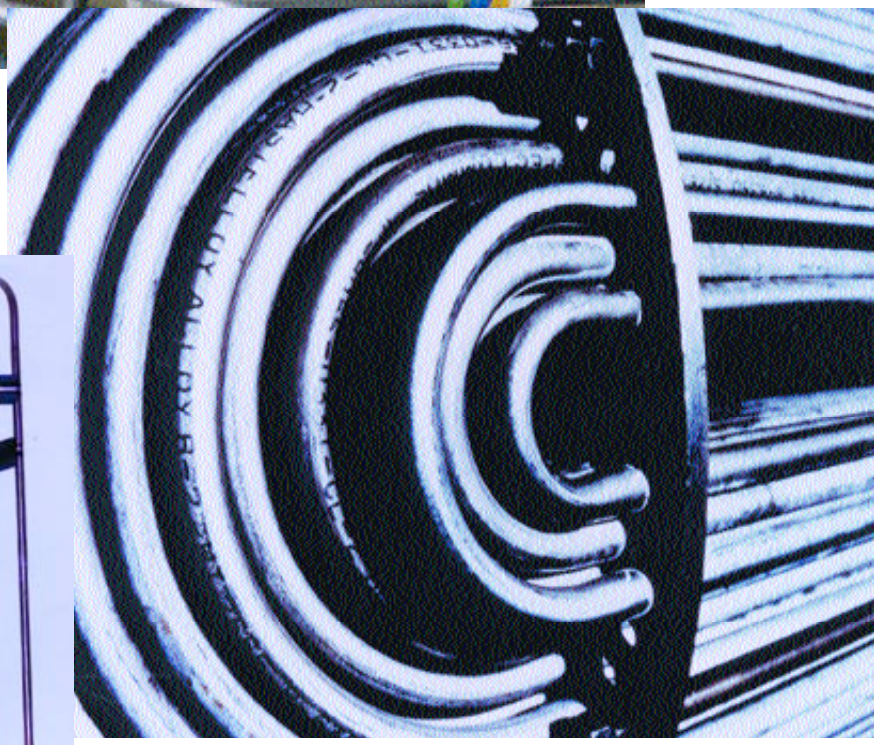


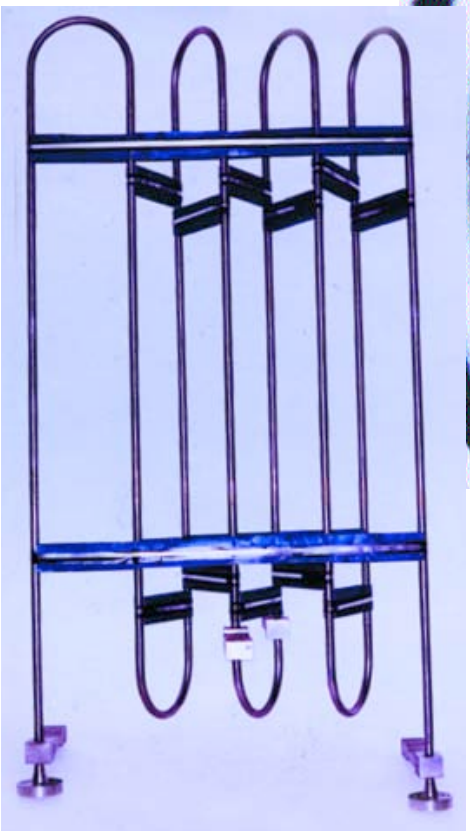












ALLOY COMPOSITION AND DESCRIPTION

HASTELLOY® Family of Corrosion-Resistant Alloys					Nickel-Base						
Alloy	Ni[a]	Co	Fe	Cr	Mo	W	Mn	Si	C	Cu	Others
B-2	69	1*	2*	1*	28	-	1*	0.1*	0.01*	-	-
B-3® alloy	65[b]	3*	1.5	1.5	28.5	3*	3*	0.1*	0.01*	-	Al-0.5*, Ti-0.2
C-4	65	2*	3*	16	16	-	1*	0.08*	0.01*	-	Ti-0.7*
C-2000® alloy	59	2*	3*	23	16	-	0.5*	0.08*	0.01*	1.6	-
C-22® alloy	56	2.5*	3	22	13	3	0.5*	0.08*	0.01*	-	V-0.35*
C-276	57	2.5*	5	16	16	4	1*	0.08*	0.01*	-	V-0.35*
G-30® alloy	43	2*	15	39	5.5	2.5	1.5*	1*	0.03*	2*	Cb-0.8
G-50® alloy	50	2.5*	17.5	20	9	1*	1*	1*	0.02*	0.50*	Al-0.4, Cb-0.5
G-3	42	5*	19.5	22	7	1.5	1*	1*	0.15*	2	Cb+Ta-0.5*

HAYNES® Family of High Temperature Alloys					Nickel-Base									
Alloy	Ni[a]	Co	Fe	Cr	Mo	W	Mn	Si	Al	Ti	C	B	Cu	Others
X	47	1.5	18	22	9	0.6	1*	1*	-	-	0.10	0.008*	-	-
HR-160® alloy	37	29	2	28	-	-	0.5	2.75	-	-	0.05	-	-	-
214™ alloy	75	-	3	16	-	-	0.5*	0.2*	4.5	-	0.05	0.01*	-	Zr-0.1*, Y-0.01
230® alloy	57	5*	3*	22	2	14	0.5	0.4	0.3	-	0.10	0.015*	-	La-0.02
242™ alloy	65	2.5*	2*	8	25	-	0.8*	0.8*	0.5*	-	0.03*	0.006*	0.5*	-
263	52	20	0.7*	20	6	-	0.6*	0.4*	0.6*	2.4*	0.06	-	0.2*	-
625	62	1*	5*	21	9	-	0.5*	0.5*	0.4*	0.4*	0.10*	-	-	Cb+Ta-3.7
718	52	1*	19	18	3	-	0.35*	0.35*	0.5	0.9	0.05	0.009	0.1*	Cb+Ta-5.0

HAYNES® Family of High Temperature Alloys					Cobalt-Base					
Alloy	Co*	Ni	Fe	Cr	Mo	W	Mn	Si	C	Others
188	39	22	3*	22	-	14	1.25*	0.35	0.10	La-0.03
25	51	10	3*	20	-	15	1.5	0.4*	0.10	-

HAYNES® Family of High Temperature Alloys					Iron Base							
Alloy	Fe*	Ni	Co	Cr	Mo	W	Mn	Si	Al	N	C	Others
556™ alloy	31	20	18	22	3	2.5	1	0.4	0.2	0.20	0.10	Ta-0.6, Zr-0.02, La-0.02
HR-120® alloy	33	37	3*	25	2.5*	2.5*	0.7	0.6	0.1	0.20	0.05	Cb-0.7, B-0.004

HAYNES® Titanium Alloy										
Alloy	Ti*	Al	V	Fe	Sn	Cr	C	N	O	H
Ti-3Al-2.5V	94	3	2.5	0.25*	-	-	0.05*	0.02*	0.12*	**

*Maximum ** Varies with specifications a As balance b Minimum

ALLOY DESCRIPTION

CORROSION-RESISTANT ALLOYS

HASTELLOY® B-2 alloy (N10665)
Superior resistance to hydrochloric acid, aluminum chloride catalysts, and other strongly reducing acids.

HASTELLOY B-3® alloy (N10675)
Outstanding resistance to hydrochloric acid and other strongly reducing media. Superior thermal stability, fabricability, and resistance to stress corrosion cracking relative to its predecessor, B-2 alloy.

HASTELLOY C-4 alloy (N06455)
High-temperature stability in the 1200ºF-1900ºF (650ºC-1040ºC) range as evidenced by good ductility and corrosion resistance. Virtually the same corrosion resistance as C-276 alloy.

HASTELLOY® C-2000® alloy (N06200)
Most versatile, corrosion-resistant alloy with excellent resistance to uniform corrosion in oxidizing or reducing environments. Excellent resistance to stress corrosion cracking and superior resistance to localized corrosion as compared to C-276 alloy.

HASTELLOY C-22® alloy (N06022)
Better overall corrosion resistance in oxidizing corrosives than C-4, C-276, and 625 alloys. Outstanding resistance to localized corrosion and excellent resistance to stress corrosion cracking.

HASTELLOY C-276 alloy (N10276)
Highly versatile, corrosion-resistant alloy. Very good resistance to reducing and mildly oxidizing corrosives. Excellent stress corrosion cracking resistance and very good resistance to localized attack.

HASTELLOY G-30® alloy (N06030)
Many advantages over other metallic and non-metallic materials in handling phosphoric acid, sulfuric acid, nitric acid, fluoride environments, and oxidizing acid mixtures.

HASTELLOY G-50® alloy (N06950)
Ni-Cr-Fe-Mo alloy has been widely used for severe sour gas (OCTG) applications with outstanding corrosion resistance, including elemental sulfur.

HASTELLOY G-3 alloy (N06985)
Improved version of alloy G with better fabricability and weldability.

TITANIUM ALLOY

HAYNES Ti-3Al-2.5V alloy (R56320)
Alloy used where strength/weight ratio is of prim importance (43 percent lighter than 21-6-9 stainless steel).

HEAT-RESISTANT ALLOYS

HASTELLOY X alloy (N06002)
Very good balance of strength, oxidation-resistance, and fabricability.

HAYNES® HR-160® alloy (N12160)
Oustanding resistance to sulfidation and other high-temperature aggressive environments.

HAYNES 214™ alloy (N07214)
Oustanding resistance to oxidation at temperatures up to 2300ºF (1260ºC), excellent resistance to carburization, and excellent resistance to chlorine-bearing environments.

HAYNES 230® alloy (N06230)
Best balance of strength, thermal stability, oxidation resistance, thermal cycling resistance, and fabricability of any major high-temperature alloy.

HAYNES 242™ alloy (N10242)
Age-hardenable alloy with excellent strength to 1300ºF (705ºC), low thermal expansion characteristics, good oxidation resistance to 1500ºF (815ºC), and excellent fabricability. Also has excellent resistance to high-temperature fluorine and fluoride-bearing environments.

HAYNES 263 alloy (N07263)
Age-hardenable alloy with excellent strength in the 1000ºF-1600ºF (540ºC-870ºC) temperature range and excellent forming and welding characteristics.

HAYNES 625 alloy (N06625)
Widely used in various aerospace, chemical process, and industrial heating applications.

HAYNES 718 alloy (N07718)
Age-hardenable alloy with excellent strength to 1200ºF (650ºC).

HAYNES 188 alloy (R30188)
Excellent strength with superior oxidation resistance and thermal stability compared to HAYNES 25 alloy. Good sulfidation resistance.

HAYNES 25 alloy (R30605)
Excellent strength, good oxidation resistance to 1800º (980ºC), very good sulfidation resistance, and relatively good resistance to wear and galling.

HAYNES 556™ alloy (R30556)
High-strength alloy with broad spectrum of resistance to high-temperature corrosive environments.

HAYNES HR-120® alloy (N08120)
High-strength, economical alloy, with good resistance to industrial environments.

STANDARD PRODUCTS

By Brand or Alloy Designation:

HAYNES International

HASTELLOY® Family of Corrosion-Resistant Alloys

B-3®, C-4, C-22®, C-276, C-2000®, C-22HS®, G-30®, G-35®, G-50®, HYBRID-BC1™, and N

HASTELLOY Family of Heat-Resistant Alloys

S, W, and X

HAYNES® Family of Heat-Resistant Alloys

25, R-41, 75, HR-120®, HR-160®, 188, 214®, 230®, 230-W®, 242®, 263, 282®, 556®, 617, 625, 65SQ®, 718, X-750, MULTIMET®, NS-163™, and Waspaloy

Corrosion-Wear Resistant Alloy

ULTIMET®

Wear-Resistant Alloy

6B

HAYNES Titanium Alloy Tubular

Ti-3Al-2.5V

Standard Forms: Bar, Billet, Plate, Sheet, Strip, Coils, Seamless or Welded Pipe & Tubing, Pipe Fittings, Flanges, Fittings, Welding Wire, and Coated Electrodes

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