

Supplementary Report

STAINLESS STEELS

GENERAL HISTORY, TYPES, CHARACTERISTICS AND APPLICATIONS

Stainless steels possess unusual strength, corrosion and heat resisting qualities and have innumerable applications where the appearance or performance of a product is adversely affected by corrosion or the action of heat.

Out of the many possible elements which might be alloyed with iron or steel, chromium is the only one yet found that has the unique property of conferring upon them, at reasonable cost, remarkable resistance to corrosion and oxidation.

Chromium was first added to steel in 1821, and although the superior oxidation resistance and other properties were recognized, their significance and useful development were not realized for almost a century. Starting with the addition of chromium to structural steel in 1865, the commercial use of relatively small amounts of chromium in special steels has increased continuously and led the way to high chromium-low carbon steels of the stainless type. The first of these was a stainless cutlery steel containing 11%-14% chromium which was developed in 1913. Rapid progress has been made and today the number has increased to upwards of sixty different compositions, including types for practically every application requiring a heat or corrosion resistant steel.

Stainless steels, as a group, contain a minimum of 10.00% chromium, since that amount has been found necessary to prevent oxidation occurring in many environments. For the maximum corrosion resistance with a minimum of chromium, a low carbon content is desirable. However, where the nature of application demands greater hardenability, an increased carbon content is essential, even though some corrosion resistance properties are sacrificed. Gradual increases in the chromium content produce progressive, though not proportional increases in corrosion and heat resistance and also produce fundamental changes in the physical characteristics and structure of the steel. In combination with chromium, other elements may be alloyed with iron to obtain special characteristics. The most important of these elements is nickel, and the iron-chromium-nickel type of alloys has enjoyed the widest range of application of any of the stainless steels. The addition of other elements, such as molybdenum and sulphur likewise impart special characteristics.

Variation of the combination and proportion of the alloying elements results in the production of three distinct groups of stainless steel under two general types.

I Straight Chromium Type

- (1) Iron-chromium Alloys - Hardenable by Heat Treatment.
- (2) Iron-chromium Alloys - Non-hardenable by Heat Treatment.

II Chromium-Nickel Type

- (1) Iron-chromium-nickel Alloys - Hardenable by Cold Working only.

STAINLESS STEELS

Page 2.

Each of the three groups of stainless steel has its distinguishing characteristics, and each composition of steel within these groups has its own properties depending on the supplementary additions which may have been made to impart special qualities. Corrosion phenomena are of many types and the rate of corrosion increases with rising temperature. The rate of corrosion of every piece of iron or steel depends on its composition, upon the means taken for its protection, and upon the individual conditions existing in the particular locality in which it is in use. Consequently, the wide variety of compositions of stainless steel offer advantages in selecting the proper material to meet a particular set of conditions. A comprehensive listing of all compositions and their physical properties would be far too voluminous for the scope of this report and it is necessary to confine description to general lines.

Rustless Iron and Steel Corporation manufactures twelve standard grades of stainless steel and in addition produces other stainless alloys of special analysis which enables it to furnish almost any type of stainless steel. Since the twelve standard grades are representative of the stainless steel field, brief comments on each of these grades are given in subsequent paragraphs. For complete data on the different grades, reference should be made to the company's Handbook. Each manufacturer has its own trade names for the various compositions of stainless steel. Those of Rustless Iron and Steel Corporation are utilized in this discussion.

STRAIGHT CHROMIUM TYPE

Hardenable by Heat Treatment

Trade Name	<u>Defirust</u>	<u>Defirust</u> <u>Machining</u>	<u>Rustless</u> <u>13-HC-35</u>	<u>Rustless</u> <u>17-HC-60</u>	<u>Rustless</u> <u>17-HC-90</u>
Stainless Steel Type No.	#410	#416	#420	#440	#440
Chemical Analysis:					
Carbon	0.15 Max	0.15 Max	0.40 Max	0.60-0.70	0.90-1.10
Chromium	10.00-14.00	12.00-14.00	12.00-14.00	14.00-18.00	14.00-18.00
Nickel	0.50 Max	0.50 Max	0.50 Max	0.50 Max	0.50 Max
Sulphur	---	0.15 Min	---	---	---
Molybdenum	---	---	---	---	---

Defirust is an air or oil hardening stainless steel that possesses good corrosion resisting properties, has fair resistance to heat, and is not appreciably affected by exposure at sub-zero temperatures. A wide range of physical properties may be secured by heat treatment. Cold forming and machining properties of Defirust are relatively good and it is very responsive to manufacturing operations. It may be readily welded if annealed. Defirust can be used in applications involving exposure to process solutions of neutral salts, basic salts, natural food acids, waste products, natural waters low in total solids, iron-bearing mine waters, and highly acid and abrasive copper solutions. It is also used where dampness alone, or coupled with chemical pollution, rapidly deteriorates ordinary steel, or where wear or inaccessibility make paint protection difficult

as in grain elevator chutes, coal handling equipment and trash screens. Defirust is extensively used for screws, bolts, valve parts, turbine blades, pump rods, pistons, golf club heads, and similar applications requiring a combination of high strength and corrosion resistance. The negligible effect of sub-zero temperature exposure recommends it for use in refrigeration equipment. In a cold rolled, work hardened state, it may be used for the cheaper grades of cutlery.

Defirust Machining is a free cutting, air or oil hardening stainless steel with physical characteristics and corrosion and heat resisting properties similar to those of Defirust. It has special non-galling and non-seizing properties, and may be readily turned, threaded, drilled, formed or reamed, or cut on standard automatic screw machines at speeds approaching those used for ordinary Bessemer screw stock. Defirust Machining grade has fair cold forming properties, but is not generally welded. It is used for screws, valve parts, pump shafts, and similar applications where processing involves considerable machining. It is also of outstanding value for applications where the service involves friction under high pressures or at elevated temperatures.

Rustless 13-HC-35 is a high carbon air or oil hardening stainless steel of the original cutlery type. A wide range of physical properties may be obtained by heat treatment. Cold forming and machining properties are fair when the material is in the annealed condition. It is not generally welded. Maximum resistance to corrosion is developed only when the material is in the fully hardened and polished condition, and it resists attack by such media as vinegar, fruit and vegetable juices, food products, alkalis, lye, ammonia and sterilizing agents. Rustless 13-HC-35 is used for cutlery, tableware, ball bearings, valve trim, scissors, surgical and dental instruments, and similar applications where a combination of high hardness and excellent corrosion resistance is desirable.

Rustless 17-HC-60 is a high carbon air or oil hardening stainless steel of the modified cutlery type. A wide range of physical properties may be obtained by heat treatment. Cold forming and machining properties are fair when the material is in the fully annealed condition. It is not generally welded. Maximum resistance to corrosion and tarnishing is developed only when the material is fully hardened and with exposed surfaces polished to a high lustre. Under such conditions it is fully resistant to staining by fruit juices, food products, vinegar, kitchen cleaning compounds, alkalis and sterilizing agents. Rustless 17-HC-60 is widely used in applications where corrosion resistance, coupled with a good cutting edge, or abrasive resistance, are required, as in cutlery, dental and surgical instruments, ball bearings and valve parts.

Rustless 17-HC-90 is a high carbon air or oil hardening stainless steel of the ball bearing type. A wide range of physical properties may be obtained by heat treatment. Cold forming and machining properties are fair when the material is in the fully annealed condition. It is not generally welded.

STAINLESS STEELS

Page 4.

Maximum resistance to corrosion is developed in this grade only when fully hardened. Rustless 17-HC-90 material has greater hardening properties than either of the two types of high carbon steel described above, and is used extensively for severe abrasive service, such as is encountered by balls and seats in valves handling abrasive or corrosive materials.

STRAIGHT CHROMIUM TYPE

Non-Hardenable by Heat Treatment

Trade Name	<u>Rustless 17</u>	<u>Rustless 17-FM</u>	<u>Defiheat</u>
Stainless Steel Type No.	#430	#430 F	#446
Chemical Analysis:			
Carbon	0.12 Max	0.12 Max	0.12 Max
Chromium	14.00-18.00	14.00-18.00	23.00-30.00
Nickel	0.50 Max	1.00 Max	1.00 Max
Sulphur	---	0.15 Min	---
Molybdenum	---	---	---

Rustless 17 is a non-hardenable stainless steel. Its corrosion and heat resisting properties are excellent and are considerably better than the lower chromium grades. The only heat treatment generally applied is an annealing operation, since the material is practically non-hardenable. Its welding properties are only fair and its work hardening susceptibility is low. This grade possesses good machining properties, and in the fully softened condition is particularly suited to applications involving severe cold deformation. Rustless 17 is highly resistant to atmospheric conditions and will remain untarnished on exposure, provided surfaces are polished. It is widely used for parts where great strength is secondary to corrosion resistance and workability, such as for exterior trim and ornamentation in the automotive industry. The material staunchly resists nitric acid, food products, organic acids, salt water and other corrosive agents and is widely used for equipment in the chemical and food industries.

Rustless 17-FM is a non-hardenable stainless steel with the same essential properties as Rustless 17 combined with excellent free cutting qualities. It may be turned, threaded, drilled, formed, reamed, or cut on automatic screw machines at speeds approximately 90% of those used with Standard screw stock. Due to its structural nature the material is not quite as suitable as Rustless 17 for severe cold forming. It is not generally welded. Rustless 17-FM is mainly used for machined parts requiring a higher degree of corrosion and heat resistance than is provided by the Defirust-Machining grade. Its superior non-galling and non-seizing properties recommend it for use in parts subjected to friction while under heat or pressure. It provides resistance to nitric acid, food products, organic acids and salt water.

Defiheat is a non-hardenable stainless steel which is preeminently a heat-resisting alloy intended for use in parts subjected to stress and oxidation at high temperatures, but also possesses excellent resistance to corrosion. It is especially resistant to nitric acid and is resistant to both oxidizing and reducing gases up to 2000° F. However, it has a tendency to lose strength at such elevated heats, and therefore should only be used for installations where high strength and toughness are secondary to high temperature resistance. Since Defiheat is not hardenable, the only heat treatment generally applied is annealing. Machining and cold-forming properties are fair. Welding operations on Defiheat are not usually recommended. It is widely used for furnace parts, preheaters, annealing boxes, conveyor chains, exhaust manifolds, and equipment for handling nitric acid and mixed acids. It also has excellent resistance to such media as sea water, acid mine water, and hot sulphur-bearing gases.

CHROMIUM-NICKEL TYPE

Hardenable by Cold Working Only

<u>Trade Name</u>	<u>Defistain</u>	<u>Defistain Machining</u>	<u>Rustless 18-12-MO</u>	<u>Rustless 25-12</u>
Stainless Steel Type No.	#302, 304, 308	#303	#316, 317	#309, #309S
Chemical Analysis:				
Carbon	0.12 Max	0.20 Max	0.09 Max	0.20 Max
Chromium	18.00-22.00	18.00-20.00	16.00-20.00	22.00-26.00
Nickel	8.00-12.00	8.00-10.00	14.00 Max	12.00-14.00
Sulphur	---	.15 Min	---	---
Molybdenum	---	---	2.00-4.00	---

Nickel lowers the dissolution rate of its solid solution in iron in essentially all reagents, and hence retards corrosion. When this effect is superimposed upon the passivating effect of chromium when present in excess of some 10%, an unusual resistance to any attack under oxidizing conditions is conferred upon the alloy. Due to the sluggish manner in which high chromium steels transform, it is possible, by the addition of metals, such as nickel, to produce and retain exceedingly persistent austenite by moderately rapid cooling from 1825 ° - 2190 ° F. These austenitic chromium steels can not be heated to give specific properties, but they have exceptionally good cold working properties and the hardness, yield point and tensile strength are increased by this method. They are adaptable to severe deep drawing operations, and are suitable for use in the cold rolled condition if high strength is desired. The combination of slow oxidation and good high temperature strength make these materials indispensable in many industries. These steels have the low magnetic susceptibility and the high coefficient of expansion typical of austenite. Due to their ease of fabrication by welding, bending, forming, or spinning, the austenitic steels have enjoyed the widest range of application of any of the stainless steels.

Defistain grades are commonly referred to as "18-8" stainless steels. They can be hardened only by cold working which also readily increases tensile strength through a wide range. As Defistain alloys are not hardenable by heat treatment, they are generally used in an annealed or cold drawn condition. Excellent tensile properties are maintained at sub-zero temperatures. Defistain alloys are also highly satisfactory for intermittent service at high temperatures. Machining properties are fair. Welding properties are very good. Normally these alloys are non-magnetic. Combining unusual physical properties with remarkable resistance to all ordinary corrosive agents encountered in domestic and industrial use, they constitute a widely used group of stainless steels. Properly polished surfaces will remain untarnished indefinitely when exposed to atmospheric conditions. Defistain alloys respond to almost every type of fabrication. They are extensively utilized in equipment for handling acetic, nitric and citric acids, food and milk products; in valve trim, screws, bolts, welding wire, and oil refinery equipment. Investigation of the possibility of broad application of these alloys in aircraft fabrication is under way. Hard drawn Defistain wire is excellent for springs operating under adverse conditions.

Defistain-Machining stainless steel can be hardened only by cold working and, with minor exceptions, is comparable in physical, tensile, and corrosion resisting properties to Defistain described above. The addition of sulphur confers valuable free-cutting properties to this material which permits it to be cut in automatic screw machines at speeds up to 70% of those used in machining standard screw stock. Its non-galling, non-seizing characteristics are also excellent. Owing to the structural nature of Defistain-Machining, it is not as adaptable as Defistain to severe cold upsetting operations and is not ordinarily welded. As its properties would suggest, Defistain-Machining is used in parts subjected to friction, as in valves and pumps, and other applications requiring a free-cutting, non-galling metal having high resistance to corrosion.

Rustless 18-12-MO grade represents another variety of "18-8" stainless steel which can be hardened only by cold working and is distinguished by its high molybdenum content. As it is not hardenable by heat treatment, it is generally used in the annealed or cold drawn condition. It may be severely cold worked. Because of the high molybdenum content, this grade is particularly suited for applications involving severe corrosion resistance, especially the so-called "pitting" type corrosion. It is superior to many other metals at elevated temperatures in that it retains a high order of strength and toughness because of its remarkable resistance to creep. Machining properties are only fair, being similar to those of Defistain. Rustless 18-12-MO grade possesses excellent welding characteristics and subsequent heat treatment is not necessary for welds to possess high strength, toughness and structural stability. It is the most corrosion resistant of the stainless alloys. The addition of molybdenum very definitely increases resistance to non-oxidizing acids, such as sulphuric, phosphoric and acetic. This alloy is widely used in the paper industry in contact with severely corrosive sulphite liquors, and in the textile industry for use with many mineral and organic acids, dyes, and bleaches. Ease of cleaning and lack of contamination from metallic salts are important requirements of this latter industry. Other typical applications are in the manufacture of cellulose and in handling photographic chemicals.

STAINLESS STEELS

Page 7

Rustless 25-12 grade is a cold work hardening type of stainless steel which is primarily intended for use in high temperature service, although it is also highly resistant to a wide variety of corrosive agents. As it can not be hardened by heat treatment, it is generally used in the annealed or cold drawn condition. In addition to hardening, its tensile properties can be increased by cold deformation. Machining properties are only fair. Welding characteristics are good and similar to those of Defis-tain. Rustless 25-12 possesses exceptional strength and toughness at temperatures up to 2000 ° F. Oxidation is negligible at all temperatures under 2000 ° F. It is used for furnace parts, oven linings, still tube supports and similar applications where superior heat resistance is required.

The foregoing discussion of stainless steels provides evidence that the wide range of properties which are available in the different alloy compositions make them adaptable to meeting almost any corrosion, heat, or acid resisting problem. Likewise, the extensive diversification of applications in industry is indicated.

WHK:MW

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STAINLESS STEEL APPLICATIONS

Explosive plants
Aircraft -- exhaust flanges, cable fittings, pump
rods, bomb racks, etc.
Turbine blading
Valves
Screws, bolts and nuts
Surgical instruments
Signalling apparatus
Navigation instruments
Gears
Electrical instruments
Ship construction
British Iron and Steel Corporation
Navy yards and Army arsenals
Chemical plants
Field ranges, kitchenware
Artillery equipment
Diesel engines
Hardware for parachutes
Submarine detection equipment

From the desk of--
C. E. TUTTLE

Mr. M. K. Schnurr, Sec.-Treas.,
Rustless Iron and Steel Corp.