Volume 1

The Weighs and Means of Scrap

**The Complete Guide to
Buying & Selling Stainless & Alloys
Including Chemistry, Characteristics & Applications**

Larry M. Clark

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Volume I

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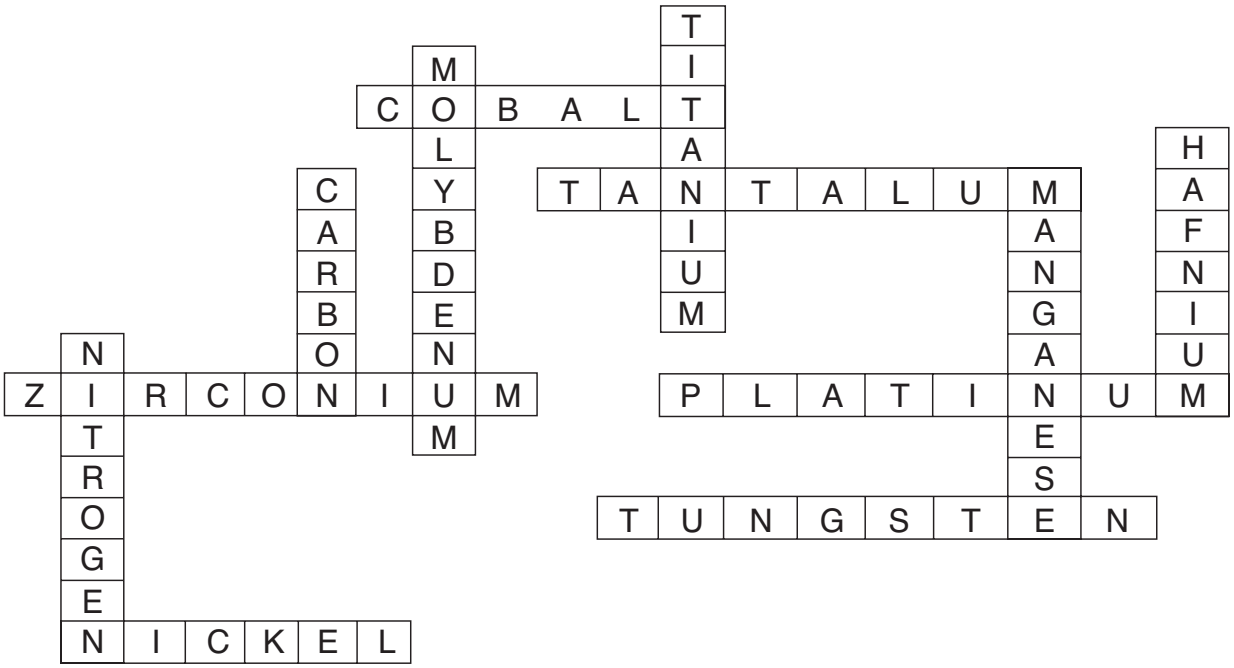
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The Weighs & Means of Scrap

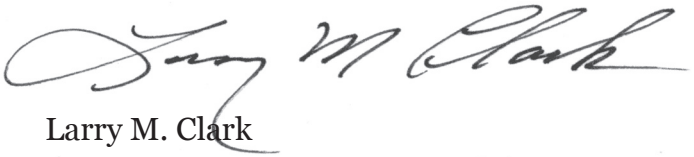
Preface

Being a good scrap buyer is like the making of a good wine, it takes time to perfect. The buyer must be able to sell himself. He must have the confidence and the ability to identify the scrap and give the seller the right price for that particular item. Confidence comes through knowledge, and knowledge comes through hard work and the perseverance to become proficient in the chemistry, characteristics and applications of all the many alloys and elements. The information in this book and its daily application can put you directly into one of the most rewarding and challenging fields of work available today.

I have laid this book out in the following format in order to help you understand the myriad of options available for each product, first the chemical composition, secondly the characteristics of each alloy, and finally the applications for each. If no application is listed that is because at the time of this writing that information is proprietary.

I personally feel that if you study this book carefully anything is possible. My sincere desire is that this book will help young men or women to achieve their life goals and enjoy a successful career in the scrap industry.

With best wishes,



Larry M. Clark

Chapter I

Getting Started

WITHOUT ANY KNOWLEDGE OF THE SCRAP BUSINESS, I found myself working in the mailroom of one of the largest scrap processors in the United States. I soon found that scrap processors play a vital role in converting our junk or scrap back into new-finished products. Scrap processors purchase both ferrous and non-ferrous scrap shipping to consumers all over the world. I was given the opportunity to transfer to a local scrap yard, actually pricing and weighing scrap iron that came in over the large truck scale. I soon realized that I had to build trust in these people and this came with time. They wanted to be weighed correctly and to be paid fair prices. There was one small peddler that brought his scrap into the yard in a grocery push-cart. He also had a little puppy that he trained to sit on the far end of the truck scale. The dog would sit quietly on one end of the scale and the fellow would try to distract me so I would not notice him. I would not say a word, until after he had unloaded his 150 pounds of scrap out of the cart, then I would ask "Where is your dog?" and he would reply "What dog? I don't have a dog?" This would go on quite frequently, and I would tell him over and over, "Where is that dog I bought?" He would just smile, and then he and the dog would cross the railroad track together. As a buyer I also dispatched the trucks for local industrial accounts, and of course, the person on the dock did not call when he was supposed to and the scrap container was full, and they needed it picked up immediately. It was a learning experience.

After two years of buying ferrous scrap, I was given the opportunity to buy non-ferrous scrap. I was soon taught the four words that are always spoken when a customer backs his truck or car up to the dock "What do you have?" These four words are the magic phrase that a buyer will use repeatedly. I found that I could identify the grade of copper by simply looking at the material, and if I could identify the use of most brass items, I could usually identify the alloy. When I asked the person, "What do you have?" I knew what he had, I knew the value, but I wanted to know what he thought he had.

Nevertheless, wisdom should be used carefully, to insure that the seller will return with more scrap. Taking advantage of his ignorance may well show him you can't be trusted and he may not come back to sell additional material. I soon found that buying scrap was fun and exciting. It was a new game and I wanted to play. The object of the

game was to identify the grade, know its value and see just how cheap I could purchase the scrap.

I also learned that a good buyer must love the business. The thought of competing to purchase a particular item or a group of different items will likely energize you beyond your greatest imagination. This burst of adrenaline can be compared to winning a sports event, beating a challenger and beating the odds. The competition to be the victor can become an obsession, but one must be able to recognize when to walk away from a bid or sale. With environmental and liability issues today, one must be very careful not to jeopardize himself.

After purchasing scrap over the scale for three years, I was given the opportunity to buy scrap from small scrap dealers. This was like leaving a small pond and diving directly into the ocean. Buying scrap from an experienced scrap operator is very difficult. You may think that you are smart and you can pick the person off in your pricing, but you cannot. The old veteran scrap dealers are well qualified in all survival methods of buying and selling that go far beyond what you might imagine. In fact, he may take you out back and show you the worst thing in his yard to just see how much you will pay for a worthless item. Or he may show you an item and call it something else, just to see what kind of reaction you might have.

To be a good buyer one must earn the confidence and trust of his customers. Even if you consider yourself a good scrap buyer you will not necessarily be likeable to everyone. You may be criticized for your lack of knowledge, or your arrogance, or your ability of making others feel weak or inadequate. Scrap prices can fluctuate significantly on a simple rumor, a strike, or other non-related happenings. Therefore, as a buyer you must show everyone that you want repeat business and are not looking to just make a one-time buy. Winning over a new customer may take more time than you might think, you must be patient and show the customer that you understand his reluctance to change and when the time is right you will get the business.

You will realize that you will never know everything, and that every time you visit a new scrap yard or industrial account you will learn a little more. After a while, you will find that you have acquired a lot of knowledge. Finally yet importantly, do not be fearful of making a mistake, only acknowledge it and learn from the experience.

Chapter II

Recognizing Scrap and its Uses

A GOOD SCRAP BUYER MUST LEARN TO RECOGNIZE THE ALLOY from its use or application. In our search for new fuels, faster communication, more efficient transportation we are creating new alloys using new combinations of many different elements. These new and exotic alloys make many of our products used today lighter, stronger and more fuel-efficient. The simple addition of one or more elements can give extended life to many of the products we use today. One must learn to recognize the properties of different elements and learn that by adding specific elements to alloys can ultimately enhance its use, making it more suitable to be used in a particular application.

Depending on the application, additions of nickel, chrome, carbon, or other elements may be added. Almost every product we use today is a combination of several elements to make the product harder, more flexible or wear abrasive for a particular use or application. We see the effects of alloy additions in each grade of stainless and especially in the high temperature alloys. The percentage added to each alloy adds a different characteristic or capability, including the reverse order of addition at the time of melting can change the characteristics and ability to perform.

The expanded use of cobalt, tungsten, titanium, and tantalum continue to extend the life of parts used in extreme heat and corrosive applications. Thermo spray and Sputter Coating of these same elements tends to protect and give extended wear to parts exposed to high heat and corrosive applications. Piston rings and pistons are coated with Moly to extend the life and wear from exposure to high heat and friction. Plasma screens are coated to protect the glass, CD's are coated to protect them from being scratched, almost every electrical part in a computer or telephone is coated to insure corrosion resistance and electrical failure. Technology is making great strides in developing new alloys that can withstand many corrosive solutions and chemicals that make our products safer and giving longer life to many products used today.

Scientist refers to *Elements* as the building blocks of nature. Each element is a pure substance that is unable to be split into any simpler pure substance. The smallest particle of an element that can exist is an atom. Atoms consist of subatomic particles. The most important of these are protons, which have positive electrical charges. Electrons have

negative electrical charges, and Neutrons, which are electrically neutral. The atomic number of an element is the number of protons in one atom of the element. Each element has a different atomic number. Elements with atomic numbers 1 (hydrogen) to 94 (plutonium) occur naturally on Earth. Using nuclear reactors and particle accelerators created the remaining artificial elements.

Metallurgists have grouped combinations of certain elements that give similar characteristics and are compatible in specific uses and applications. Using the highest percentages of elements in each alloy one can see uniform similarities in applications and specific characteristics of each alloy in the group. Pricing for each group follows the same guidelines for each alloy shown.

Chapter III

Where do you find Scrap?

The single largest source of scrap is the manufacturer or assembly plants located throughout the country. These manufacturers make everything from automobiles to washing machines and every other product purchased at your local hardware store, discount store and a multitude of other stores throughout the country. Due to product liability, manufacturers purchase only certified material directly from mills or service centers. Each mill and service center will provide copies of the original mill certificates, showing the heat number, and complete chemistry. These mill certificates allow you as a manufacturer to guarantee the strength and endurance needed to perform the task the tool or part is designed to perform.

Purchasing new production scrap directly from the manufacturer allows you to possibly market this scrap at a significant premiums over #1 HMS or a standard P & S (plate & structural) and if the material is a stainless or even a chrome alloy this will also potentially allow you to market this at a significantly higher prices to specialty foundries or mills that require material to be segregated and packaged to insure the uniform chemistry.

Manufacturers may purchase coils, plate, wire, or pipe from mills or service centers, shipping this material via railcars, truck and barge. New coils and plate can become unsuitable if water marked, or if coils are damaged and unable to feed directly into the de-coiling machines. The term “heads” and “tails” is the unused portion of a coil not shipped to the service center or manufacturer.

Computerized plasma or laser cutting machines generate skeleton scrap from coils and plate. Manufactures stamp, press, roll, and shape and weld all grades of material into refrigerators, washing machines, automobile parts and many other household or industrial products. Many manufacturers also may generate very heavy scrap metal. Manufacturers generating this heavy scrap are most commonly making equipment used in chemical, refinery and other industries that manufacture equipment used in high pressure, high stress application, and high temperature and corrosive applications.

The second largest source of scrap is the service industry. Today we live in such a fast-paced world that most of us do not have time to fix or repair our cars or the stopped

up sink. The real issue is that almost everything we use has a small computer or chip that we have no idea how to repair or fix. Therefore, we are dependent on people with specialized skills to fix or repair our cars, trucks, dishwashers, and computers. These people generate tons of copper, brass, stainless and iron. They may deliver this scrap material directly to the local scrap facility. However, the people have the same problem that you and I have. They are so busy and cannot afford the loss of an employee to leave during normal working hours. For that reason, many smaller shops or manufacturers sell their scrap directly to hustlers or other smaller scrap dealers or processors.

The third largest generator of scrap is the scrap dealer. The scrap dealer generates scrap from many sources. The scrap dealer wants to establish his business with a friendly reputation that he welcomes direct traffic off the streets. Over the scale traffic consists of homemakers selling aluminum cans, people cleaning out their garage, the service industry and the peddlers. The peddler is one that has no business license or actual place of business but roams the streets, alleys, vacant lots, closed business, and, unfortunately, even theft from unsuspecting people or businesses to collect anything of value. The over the scale or walk in traffic is the most lucrative scrap source. Many of these people have no idea as to what the scrap is actually made from, nor its value. The scrap dealer maximizes his margin purchasing directly from these customers. Complementing the over the scale and the industrial scrap a dealer might also seek to purchase directly from smaller dealers that find it necessary to turn their cash faster.

In addition, Gypsies are one of the most unique sources. The term “Gypsy” refers to an ethnic group of people that have the ability to source scrap, to make deals and purchase scrap from large and small companies at prices lower than what conventional scrap dealers would pay. Gypsies are probably the largest single supplier to larger scrap dealers.

Chapter IV

What is Stainless Steel?

THE TERM *STAINLESS STEEL* refers to a combination of iron and chromium with the addition of other elements including nickel. Products manufactured out of stainless steel are made to serve a particular service or need and they do not rust or break and they look good for years. The product will be durable and not easily damaged to insure a long life. Depending on the use, the product can be manufactured out of thin sheet material making it strong but easily handled in the home and by children. Stainless steel products are very tough and scratches can easily be removed keeping its finish appealing to the eye. Each stainless product has a particular quality or need that could make the chemistry different. Specialty steel mills produce plate, coils and structural shapes to be shipped to large warehouses that de-coil and cut, size, polish and prepare the stainless to be shipped to service centers or manufacturers. Large service centers resale this new material to small and large manufacturers to make the mixing bowls, cookware, utensils, cutlery tools, large and small household products as well as automobile parts.

Historically consumers have used as much as 75% scrap stainless and the balance a combination of Ferro-nickel, Ferro-chrome, Ferro-manganese and select grades of steel scrap. The specialty mills purchase stainless scrap from the large stainless processors and supplement their melts with certified ferroalloys. Using stainless steel scrap over Ferro-alloys has greatly reduced the cost of making stainless steel. The availability of stainless steel scrap greatly affects the price consumer's pay for nickel to make stainless steel.

Consumers manufacture many different grades of alloys of stainless steel, each having its own specific chemistry and applications. Depending on the end use, the product might be made into coils or sheet, slabs or bars. The chemistry of each must meet many requirements that enable a manufacturer to stretch, shape, stamp, draw and roll into many products with many different applications and requirements for the actual finished product. When someone says it is made out of stainless, we immediately assume that this product will have a long life, and that it can withstand corrosion, heat and many others stress applications. The combination of iron, chrome and nickel with the addition of variable percentages of other elements including carbon and manganese give each

stainless steel grade a characteristic or quality that makes each different. The addition of chrome to iron makes the alloy very hard and strong. The addition of nickel to this same alloy gives it many specific qualities making it very safe for food and pharmaceutical manufacturing.

When we say “It is made of stainless steel”, we are not saying what grade it is, but we are just saying that it is made well, and will last for years. We might think that if the material is “magnetic”, then it is “not” real stainless steel. There are magnetic and non-magnetic stainless steels and like all metals, each derives their physical properties from the presence of specific “Phases” in the microstructure of the metal. Ferrite, Martensite and Austenite are all phases of stainless steel that can be formed. These phases are related to a multitude of processing parameters and have distinct properties, which in turn affect the steel. Many of these properties are added in reverse proportions, so a balance must be found between them. In general, the harder and stronger the steel, the more brittle it becomes. The three types of stainless steel are distinguished by the metallurgical architecture, which depends on the quantity of various elements present in the alloy. Because each can be categorized by its structure, each can also be differentiated by its end-use application. For instance, ferritic stainless steel contains no nickel, so they are generally not used in applications where toughness and hardness (two characteristics the nickel brings to the metal) are required.

Chapter V

TYPES OF STAINLESS STEEL

Martensitic Stainless Steel

MARTENSITE IS A VERY HARD MICRO-CONSTITUENT with the formation of an acicular structure. In general, a *"Martensitic alloy"* is one of a high chrome and carbon content in a ferrous material. However, the term *"Martensitic"* actually references the condition of the matrix structure, and can apply to any variety of material whereby Martensite is able to form. The presence of carbon is required for Martensite to form, and enhanced significantly by chrome (from Chromium-carbide), especially when heated to the Martensitic range and quenched.

Characteristics:

- Contains between 11 to 17% Chromium for corrosion resistance
- Carbon levels from .10 to .65%, allows materials to be hardened by heating to a high temperature, giving maximum hardness, strength and resistance to abrasion and erosion.
- Magnetic under all conditions.
- Contains little or no nickel in most cases.
- Uses: cutlery, scissors, surgical instruments, wears plates, garbage disposal shredder lugs and industrial knives.

Ferritic Stainless Steel

As in ferrite is a cubic crystal structure in which, unless otherwise designated, alpha iron is the solvent element in an essentially carbon free solution. Ferrite is magnetic and has several forms, more than one of which may exist in a single microstructure, such as *alpha* and *delta* ferrite, which when present will be separated and an area of Austenite. Fully ferritic steel is only obtained when the carbon is low.

- Similar chromium to Martensitic stainless, but carbon content is lower (however, Chromium content can be as high as 27% for maximum resistance to oxidation at high temperatures), with Molybdenum additions, reducing cost over nickel bearing or nickel base corrosion resistant materials.
- Resistant to chloride stress corrosion cracking.
- Magnetic under all conditions.
- Maximum softness, ductility and corrosion resistance achieved through the annealing process.
- Hardened using cold-work conditions.
- Contains no nickel.

Austenitic Stainless Steel

The result of non-magnetic solid solution of iron carbide in gamma iron called *"Austenite"* with the presence of alloy elements such as nickel, rendering the material Austenitic at ambient temperatures. In Austenitic stainless, nickel replaces carbon as the solvent element and the microstructure becomes more or less magnetic depending on the presence of non-magnetic Austenite and magnetic ferrite, which is directly correlative to the values of Austenite enhancing elements such as nickel, chrome, and silicon available in the alloy.

- Contains anywhere from 4% to as high as 35% Nickel plus molybdenum or copper and sometimes stabilizing elements...
- Non-Magnetic.
- Extremely ductile, can be cold-worked to achieve maximum combination of strength and toughness.
- Certain varieties may be used at temperatures between negative 200 degrees centigrade and 1,100 degrees centigrade, without sacrificing integrity or the required characteristics (formability and strength).

Chapter VI

Categories of Stainless & Alloys

Iron Based Stainless

400 Martensitic Stainless – Fe+ Cr

200 Austenitic Stainless – Fe + Cr + Mn

300 Ferritic Stainless – Fe + Cr + Ni – with and without Mo

High Nickel Casting or “Superasutenitic” – Fe+ Cr + Ni – with and without Cu & Mo

Heat Treat Casting – Fe + Cr + Ni

Duplex Stainless – Fe + Cr + Ni + Mo – with and without Cu

Precipitation Hardness – Fe + Ni + Cr + Mo – with and without Cu

Copper and/or HQ Stainless = Fe + Cr + Ni + Cu – with and without Mo

Heat-Corrosion Resistant, Valves and Iron-Based “Super Alloys”
Fe – Cr – Mn – with and without Mo

Heat-Corrosion Resistant Iron-Based Valve Steels – Fe + Cr + Ni + Manganese

Nickel Alloys with and without Chrome and Moly
Ni + Cr + Mo + with small amount of Cu in many alloys

Nickel Chrome Alloys with other Elements
Ni + Cr with small amounts of Co, Mo, Cu, Al and other elements

Nickel Based Alloys

Nickel Cobalt Alloys - Ni + Co + Cr – *may have small amount of Al, Cu, and Fe*

Cobalt Alloys - Co + Ni + Mo + Fe

Maraging Steels - Ni + Co + Mo + Ti

Chapter VII

Characteristics of Alloying Elements

Carbon
Low carbon improves resistance to intergranular stress-corrosion cracking.

Chromium
Chromium is used to harden steel, to manufacture stainless steel, and many other alloys currently used. Other uses of chromium are in plating surfaces to produce a hard beautiful surface to prevent corrosion and giving glass an emerald green color.

Chromium/Molybdenum
The addition imparts a high level of resistance to pitting and crevice corrosion.

Cobalt
The addition of cobalt to alloys makes many alloys suitable for high temperature creep and fatigue resistance non-rotating applications where stress levels are lower than for rotating components.

Hafnium
Improves ductility of turbine parts

Manganese
Improves the rolling and forging qualities, strength, toughness, and stiffness, wear resistance, hardness and hardenability.

Molybdenum
Contributes to the hardenability and toughness of quenched and tempered steels, improves the strength of steel at high temperatures.

Nickel
Gives extended life to corrosive applications, heat applications, stress, and salt water.

Nitrogen
Strengthens stainless, with improved ductility at high temperatures.

Platinum
Improves corrosion resistance.

Tantalum
Improves corrosion resistance.

Titanium
Improves corrosion resistance.

Tungsten
Improves hardness.

Zirconium
Improves corrosion resistance.

Chapter VIII

Elements –Symbols – Characteristics - Applications

Element	Symbols	Atomic Number	Atomic Weight	Melting Point C	Boiling Point C	Characteristics and Applications
Aluminum	Al	13	26.97	660.32	2519	Used in refractories
Arsenic	As	33	74.92	817	603	
Beryllium	Be	4	9.02	1287	2471	
Bismuth	Bi	83	209.00	271.4	1564	Used in producing malleable irons.
Boron	B	5	10.82	2075	4000	Used in aerospace alloys
Carbon	C	6	12.00	4492	3825	Found in most alloys
Chromium	Cr	24	52.01	1907	2671	Used to harden steel, stainless and many metals.
Cobalt	Co	27	58.94	1495	2927	Increases hardness, resistant to oxidation
Columbium	Cb		92.91			
Copper	Cu	29	63.57	1084.62	2562	Used in coinage metal
Hafnium	Hf	72	178.49	2233	4603	
Iron	Fe	26	55.84	1538	2861	Increases hardness combined with Ni, Cr, V
Magnesium	Mg	12	24.32	650	1090	Light weight, durable in stress applications
Manganese	Mn	25	54.94	1246	2061	Improves rolling and forging qualities in steel

Molybdenum	Mo	42	96.00	2623	4639	Adds to hardenability and toughness in alloys
Nickel	Ni	28	58.69	1455	2913	Resist corrosion, add hardness and strength
Niobium	Nb	41	92.91	2477	4744	Used in stainless and high temp alloys
Nitrogen	N	7	14.01	-210	-195.79	Used in annealing stainless steel and alloys
Oxygen	O	8	16.00	-218.79	-182.95	
Phosphorous	P	15	31.02	44.16	280.5	Used in steel, brass and many other alloys
Platinum	Pl		195.20			
Rhodium	Rh		102.90			
Samarium	Sa		150.40			
Silicon	Si	14	28.06	1414	3265	Increases mechanical and electrical properties
Sulfur	S	16	32.06	95.3	444.6	
Tantalum	Ta	73	180.88	3017	5458	Adds strength and ductility at high temperatures,
Tellurium	Te		127.60			
Thoruim	Th		232.10			
Tin	Sn	50	118.71	231.93	2602	Prevents corrosion
Titanium	Ti	22	47.9	1668	3287	Extremely strong, light weight, corrosion resistant
Tungsten	W	74	184.00	3422	5555	Add hardness, strength to alloys in cold and high
Vanadium	V		50.95			
Zirconium	Zr	40	91.22	1855	4409	Resist corrosion

Chapter IX

Grades of Stainless & Alloys

Fe & Cr
400 Series Stainless

The cost of making 400 Series is considerably less than making the more exotic 200 and 300 Series stainless steel, and therefore we find many of these products used in parts or other products that we use daily. We are unaware of the spring used on the oven door, the cooking racks in our ovens, the utensils we use daily, surgical instruments, the ball bearings that make things move easily, the plating vats, and the automotive trim. Its magnetic quality often makes people think the product is “iron”, but in reality, we simply call it “400 Series Stainless”.

- What is 400 Series Stainless?
  Highly magnetic Iron based alloy with Chrome levels of 10 to 27%, primarily with little or no contained Nickel.
- What is the relative chemistry?

Highest Contained Element	Iron	74.0 to 86.0 %
Second Highest Contained Element	Chrome	10.5 to 27.0 %

  Small amount of Ni 1.5 to 2.5% in some 400 Alloys
- What are the characteristics of 400 Series Stainless?
  Corrosion and oxidation resistant, attains high hardness,heat-resisting.
- What are the applications of 400 Series Stainless?
  Turbine parts, surgical instruments, valves, cutlery, catalytic converters, mufflers hangers, steam turbine buckets, gas turbine compressor blades, nuclear reactor rod mechanisms, high strength bolts, ball bearing and races, furnace parts, heat treating boxes.

Fe-Cr-Mn+/+small amount of Ni & N
200 Series Stainless

The 200 Series is relatively new, having been developed in 1957-58, when nickel was scarce, and often used as a substitute for 300 Series. The approximate analysis is as follows: Nickel 3-6%, Chrome 16-20%, Manganese 5-10%, used at a ratio of 2% for each percent of nickel replaced in 300 Series. The hardness is higher with excellent ductility and superior creep properties at elevated temperatures.

- What is 200 Series Stainless?
  High-manganese, nitrogen-strengthened Austenitic stainless steel that provides substantially higher yield and tensile strengths than Type 304 stainless and has general-corrosion resistance between that of Type 430 and Type 304 stainless.
- What is the relative chemistry of 200 Series Stainless Steel?

Highest Contained Element	Iron	65.0 to 67.0 %
Second Highest Contained Element	Chrome	16.0 to 19.0 %
Third Highest Contained Element	Manganese	7.50 to 15.0 %

  Small amount of Ni from 1.4 to 5.5%

- What are the characteristics of 200 Series Stainless Steel?
  Non-magnetic as annealed and becomes magnetic after cold work, low nickel, Austenitic stainless steel. The hardness is higher with excellent ductility and superior creep properties at elevated temperatures.

- What are the applications of 200 Series Stainless?
  Aircraft components, automobile trim and engine components, chemical process components and pollution control, coal and mining equipment, electronic components, food and pharmaceutical processing equipment, household and kitchen components, marine hardware, medical service equipment, ordnance components, as well as transportation equipment such as railroad freight and passenger transit cars, trucks, ship containers.

Fe-Cr (+/-) Higher Mn
Nitronic Stainless

The Nitronic Alloys were created to replace the more costly high nickel and molybdenum contained 316 and 317 stainless with less expensive manganese replacing much of the nickel and little or no contained Molybdenum.

- What is Nitronic stainless?
  Nitronic stainless possess' superior corrosion resistance with roughly twice the yield strength of standard Austenitic stainless at room temperature. The hardness is higher with excellent ductility and superior creep properties at elevated temperatures. Other advantages of Nitronic Stainless Steels include very good mechanical properties at both sub-zero and elevated temperatures, along

with low temperature impact resistance, as well as superb resistance to high temperature oxidation.

- What is the relative chemistry of Nitronic Stainless Steel?

Highest Contained Element	Iron	65.0 to 67.0 %
Second Highest Contained Element	Chrome	16.0 to 23.0 %
Third Highest Contained Element	Manganese	5.0 to 15.0 %

Small amount of Ni from 1.4 to 13.5%

- What are the characteristics of Nitronic Stainless Steel?
  - Non-magnetic, corrosion resistant with excellent wear and galling resistance while being twice as strong as the standard Austenitic stainless.
  - High temperature strength, hardness and corrosion resistance to combustion products
  - Magnetic permeability remains very low after severe cold working and at cryogenic temperatures.
  - Excellent toughness at cryogenic temperatures while remaining nonmagnetic after severe cold work

- What are the applications of Nitronic stainless?
  Aircraft components, automobile trim and engine components, chemical process and pollution control, coal and mining equipment, electronic components, industrial applications, marine hardware, truck and bus frames, ship containers, communication & pole line fasteners, rebar, nuclear, as well as cryogenic applications.

Fe-Cr-Ni
300 Series Stainless

The 300 Series Stainless is the most widely used stainless, and is classified as Austenitic, and is hardenable only by cold working methods. These grades of stainless have chromium (approx. 18 to 30%) and nickel (approx. 6 to 20%) as their major alloying additions. The most widely used grade is Type 304, referred to most commonly as 18-8, is the largest tonnage grade and has a nominal analysis of 8% Nickel and 18% Chromium with varying amounts of other elements added to change the metallurgical properties. For example, Molybdenum, or “Moly”, is contained in Type 316 and Type 317, and Titanium is added to Type 321.

The nickel content in 300 Series changes their fundamental structure and nature, lowers their thermal conductivity, doubles their coefficient of expansion and makes them non-magnetic as compared to straight chromium 400 Series alloys. These alloys are highly resistant to corrosion and possess great strength and oxidation resistance at elevated temperatures, yet retain good ductility at extremely cold temperatures. In the annealed state, 300 Series stainless steels possess unusual ductility and formability, high impact strength and high tensile strength compared to mild carbon steels. The 300 Series has excellent fabrication characteristics, including good weld ability.

- What is the relative chemistry of 300 Series Stainless?

Highest Contained Element	Iron	50.0 to 75.0 %
Second Highest Contained Element	Chrome	4.0 to 28.0 %
Third Highest Contained Element	Nickel	0.0 to 36.0 %

- What are the characteristics of 300 Series Stainless?
  Good corrosion resistant, heat resistant, good weldability, high temperature strength.
- What are the applications of 300 Series Stainless?
  Pots & pans, flatware, countertops, sinks, oven parts, automotive and architectural trim, brewery, beverage, dairy, food and meat processing equipment, hospital equipment, tubing, furnace parts, chemical processing equipment, heat exchanger tubing, high temperature bolts, springs, valves, compressor blades and vanes, pressure vessels, crusher rolls, pump parts, jaw crushers, hammer mills, grinding balls, mill liners.

Fe-Cr-Ni
High Nickel Castings or "SuperAustenitic"

- What is the relative chemistry of High Nickel or SuperAustenitic Castings?

Second Highest Contained Element	Chrome	8.0 to 32.0 %
Third Highest Contained Element	Nickel	1.0 to 68.0

** The Chrome & Nickel percentages may vary dramatically*

- What are the Characteristics of High Nickel Castings
  Resistant to sulfuric acid and many reducing chemicals, heat resistant, resistant to high temperature oxidation, as well as resistant to rural, industrial and marine atmosphere.

- What are the applications of High Nickel Castings?
  Pump parts, impellers, valves, and digesters, processing equipment in corrosion-erosion environments, cylinder liners, hydraulic components, and steam turbine parts, useful in the pulp and paper industry, heat exchangers.

Fe-Cr-Ni
Heat Treat Castings

- What is meant by "Heat Treat Castings"
  Contains sufficient Nickel and Chrome combinations that allow the material to be exposed to high heat and maintain strength and durability.

- What is the relative chemistry of Heat Treat Castings?

Highest Contained Element	Iron	32.0 to 85.0 %
Second Highest Contained Element	Chrome	11.0 to 36.0 %
Third Highest Contained Element	Nickel	0.50 to 37.0 %

- What abbreviations are used to designate Heat Treat Castings?

  Not all castings are suitable for extreme heat, and the prefix letter H. designates castings that were developed for heat applications. Following the letter H are other letters referring different elements or percentages of the alloy. One can quickly see that the numbering sequence begins at the letter C and continues thru the alphabet and the numbers refer to percentages or other connotations associated with each alloy. HC-30 refers to H for heat, C refers to chrome, and the 30 refers to the 30% chrome contained.

  Another accepted means of referring to designate *heat treated alloy castings* is by referring to the percentage contained of nickel and *chrome* in each alloy. These alloys are referred to as the *"Nickel Chromes"*. The *higher* of the two elements is listed first. If you use these abbreviations frequently, one will soon learn the numbers and does not even think about which come first. For example HH is 25/12, *25* stands for the percentage of *chrome*, and *12* stands for the percentage of *nickel* contained. The alloy *HK* is *25/20*, *25* stands for the percentage of *chrome*, and *20* stands for the percentage of *nickel*. However, we find that *HT* or *35/15*. The number *35* stands for the percentage of *nickel contained,* and the *15* stands for the percentage of *chrome contained*.

  To summarize the above, 3 or 4 digit numbers with no letters usually designates the material is wrought. The prefix C designates the alloy is a casting. The prefix H designated a Heat resistant cast alloy that will have varying amounts of nickel and chrome.

- What are the applications of Heat Treat Castings?

  Pump parts, reformer tubing, furnace parts, steam turbine parts, jet engine parts, valves, heat exchanger parts, furnace grates, dampers, pouring spouts, gas burner parts, billet skids, furnace covers, electrode arms, conveyor belts, annealing trays, tube supports, carburizing boxes, exhaust manifolds, radiant tubes and retorts, hearth plates, muffles.

Fe-Cr-Ni-Mo
Duplex Stainless

- What is Duplex?

  Called Duplex because of its mixed microstructure `with about equal proportions of ferrite and Austenite. Duplex stainless steels are families of grades, which range in corrosion performance depending on their alloy content.

  Duplex alloys are essentially a compromise possessing some of the ferritic stress corrosion cracking resistance and much of the superior formability of the common Austenitic stainless alloys, at a cost saving over the high nickel alloys.

- Types of Duplex Stainless

  Lean Duplex such as 2304, which contains no deliberate Mo addition, *2205*, the work-horse grade accounting for more than 80% of duplex usage, 25Cr Duplex such as Alloy 255 and DP3, Super duplex, with 25-26 Cr and increased Mo and N compared with 25 Cr grades, including grades such as 2507, Zeron 100, UR 52N+, and DP-3W.

- Benefits of using Duplex
  - High strength.
  - High resistance to pitting, crevice corrosion resistance.
  - High resistance to stress corrosion cracking, corrosion fatigue and erosion.
  - Good sulfide stress corrosion resistance.
  - Low thermal expansion and higher heat conductivity than Austenitic steels.
  - Good workability and weldability.
  - High energy absorption.

- What application will we see Duplex used?
  - Heat exchangers, tubes and pipes for production and handling of gas and oil.
  - Heat exchangers and pipes in desalination plants.
  - Pressure vessels, tanks and pipes in process industries handling solutions containing chlorides.
  - Rotors, fans, shafts and press rolls where the high corrosion fatigue strength can be utilized.

Fe-Cr-Ni (+/-) Mo – Cu
Precipitation Hardness Stainless

- What is Precipitation Hardened Stainless?

  Chrome and Nickel containing steel that provide an optimum combination of the properties of Martensitic and Austenitic grades, that have been heat treated giving them high strength and have the corrosion resistance of Austenitic stainless steel. This heat treatment leads to precipitation hardening of a Martensitic or Austenitic matrix. Hardening is achieved through the addition of one or more of the elements Copper, Aluminum, Titanium, Niobium, and Molybdenum.

- What are the applications is PH Stainless used?
  - Gears
  - Valves and other engine components.
  - High strength shafts.
  - Turbine blades.

Fe-Cr-Mn (+/-) Mo
Heat-Corrosion Resistant Iron-Based "Superalloys"

- What is the relative chemistry of Iron Based corrosion resistant steels?

Highest Contained Element	Iron	48.0 to 92.0 %
Second Highest Contained Element	Chrome	4.0 to 27.0 %
Third Highest Contained Element	Manganese	8.00 to 20.0 %

** Many alloys have 0.0 to 4.5% Moly*

- What are the characteristics of Iron Based corrosion resistant steels?
  - Corrosion, wear and heat resistant, creep resistant, high strength.
  - Heat-Corrosion Resistant Iron-Based "Superalloys"

- What are the applications of these Iron-Based corrosion resistant steels?
  For high temperature steam valves and gas turbines, petroleum refining industry, nozzle and nozzle support struts, diesel engine valves and coal handling equipment, heat exchangers.

Fe-Cr-Ni-Mn
Heat-Corrosion Resistant Iron-Based Valve Steels

- What alloy are valves made from?
  Engine valves are made from high quality alloy steel that include Austenitic steel, Martensitic steel, bimetal and super alloys such as Nimonic and Inconel 751 etc.

- Why are some engine valves sodium filled?
  Sodium filled valves give greater heat dissipation over solid valves as well as saving some weight.

- Types/Grades of Valve Steel Mfg.
  - Martensitic Grades 0.060max Ni, 7-13% Cr, 0.50-1.00 Mn
  - Austenitic Grade 7.5-15% Ni, 13-20% Cr, 0.70-1.30 Mn
  - Nitrogen Enriched Austenitic Grade
    1.5-12.00 Ni, 18-24.00% Cr, 0.80-10.00% Mn, 0.15-0.50 N

- Why do processors price "auto valves" based on being material being a "Type 201" Stainless Steel?
  On the average mixed lots of auto valves will likely have 3.5 to 5.0% Nickel, with 17.0% Chrome, or something similar to Type 201 Stainless.

Ni-Cr-Mo (+-) Cu
Nickel Alloys with and without Chrome and Moly

- What chemistry justifies material being described as Nickel Alloy Material?
  1. 25% minimum Nickel contained
  2. Less than 50% contained iron

- What is the relative chemistry of Nickel-Chrome-Moly Alloys?

Highest Contained Element	Nickel	34.0 to 93.0 %
Second Highest Contained Element	Chrome	1.0 to 31.0 %
Third Highest Contained Element	Molybdenum	0.0 to 30.0 %

** Small amount of Cu is found in many alloys*

- What are the characteristics of Nickel Alloys with and without Chrome -Moly?
  Good corrosion resistance to oxidizing media such as nitric acid sulfuric acid, phosphoric acid and chloride environments, higher tensile and creep strength at elevated temperatures.

- What are the applications most often found for Nickel-Chrome-Moly Alloys?
  Aircraft fasteners & parts, drill collars, seawater handling equipment, food processing equipment, oil & gas production equipment, turbine and super-chargers wheels and afterburner parts, acetic acid distillation plants, chemical plants, phosphate plants, equipment in pulping liquors.

- What are the most popular Nickel-Chrome-Moly Alloys used:
  29-4, 254 SMO, 316, 317, AL-6X, Jessop JS 700, Carpenter 20, Carpenter 20-CB-3, Discaloy, Hastelloy C, C-4, C-22, C-276, C-2000, Hastelloy G, G-50, Hastelloy S, Hastelloy X, Illium B, G, Incoloy 825, 901, 925, Inconel 625, 725

Ni-Cr (+/-) Co, Mo, Cu, Al and other elements
Nickel Chrome Alloys with other Elements

- What is the relative chemistry of Nickel Chrome Alloys with other elements?

Highest Contained Element	Nickel	15.0 to 62.0 %
Second Highest Contained Element	Chrome	0.0 to 25.0 %

** may have small amounts of cobalt, molybdenum, copper, aluminum and other elements*

- What are the characteristics of Nickel Alloys with other elements?
  Heat resistant and corrosion resistant.

- What applications might we fine Nickel Chrome Alloys with other elements?
  Mixing tanks, heat exchangers, process piping, pump shafts, toasters, heating elements in electric furnaces, electric ranges, thermocouples, conveyor

belts, gas turbine hot section components, turbine disc, extrusion dies, furnace parts, and steam generator components.

- What are some of the most popular Nickel Chrome Alloys with other elements?
  A-286, AL-6XN, Carpenter 20, Carpenter 20 CB-3, Duplex 2205, GMR 235, Incoloy 800, 801,802, 804, 805, 825, 840, 925, Inconel 600, 601, 690,706,713, 721, 738, Nichrome, Nimonic 75, 80, Ni-Resist 1, 2, 3,4,5, RA 330, RA 333

Ni-Cr (+/-) Co, Mo, Cu, Al and other elements
Vacuum Quality – Air Melt – Nickel Refinery Nickel Chrome Alloys

VACUUM ALLOYS

- What are vacuum alloys?
  Vacuum alloys take their name from the melting process used to produce them. These materials are made by charging virgin metals, scrap or a combination of the two into a furnace (usually an induction furnace) that is contained inside a large vacuum chamber. The initial charge can often be made with the furnace open to the atmosphere but the melting, back charges and pouring are all done under vacuum.

- Why are vacuum furnaces used to melt alloys?
  To protect easily oxidized elements (called reactive elements) from vaporizing during the melt (Ti, Al, Nb, Re, Mo, W, Ta, a long list).
  To lower the gas content of the alloy (E-Bright was a stainless steel melted in vacuum for this reason as it had very low oxygen and nitrogen requirements).

- What are size requirements for vacuum scrap?
  Size requirements should be verified with the smelter but most have specifications that require 2’ by down. The size limits are determined by the size of the air lock that the scrap must pass through during back charging. Much larger pieces can be sold to vacuum smelters with special permission. These larger pieces will have a hook welded to them by the smelter and loaded by crane in the first charge of a campaign while the furnace is open.

- What are the requirements for vacuum melt alloys?
  Scrap for vacuum melting must be clean of dirt, scale and grease (in short– any foreign matter). Solids should be shot blasted and turnings must be degreased. Turnings should also have any “fines” removed after crushing to protect the vacuum pumps. All scrap must be absolutely clean as there is no way to remove carbon in a vacuum furnace and an induction furnace cannot tolerate a slag. All vacuum scrap must be free of blind holes, to insure steel shot does not get wedged inside.

AIRMELT ALLOYS

- What are airmelt alloys?
  Airmelt alloys usually refer to materials that can be melted in the open air. The furnaces used can be either of the arc or induction type. Some alloys that are usually thought of as “Vacuum” can also be melted in air if the final application is not critical (I-718 is Vacuum for rotating aircraft parts but can be air melted for shear blades and piping).

- What are size requirements for airmelt scrap?
  Scrap for airmelt is usually 4’ by down. Here again, the smelters specifications should be checked to avoid unnecessary cutting or a rejection.

- What are the requirements of airmelt alloys?
  Airmelt scrap need not be cleaned by shot blasted. It must however be free of noticeable dirt, trash, rags, plastic or any other nonmetallic material. The scrap should be free of alloys other than what was sold unless it was sold as a blend guaranteed to hit a specific chemistry.

REFINERY ALLOYS

- What are refinery alloys?
  The term refinery usually refers to materials that cannot be re-melted as them. This would be things like extremely contaminated turnings, grindings, solids that cannot be cleaned of contaminates. Some sludges can sometimes be considered refinery grade. Refinery items can go through one or several processing steps (thermal and chemical) deigned to concentrate one or several valuable elements.

- What are size requirements for airmelt scrap?
  Size specifications must be taken from the refinery. They are all different but most will not take anything over 4’X4’.

- What are the requirements of airmelt alloys?
  Materials going for refinery can be pretty ugly. They should however be free of any large amounts of non-metallic materials (plastic, trash, rocks and dirt etc.).

Ni-Co-Cr (+/-) Al, Cu, Fe
Nickel Cobalt Alloys

- What is the relative chemistry of Nickel Cobalt material?

Highest Contained Element	Nickel	14 to 60%
Second Highest Contained Element	Cobalt	5 to 30%

Third Highest Contained Element Chrome 8 to 28%

* *may have small amounts of Al, Cu, Fe*

- What are the characteristics of Nickel Cobalt Alloys?
  Good strength at high temperature applications, stress-rupture strength.
- What applications might we find Nickel Cobalt Alloys?
  Turbine parts, jet engine blades, springs, fasteners, tubing, shock applications.
- What are the most popular Nickel Cobalt Alloys?
  Astroloy, HR 160, IN 100, Kovar, L605, Multimet (N-155), Nimonic 90, 100, 105, 115

Fe-Ni-Mo (+/-) Co – Al
Maraging Steels

- What are Maraging Steels?
  Carbonless *Fe-Ni* alloys additionally alloyed with cobalt, molybdenum, titanium and some other elements. The 18% Ni-Maraging steels are strengthened by a process of Martensitic transformation, followed by age or precipitation hardening. Maraging steels work well in electro-mechanical components where ultra-high strength is required, along with good dimensional stability during heat treatment.

- What is an example of typical chemistry?
  17-19% Ni, 7-9% Co, 4.5-5% Mo and 0.6-0.9% Ti

- How is Maraging steel done?
  Alloys are hardened to Martensite and then tempered at 480-500 degrees C. The tempering results in strong precipitation hardening owing to the precipitation of intermetallic from the Martensite, which is supersaturated with the alloying elements. With the precipitation hardening in aluminum, copper and other non-ferrous alloys, this process has been termed ageing, and since the initial structure is Martensite, the steels have been called Maraging.

Co – Ni – W – Mo - Fe
Cobalt Alloys

- What percentage Cobalt is required to be classified as “Cobalt Alloys”?
  The cobalt contained is usually greater than 25%.

- What is the relative chemistry of Cobalt Alloys?
  Cobalt 11 to 67.0 % Chrome 5 to 34.0 %
  Nickel 1 to 37.0 % Tungsten 0 to 19.0 % Molybdenum 0 to 17.5 %
  Iron 0 to 65.0 % Carbon 0.25 to 3.8%.

- What are the characteristics of Nickel Cobalt Alloys?

High strength, corrosion and oxidation resistant, high temperature fatigue strength and ductility, high permeability.

- What applications might we find Nickel Cobalt Alloys?
  Jet engine and gas turbine components, magnets, human transplants, hard facing for wear abrasive applications such as turbine vanes, electro-mechanical devices, laminations for aircraft motors and generators, furnace parts.

- What are some of the most popular Cobalt Alloys with other elements?
  Alnico V, Elgiloy, FSX 414. HS 3, HS 4, HS 6, HS 6B, HS 25 and HS 31, Star J, HS- 188, Hiperco-50, Illium H, Mar M 509, MP-35-N, and Permendur.

Cu – Ni
Nickel Copper Alloys

- What is the relative chemistry of Nickel Copper Alloys?

Highest Contained Element	Copper	70 to 90%
Second Highest Contained Element	Nickel	9 to 33%

- What are the characteristics of Nickel Copper Alloys?
  Heat resistant, corrosion resistant, and wear resistant.

- What applications might we find Nickel Copper Alloys?
  Pump impellers, valve bodies, dairy and food machinery, flatware, rheostats, thermocouples, condensers and heat exchangers, electrical resistances, marine equipment and hardware, glass molds, drill collars, optical hardware, jewelry.

- What are some of the most popular Nickel Copper Alloys found?
  70/30 Cupro Nickel, 80/ 20 Cupro Nickel, 90/10 Cupro Nickel, Monel 400, Monel 500

Chapter X

Corrosive Resistant Alloys

Corrosive Environments

Parts and components exposed to aggressive environments in the chemical process industries require corrosion resistance greater than that provided by conventional stainless steel. When exposed to harsh chemicals, elevated temperatures and high pressures many metals deteriorate and may cause great damage creating a great risk for employees in areas where this occurs. The addition of nickel, molybdenum, copper and chromium may be used to provide resistance to the severely corrosive conditions found in chemical process and oil field environments.

Typically, stainless steels are alloys of iron to which a minimum of 11% chromium has been added, making the material resist "*rusting"* when the material is exposed to the weather. To increase the stainless' resistance to corrosion, even more chromium can be added to levels of 15%, 17%, 20% and higher. The chromium provides resistance to oxidizing environments, such as nitric acid, and to pitting and crevice attack.

What does each Element do to reduce Corrosion?

- Copper – Addition enhances nobility, improves resistance to general corrosion in sulfuric acid, and strengthens some precipitation-hardenable grades. Pitting resistance, however, can be reduced in some alloys as the copper content increases.
- Nickel -Provides resistance to reducing environments and, above 25%, improves resistance to stress corrosion cracking. Nickel and nitrogen typically retard the formation of sigma phase and intermetallic can have a harmful effect on corrosion resistance and mechanical properties.
- *Molybdenum* – Probably the most effective element for improving resistance to pitting and crevice corrosion and solid strength.
- *Nitrogen* –May be added to increase strength and improve corrosion resistance, especially to pitting or crevice attack. Higher levels of elements such as chromium and manganese increase nitrogen solubility during casting.
- Columbium and Titanium – Tend to stabilize carbon, thus minimizing formation of

chromium carbides, which can impair corrosion resistance. Along with aluminum, these elements also can be used to age harden iron- and nickel-based alloys.

- CHROMIUM – enhances passivation.
- IRON – influences passivation.
- SILICON – forms pseudo-passive films in super oxidizing-media.
- NIOBIUM (COLUMBIUM) & TANTALUM – increase solids solution strength.

Conditions and Environments that can Effect Elements Used

- The bulk solution composition, including the solution PH and concentration of it components.
- Temperature of the corrodents. In general, the corrosion rate increases with increasing temperature. Some metals that provide good service at low temperatures are unsuitable for the same solutions at more elevated temperatures.
- Source of the heat. If heat is transferred from the metal to the solution, the corrosion rate may be increased due to the higher metal temperature.
- Impurities in the corrosive medium. The presence of even minor amounts of impurities can alter the corrosion rate significantly. While chlorides are expected to increase attack, some impurities actually can reduce the corrosion rate.
- Adherent deposits. Deposits on the metal surface can cause crevice corrosion, particularly in the presence of chloride ion impurities.
- Degree of aeration. Liquids kept in closed containers, without air or air circulation, may cause different degrees of corrosion that that occurring when the same liquids are freely exposed to the air. Similarly, the presence of atmosphere gases can change the corrosive behavior of metals to a marked degree.
- Velocity of the corrodents may affect both the type and severity of corrosion.

Nickel Resistance Combinations & Uses

- Ni for ALKALIS
- Ni-Cu for REDUCING ACIDS
- Ni-Mo for REDUCING ACIDS
- Ni-Fe-Cr for OXIDIZING ACIDS
- Ni-Cr-Si for SUPER-OXID. ACIDS
- Ni-Cr-Mo for ALKALIS AND ALL ACIDS

Corrosive Resistant Stainless Steel

Resistance to General Corrosion in Sulfuric Acid

Alloy	Nickel	Chrome	Moly	Copper
Highest Resistance				
C-276	51-59.5	14.5-16.5	15-17	
20Cb3	32-38	19-21	2-3	3-4
625	55-61	20-23	8-10	
625 Plus Custom Age	55-61	20-23	8-10	
400 Monel	63-70			25-31
AL6XN	23.5-25.5	20-22	6-7	
7-Mo Plus	3.5-5.2	26-29	1-2.5	
22Cr-13-Ni-5Mn	11.5-13.5	20.5-23.5	1.5-3	
316 Gall Tough Plus	6-10	16.5-21	0.50-2.5	
316 Gall Tough	4-6	15-18		
Lowest Resistance	(0.2% YIELD STRENGTH –KSI)			

Resistance to General Corrosion in Nitric Acid

Alloy	Nickel	Chrome	Moly	Copper
Highest Resistance				
7-Mo Plus	3.5-5.2	26-29	1-2.5	
22Cr-13-Ni-5Mn	11.5-13.5	20.5-23.5	1.5-3	
20Cb3	32-38	19-21	2-3	3-4
625	55-61	20-23	8-10	
316 Stainless	10-14	16-18	2-3	
AL6XN	23.5-25.5	20-22	6-7	
Gall Tough Plus	6-10	16.5-21	0.5-2.5	
625 Plus Custom Age	55-61	20-23	8-10	
304 Stainless	8-10.5	18-20		
Gall Tough	4-6	15-18		
Lowest Resistance	(0.2% YIELD STRENGTH –KSI)			

Resistance to Chloride Pitting/Crevice Corrosion

Alloy	Nickel	Chrome	Moly	Copper
Highest Resistance				
C-276	51-59.5	14.5-16.5	15-17	
625	55-61	20-23	8-10	
625 Plus Custom Age	55-61		20-23	8-10
AL6XN	23.5-25.5	20-22	6-7	
7-Mo Plus	3.5-5.2	26-29	1-2.5	
22-Cr-13Ni-5Mn	11.5-13.5	20.5-23.5	1.5-3	
400 Monel	63.70			25-31
20Cb3	32-38	19-21	2-3	3-4
Gall Tough Plus	6-10	16.5-21	0.50-2.5	
Gall Tough	4-6		15-18	
Lowest Resistance	(0.2% YIELD STRENGTH – KSI)			

Resistance to Corrosion in Wet-Process Phosphoric Acid

Alloy	Nickel	Chrome	Moly	Copper
Highest Resistance				
C-276	51.59-5	4.5-16.5	15-17	
625	55-61	20-23	8-10	
625 Plus Custom Age	55-61	20-23	8-10	
AL6XN	23.5-25.5	20-22	6-7	
20Cb3	32-38	19-21	2-3	3-4
22Cr-13Ni-5Mn	11.5-13.5	20.5-23.5	1.5-3	
316 Stainless	10-14	16-18	2-3	
Lowest Resistance	(0.2% YIELD STRENGTH – KSI)			

Resistance to Oil-Field Environments

Alloy	Nickel	Chrome	Moly	Copper
Highest Resistance				
C-276	51.59-5	4.5-16.5	15-17	
625	55-61	20-23	8-10	
625 Plus Custom Age	55-61	20-23	8-10	
400 Monel	63.70			25-31
20Cb3	32-38	19-21	2-3	3-4
AL6XN	23.5-25.5	20-22	6-7	
22Cr-13Ni-5Mn	11.5-13.5	20.5-23.5	1.5-3	
316 Stainless	10-14	16-18	2-3	
Gall Tough Plus	6-10	16.5-21	0.5-2.5	
Lowest Resistance	(0.2% YIELD STRENGTH – KSI)			

VALVE FACING COMPOSITIONS

Description	Ni	Cr	Mo	C	Fe	Co	W
Stellite 5		29.00		1.15		Rem	4.50
Stellite F	22.00	25.00		1.75		Rem	12.00
Stellite 1		29.50		1.50		Rem	12.50
Eatonite	Rem	29.00		2.40		10.00	15.00
Eatonite 3	Rem	29.00	5.00	2.00			
Eatonite 5	16.50	28.00	4.50	1.75	Rem		

Corrosion-Resistant Nickel Alloys

Main Attributes

- Most possess high resistance to chloride-induced stress corrosion cracking.
- Many resist the aggressive reducing acids, such as hydrochloric, hydrofluoric, and to medium concentrations of sulfuric.
- Some withstand both strong reducing acids and strong oxidizing acids.
- Many exhibit high resistance to alkalis
- Some have high resistance to localized attack (pitting and crevice corrosion).
- All are ductile, and easily formed and welded.

Summary

Five important criteria should be weighed in selection alloys for severely corrosive environments in the chemical process industry.

1. Corrosion resistance – The most cost effective alloy may provide the corrosion resistance needed for the application without the needless expense of over-alloying. When evaluating the potential for degradation by one or more forms of corrosion, consider all details of environment including impurities, aeration and velocity.

2. Mechanical Properties – Determine the need for properties such as hardness, impact resistance, and fatigue strength or stress rupture resistance. Then consider the effect of the desired mechanical properties on the material's corrosion resistance.

3. Fabrication – Consider both design and fabrication. Contemplate the fabrication ease or difficulty and determine the effect of fabrication on the alloy's corrosion resistance.

4. Availability – Selection may be limited by availability of the candidate alloy. It may be wise to investigate before proceeding too far.

5. Life Cycle Cost – Make a bottom line value analysis of the prospect alloy taking into consideration the alloy price, fabrication cost, installed cost and effective life expectancy of the finished product. Factor in maintenance and replacement cost, the associated loss of productivity, and the price of late deliveries. In many cases, the more suitable and more expensive alloys will account for a small fraction of the total design life cycle cost.

Chapter XI

Exhaust Valve Steel Alloys

- What is the relative chemistry of Exhaust Valves?

Highest Contained Element	Iron	40 to 65%
Second Highest Contained Element	Chrome	2 to 24%
Third Highest Contained Element	Nickel	0 to 15%
Fourth Highest Contained Element	Manganese	0.5 to 13%

- What are the characteristics of Exhaust Valves?
  High Temperature Strength
  Abrasion resistant as well as corrosion/oxidation resistant at temperatures exceeding 800˚C.

- What are the three sections an exhaust valve can be divided into?
  1. Head
  2. Stem (high temperature, high strength and corrosion resistant alloy such as an Austenitic stainless steel or a Superalloy)
  3. Sealing surface of the valve often includes a weld overlay material, such as cobalt based, high temperature alloy.
  4. The remainder of the stem often is made of hardenable martensitic steel welded to the high-temperature heat-resistant alloy of the valve head end.

- When are Austenitic stainless grades not used?
  Austenitic stainless steels grades are no longer suitable to operate at temperatures above 1472˚ F.

- Popular Austenitic valve alloys are: 21-2N, 21-4N-Nb-W and 23-8N

- Superalloys typically used today are:
  Alloy 751, Alloy 80A, Pyromet 31 and Ni30, for example

- Why are these alloys more suitable than Austenitic stainless?

The higher amounts of nickel provide sufficient high-temperature strength or corrosion resistance.

- Why is a hard face Cobalt-based alloy applied to the face of the exhaust valve?
  To increase wear resistance

Chapter XII

Stainless & Alloy Uses

Stainless Series

3-A Duplex Alloy Steel Casting

Chemistry:

Ni 4.0-6.0, Cr 24.0-27.0, Mo 1.75-2.50, C 0.06 Mx, Mn 1.0 Mx, N0.15-0.25, P 0.04 Mx, S 0.04 Mx, Si 1.00 Mx, Fe Rem

Characteristics:

- Resistant to pitting and stress corrosion

Applications:

- Used as corrosion resistant cast steel for pumps

3RE60 (DP-1 Duplex)

Chemistry:

Ni 4.25-5.25, Cr 18.0-19.0, Mo 2.5-3.0, C 0.03 Mx, Mn 1.0-2.0, N 0.05-0.10, N 0.05-0.10, P 0.03 Mx, S 0.015 Mx, Si 1.4-2.0, Fe Rem

Characteristics:

- Good resistance to general corrosion and pitting, stress corrosion cracking in chloride-bearing environments, combined with good resistance to erosion corrosion and corrosion fatigue, its high mechanical strength is roughly twice the proof strength of Austenitic grades.

Applications:

- Seamless Tubes & Pipe

7-Mo PLUS Stainless

Chemistry:

Ni 3.5-5.20, Cr 26.0-29.0, Mo 1.0-2.5, C 0.03 Mx, Mn 2.0 Mx, N 0.15-0.35, P 0.035 Mx, S 0.01 Mx, Si 0.60 Mx, Fe Rem

Characteristics:

- Good resistance to chloride-stress-corrosion cracking, pitting corrosion, and general corrosion in many severe environments
- Greater yield strength than twice that of typical Austenitic stainless steel

Applications:

- Heat exchangers, replacing 7-Mo in petroleum refining
- Petrochemical
- Pulp and paper
- Other allied processing industries

9% Nickel Steel

Chemistry:

Ni 8.4-9.6, C 0.013 Mx, Mn 0.90 Mx, P 0.045 Mx, S 0.045 Mx, Si 0.13-0.32, Fe

Characteristics: