Bringing You Up To Speed On Steel, Aluminum, Manufactured Components, and the HTSUSes Vocabulary

What the Next 3 Hours Will Attempt To Do

- Background on Steel and Aluminum and Their Alloys
- Terminology Overview
  - Metallurgy, Processing, Manufacturing, Shapes, Standards and Specs
- Going Over The Exclusion Request and Objection Forms
  - What does THAT word mean??!?!
- HTSUS 72 and 73 for Steel
- HTSUS 76 for Aluminum

PLEASE interrupt me for questions!!

Nuggets of Wisdom

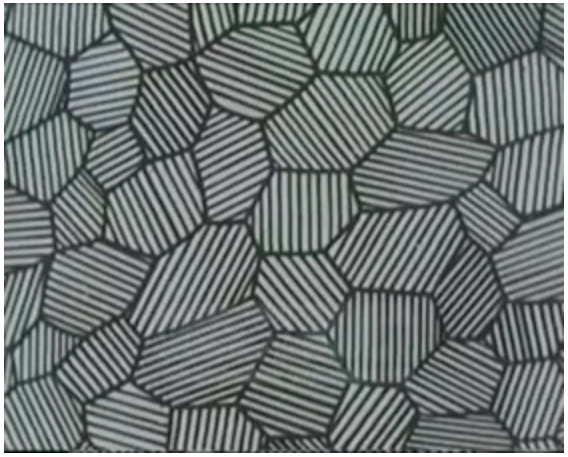
- HTSUS categories seem to be a combo of
  - Chemistry – broad categories of alloy, non-alloy, etc
  - Shape – all three dimensions plus hollow-ness
  - Somewhat intended use, tied to shape (finished products)
  - NOT mechanical properties except one value for steel

- Keep calm, and read the submission. . .

Metal Terminology Overview

- What is a Metal and an Alloy?
- Alloy Microstructure Terminology
- Alloy Chemistry Terminology
- Heat Treating Terminology
- Processing Terminology
- Mechanical Properties Terminology
- Shape and Dimension Definitions
- Standards and Specifications

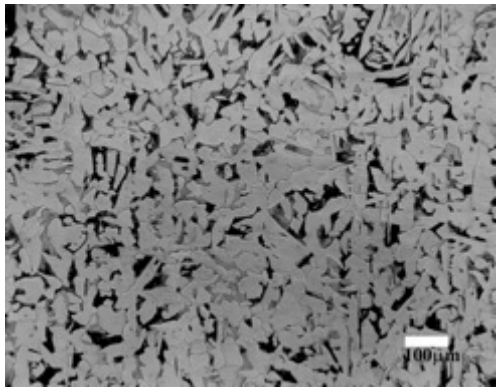
What is a metal?



- Metals and alloys are made of **crystals**
- The crystals are called **grains,** and have a **grain size**
- The grains meet at **grain boundaries**
- If the metal has more than one type of crystal, these are each called a **phase** of the alloy – ***multiphase alloy***
- Each has a different orientation, shape, size, purpose
- Each crystal is a spring of atomic bonds
- When you pull on them lightly, they stretch
- When you pull on them beyond a certain point, they permanently change shape (deform)
- The combination of crystals, grain size, grain boundaries and grain orientations is called the metal's **microstructure**
- Each microstructure has a given set of **mechanical, physical and chemical properties**

- To make an engineering alloy, you select or experimentally find:
  - The **Chemistry**
    - What elements and how much of each
  - The **Heat Treatment**
    - Heating, cooling, how hot or cool, how fast up or down, how many steps
  - The **Deformation Processing**
    - How do you deform it, at what temp, how much . . . to reach the final shape you want.

Alloy Microstructures



- The combo of heating, cooling, deforming . . . is called **"The Process"**
  - Colloquially – "Heat it and Beat it"
- You can change the microstructure via deforming, heat treating, or both.
- You are aiming to create the optimal properties in the alloy,
  while creating the component you are trying to manufacture, at the lowest cost
  - There are many process and chemistry combinations that can get you there ($ → $$$$$$)
- Certain microstructural characteristics give certain properties:
  - Small grain sizes are stronger than large ones
  - Each phase has different properties (strength, brittleness, etc)
  - Combining multi-phases gives you better properties ("composite effect")
- Certain chemistries give you better properties
  - Putting chromium in stainless steel makes it highly corrosion resistant
  - Adding elements like tungsten and molybdenum to steel form carbides and make it much harder
- Getting everything in "The Process" just right and consistently done is tricky
  - Experience counts! Starting from zero can be very tough.
- Buyers like dealing with companies that can produce what they need reliably.

Terminology – Alloy Chemistry

- **Alloy** – A mixture of several/many elements in a metal, with the aim of creating certain properties
  - Each alloy has a composition target, and each element has a **range** or **limit** on it's amount
    - **Range** – the composition of one element must lie within a set range
      - Ex: 1045 mild steel has between 0.4% and 0.5% carbon
    - **Limit** - the composition of element must not exceed (ex. contaminants)
      - Ex: 1045 mild steel must not have more than 0.05% sulfur

- **Steel** is defined at the most basic level as **iron** plus **carbon**
  - In practice, steels contain various elements to develop various properties

- **Aluminum** alloys are typically 90+% aluminum, steel can be less than 50% iron

- For steel, there are cheap and expensive alloys due to cost of additions
  - Hard, strong steels have lots of expensive additions like W, V, Nb, Mo, Cr, Ni
  - Softer, tougher steels have a little of cheap additions: C, Mn, Si

- Aluminum alloys have fewer additions, so range of cost is narrower

Terminology – Alloy Chemistry

- **Inclusions** - Non-metallic particles made from impurities
  - They come from the process of making the metal from ore
  - Incorporated as metal solidifies from a liquid if you aren't careful
  - Why a problem?
    - They are brittle – cause cracks and other problems
    - They melt and get in the way of welding
    - They can make the alloy less tough, weaker, more brittle . . .
  - Want to minimize if at all possible
    - Remove – slag particles
    - Make small – MnS particles in steel (Mn grabs sulfur and keeps it from causing bigger problems if it were free to move around)
  - Characterized by inclusion count – polish alloy and examine under microscope
    - Need to know how many, density in alloy, size, shape
    - Want few, tiny, spherical (if at all)
  - Alloys containing excessive inclusions make bad parts, and there is no way for the end user to remove them while manufacturing (they come from bad process)

Terminology – Alloy Chemistry

Sometimes, a poor heat treatment or welding procedure can change the chemistry in the alloy **locally**, and that leads to other problems

- **Segregation** - Non-uniform distribution of alloying elements, impurities or phases in metals and alloys – usually due to bad processing
  - Examples:
    - Sulfur segregation – sulfur sits on grain boundaries and makes brittle
    - Phase segregation – instead of all the different phases being mixed uniformly, some form clumped together and make non-uniform properties ("banding" in rolled steel - brittle and ductile layers)

- **Decarburization** - Removal of carbon from the outer surface of iron or steel, usually due to an incorrect heat treatment where the carbon reacts with air
  - Makes the surface softer than the middle

- **Sensitization** – During welding, re-melting messes up the alloy locally
  - Ex: welding stainless steel changes the chemistry, and the area near the weld is no longer "stainless" – i.e. it's now "sensitive" to corrosion
  - In aluminum, heating abnormally long makes the chemistry non-uniform

Terminology – Primary Processing ("Semi-Finished" Product)

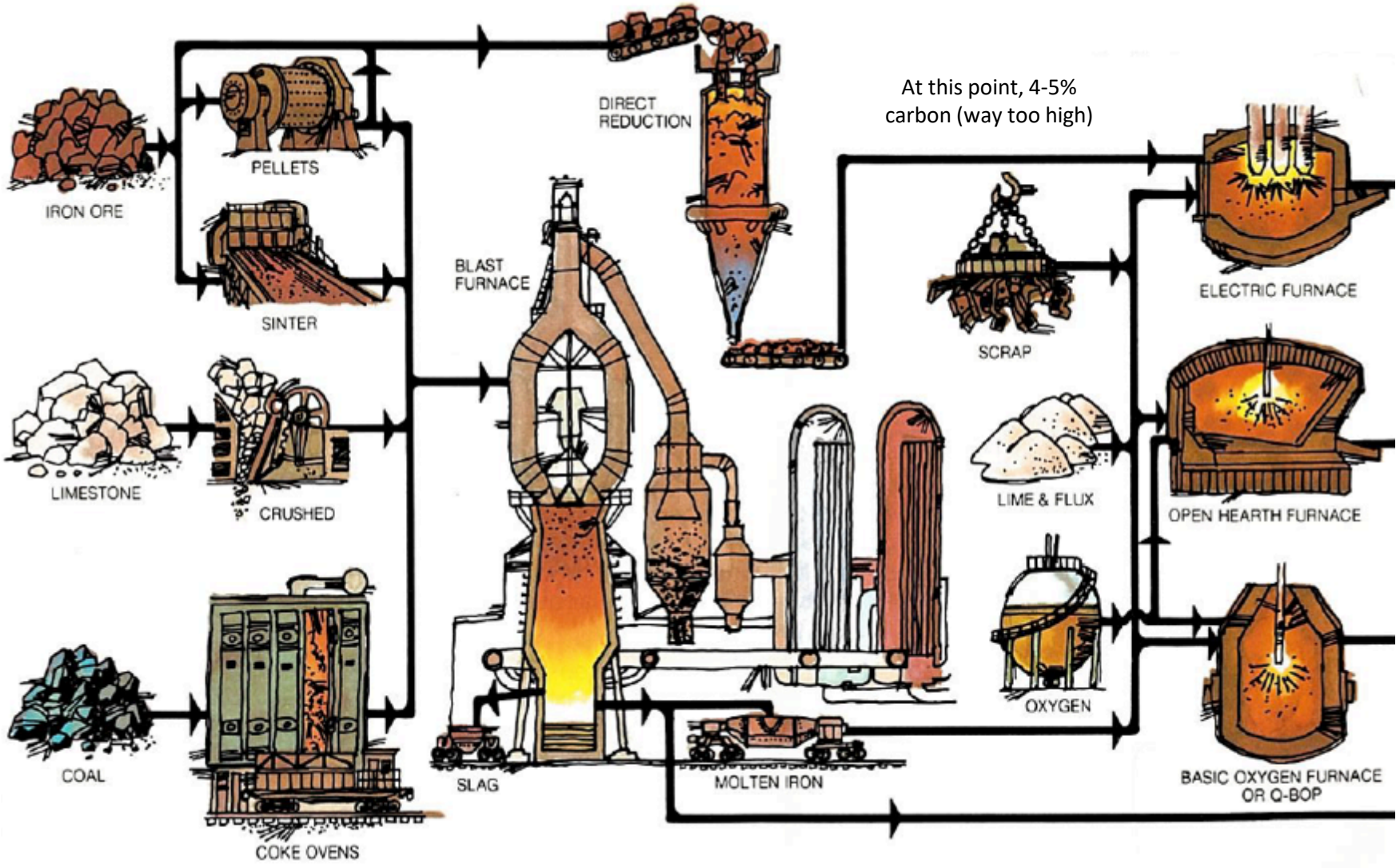
Primary processing is creating the solid shape with the right chemistry into it's first rough shape from molten metal

- **Casting** – solidifying the molten metal into some shape
  - The shape can be close to or very far from a finished product
    - Far – an ingot of steel or aluminum
    - Near – ex: a cast steel propeller for a boat that only needs polishing

- Casting of **primary shapes** is typically done at a **foundry**, sent to secondary producer
  - Ingots, slabs, plate, thick rod, bars, etc
  - Strengths not set – will be re-worked later
  - Secondary producer might work cold, reheat and work, or melt and recast
  - Secondary producer is typically buying an **alloy chemistry**

- ***Casting* of secondary shapes** is done at product manufacturer
  - Remelt the alloy – pour into mould made on site – extract part and finish
  - Primary shape is thus feedstock for secondary process

Primary Production - Steel



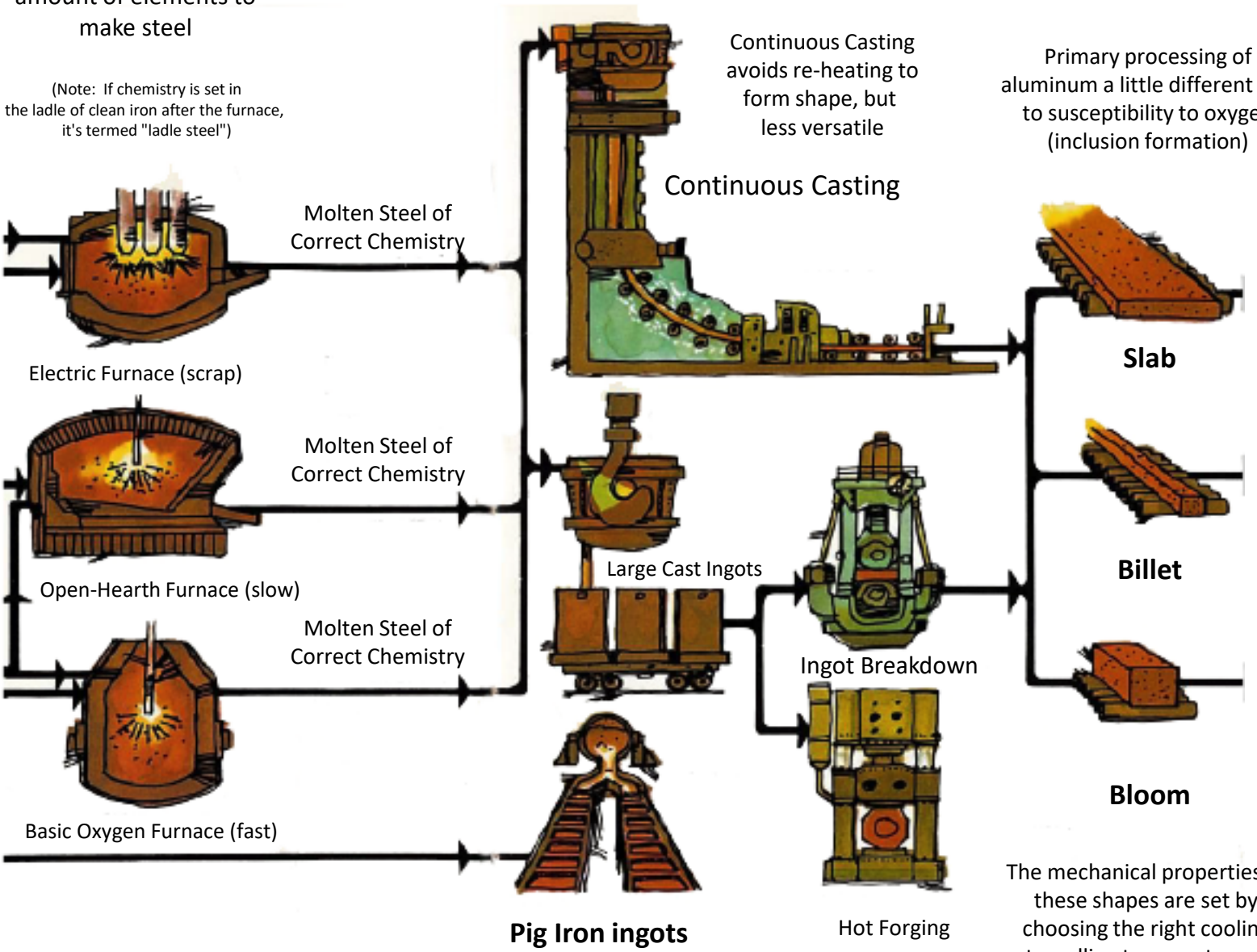
Primary Production - Steel

Blow oxygen through to clean, then add right amount of elements to make steel

(Note: If chemistry is set in the ladle of clean iron after the furnace, it's termed "ladle steel")

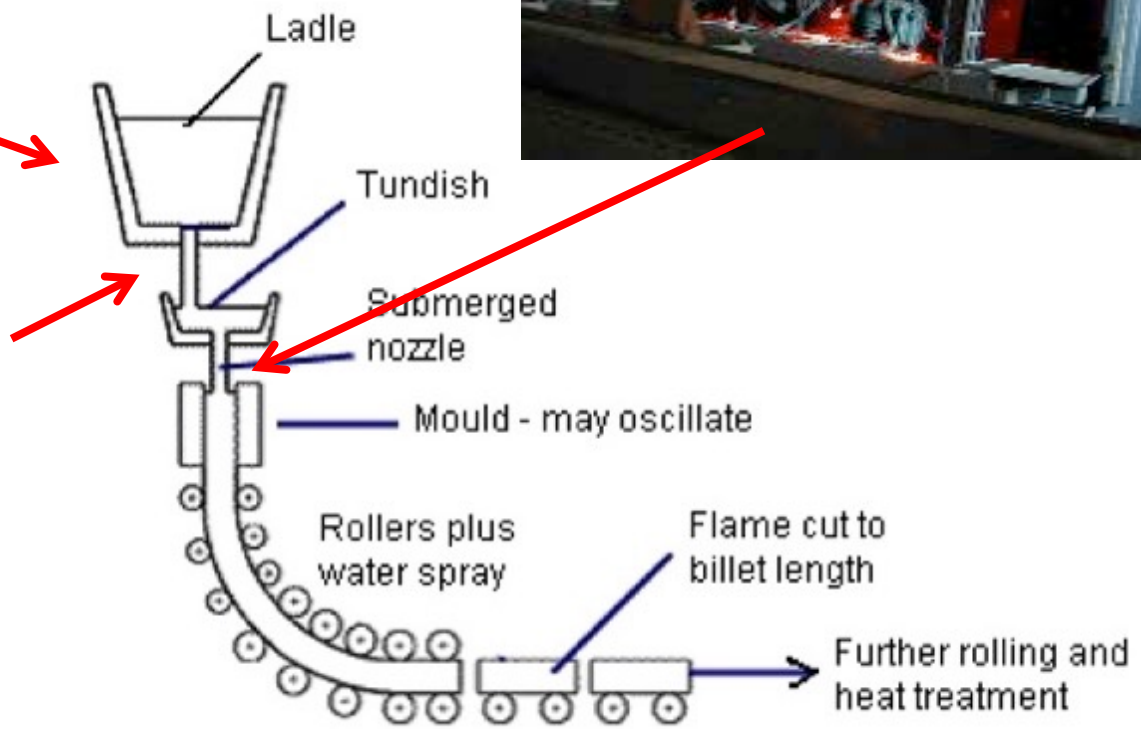
Continuous Casting avoids re-heating to form shape, but less versatile

Primary processing of aluminum a little different due to susceptibility to oxygen (inclusion formation)

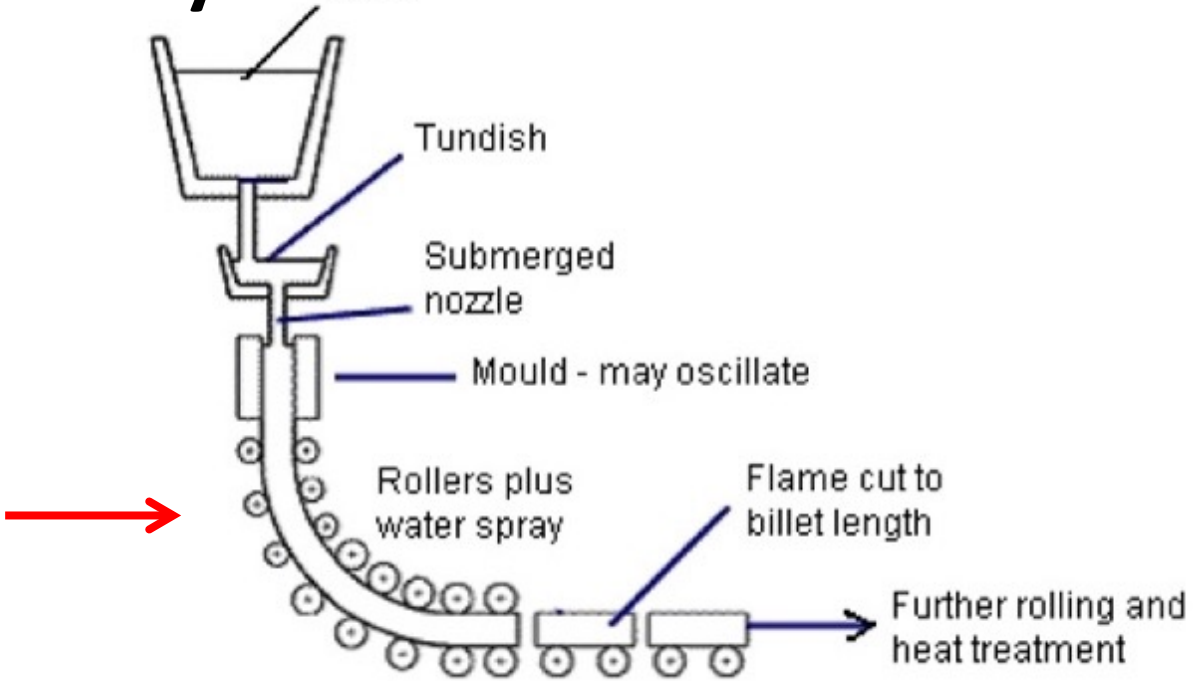


The mechanical properties of these shapes are set by choosing the right cooling rate, rolling temperature and rolling pressures

Primary Production - Steel

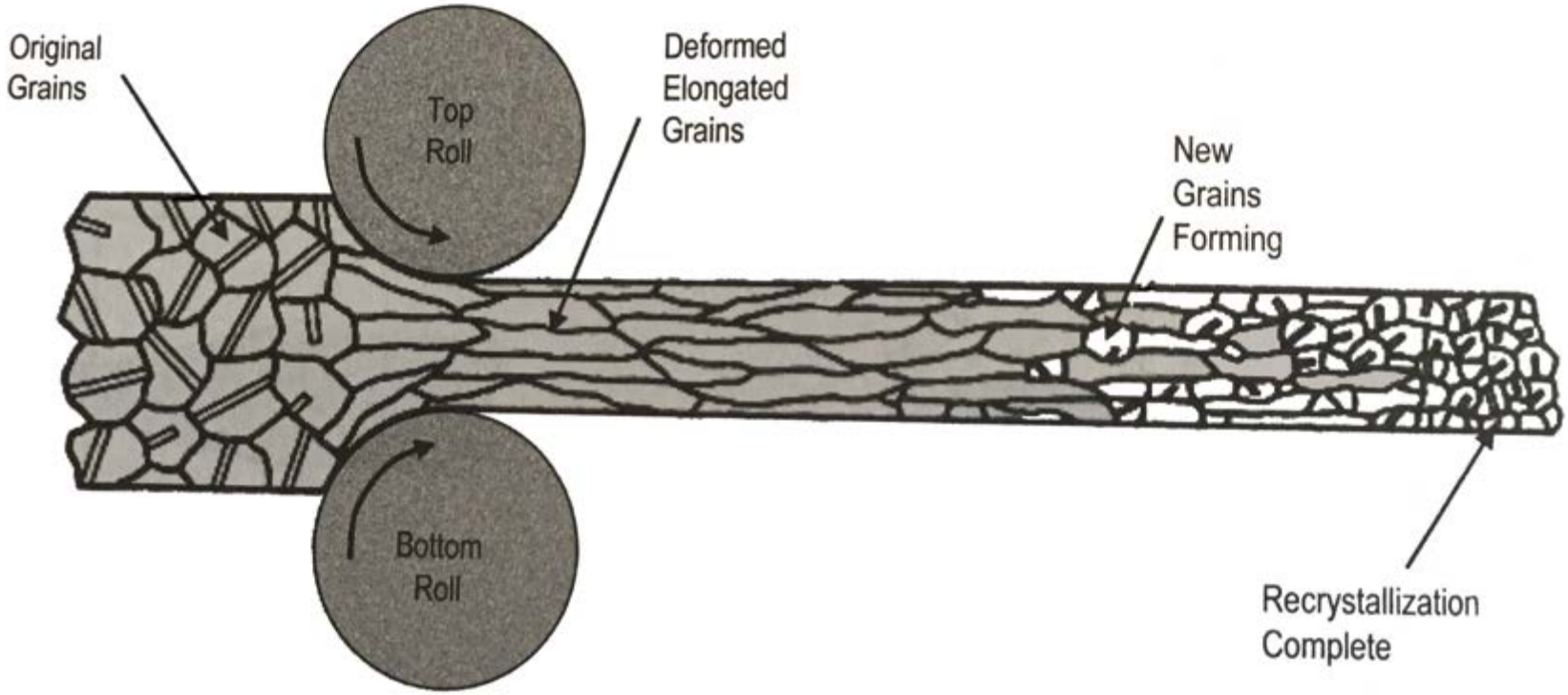


Primary Production - Steel



Prof Sir Harry Bhadeshia, Cambridge

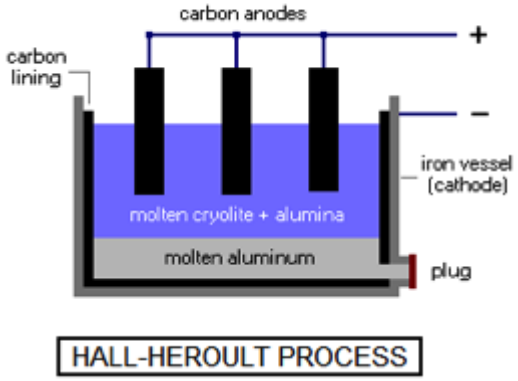
Primary Production - Steel



WICKED HOT **VERY HOT** **MERELY HOT** **VERY, VERY, VERY WARM**

As it cools, new grains grow that are smaller → stronger

Primary Production - Aluminum



HALL-HEROULT PROCESS

- Carbon react with oxygen in Al_2O_3 (Bauxite) to make Aluminum
  - Takes a huge amount of electricity
- Molten aluminum EXTREMELY reactive with air
- Must be kept isolated – no continuous casting and rolling
- Cast into pits, water cooled, extracted, cut, rolled . . .
- Although these are round, they are not bars – **not wrought** - **INGOTS**

Terminology – Primary Processing

Types of casting used by parts producers

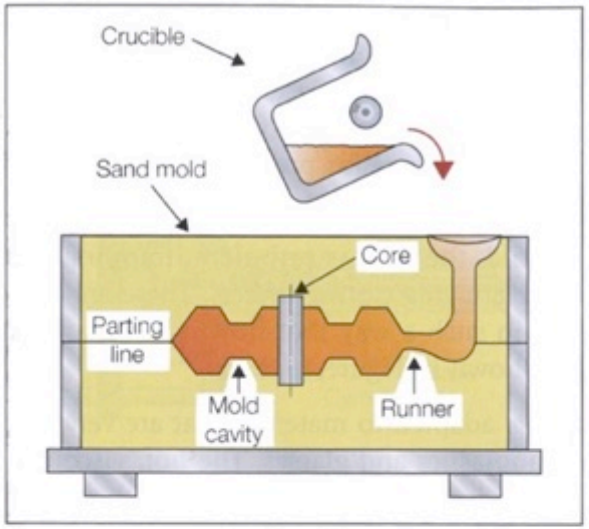
Typically buy ingots of correct chemistry and a size they can handle

Some are very cheap, some very equipment intensive

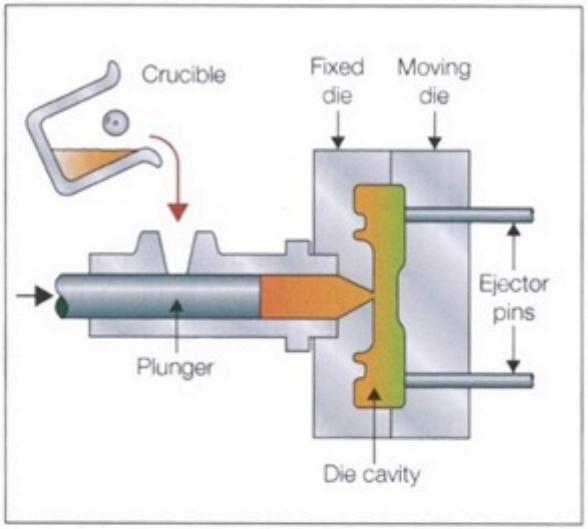
Some companies cast rough parts and sell to finishers

Some companies cast rough parts and finish and sell

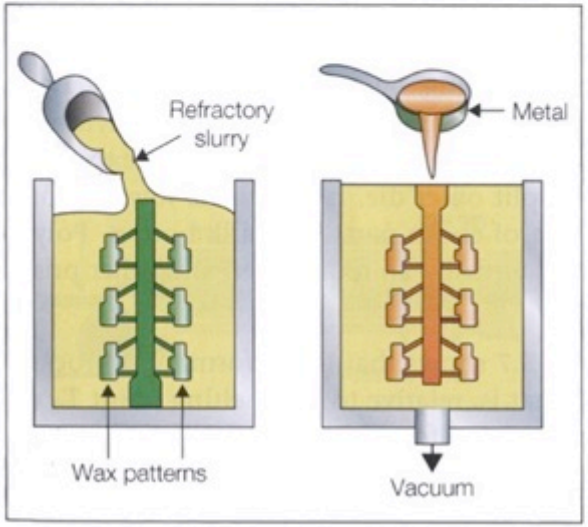
Some companies go the whole way from cast to commercial product



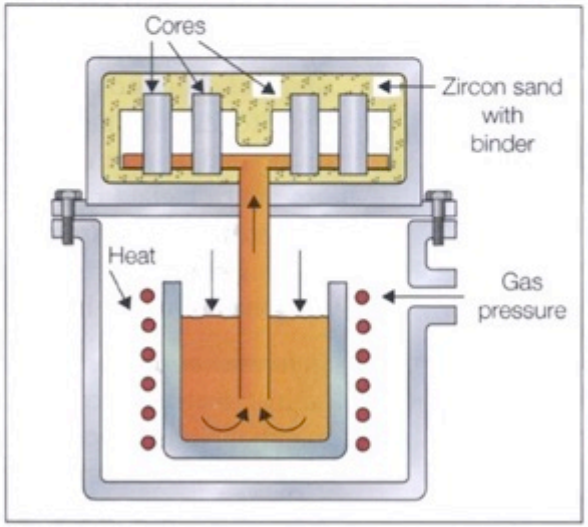
Sand casting



Die casting

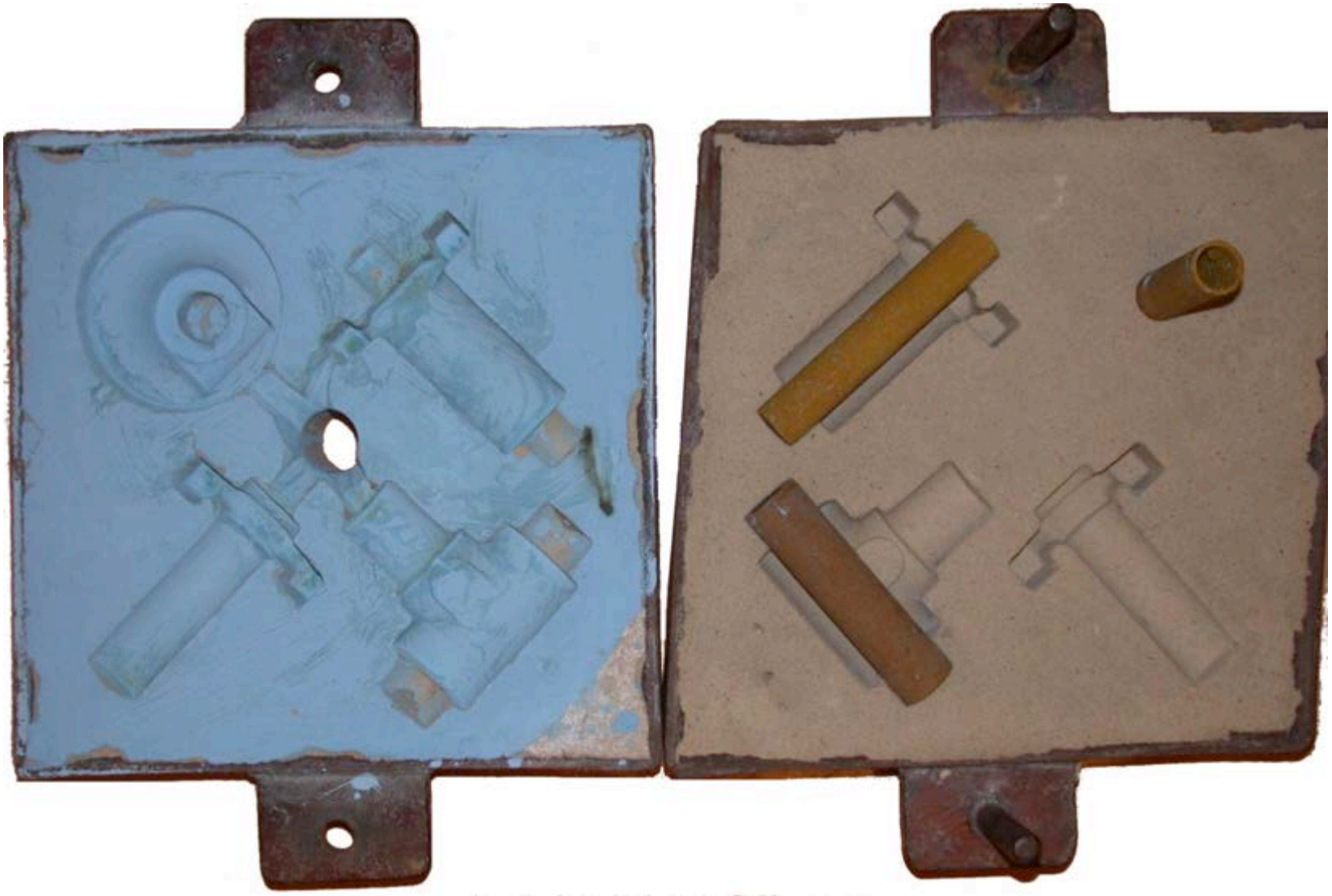


Investment casting

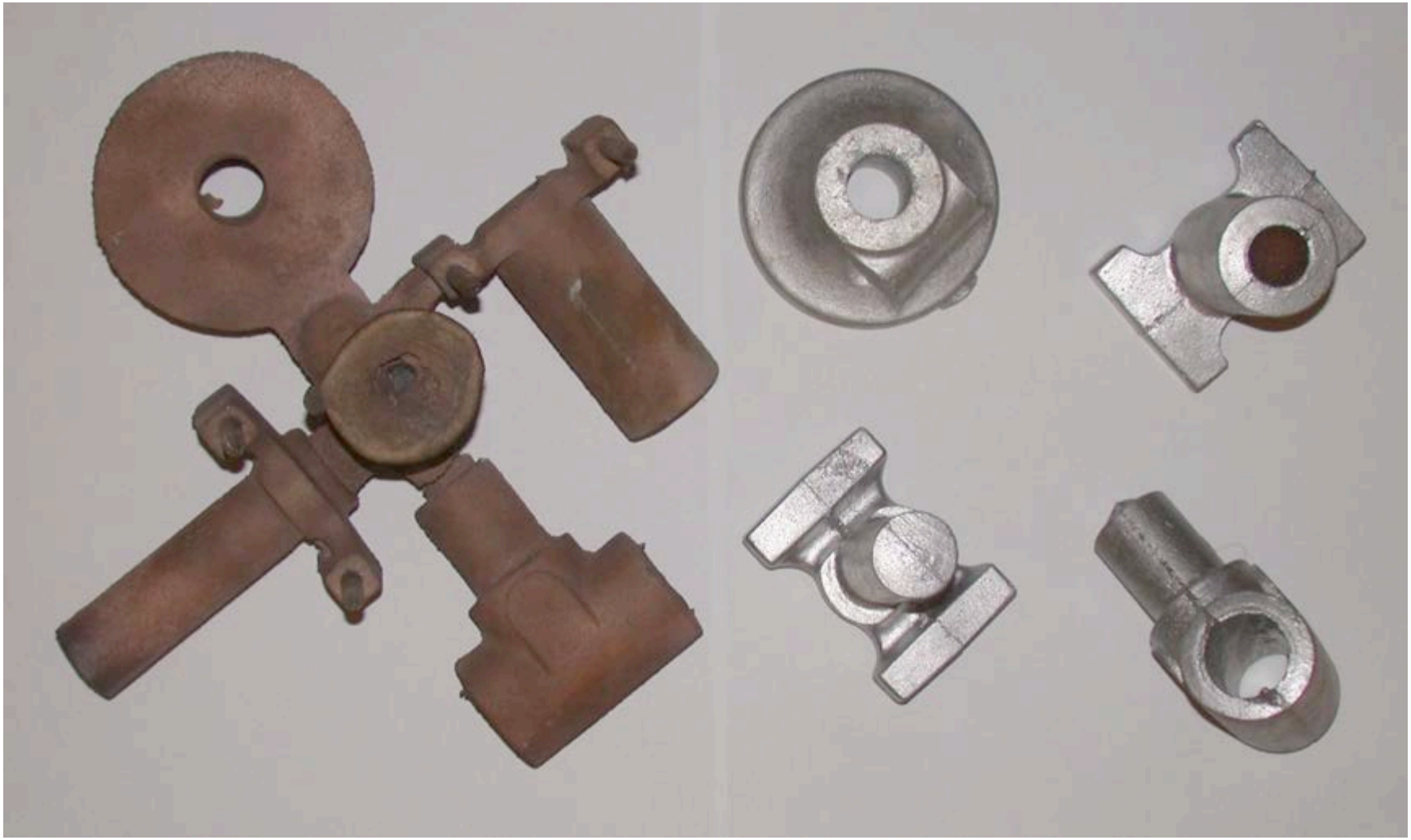


Low-pressure casting

Terminology – Primary Processing

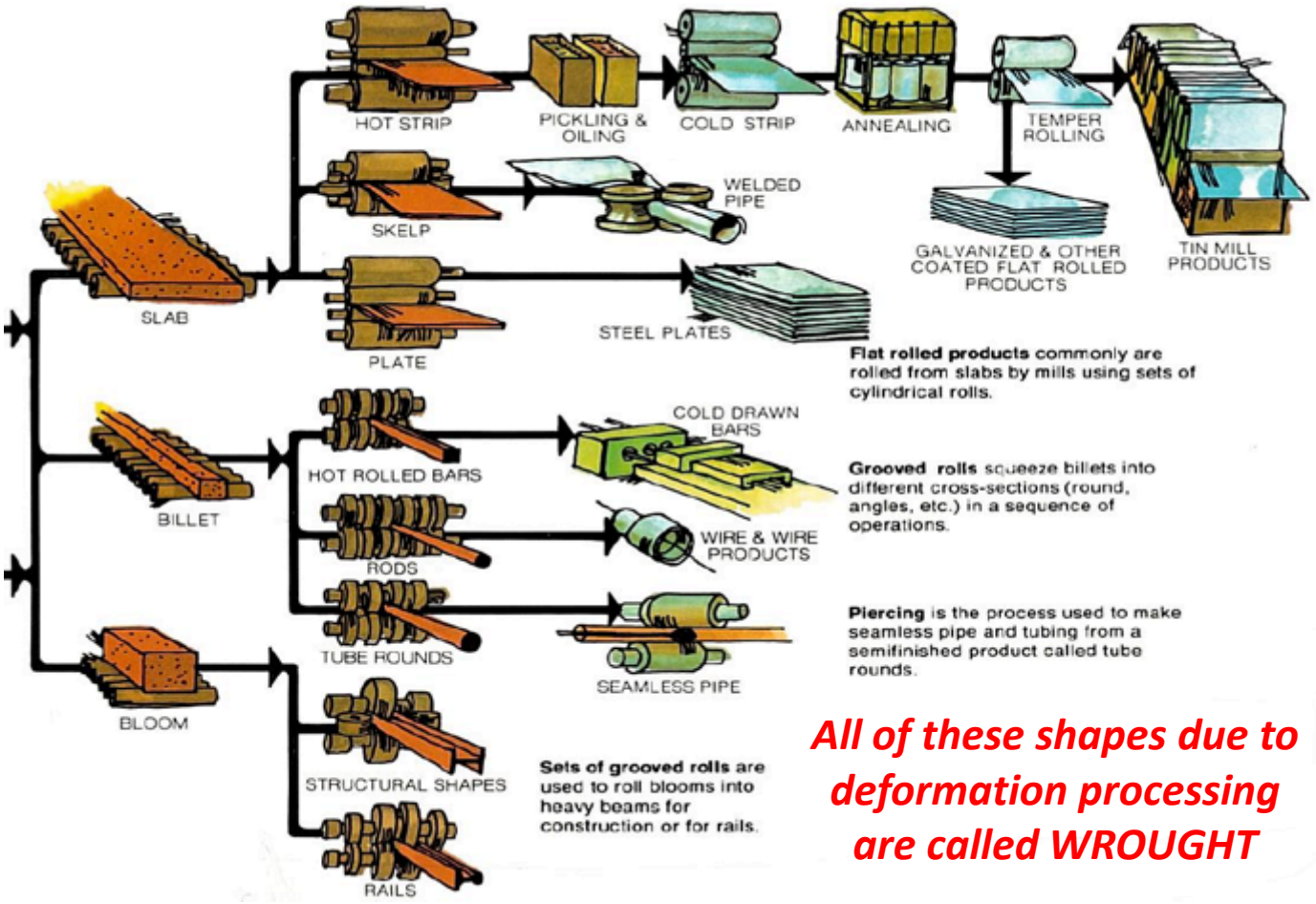


Terminology – Primary Processing



Secondary Production ("Finished" Products)

- Making something out of primary product without re-melting (hot or cold processed)
- Anything here can be bought and used by a company to make a product (product might be here too)
- Any given company can perform any number of these (and more) steps themselves
- Each step can be (and is) outsourced
  - Ex: some companies specialize in one process, and will work on many alloys with their equipment



All of these shapes due to deformation processing are called WROUGHT

Flat Rolled Products

Long Products

Pipe and Tube

Long Products

Terminology – Secondary Processing

Finished is creating the product out of material first fabricated during primary processing using temperature and deformation

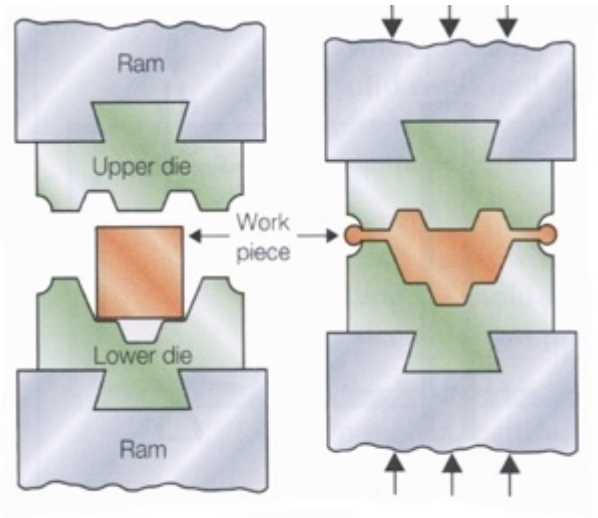
- Two main temperature categories: **Hot** and **Cold**

"Wrought", "worked", "deformed", "rolled etc" are considered SYNONYMS

  - Deforming parts **hot**:
    - (+) Hot = soft, so not as much force needed to deform
    - (+) Relaxes structure during deformation
    - (+) Can do bigger parts
    - (-) Hot = $$ to heat and keep hot
    - (-) Tools for hot deformation more expensive
    - (-) Generally need to heat treat after working to set the strength
    - Examples: hot forging, hot rolling

  - Deforming parts **cold**:
    - (+) Resulting parts are stronger
    - (+) Might not need to post-heat-treat – save $$
    - (+) Lubrication easier
    - (-) Cold = strong, so larger forces needed, smaller passes
    - (-) Typically smaller dimensions
    - Examples: drawing, sheet forming, cold rolling

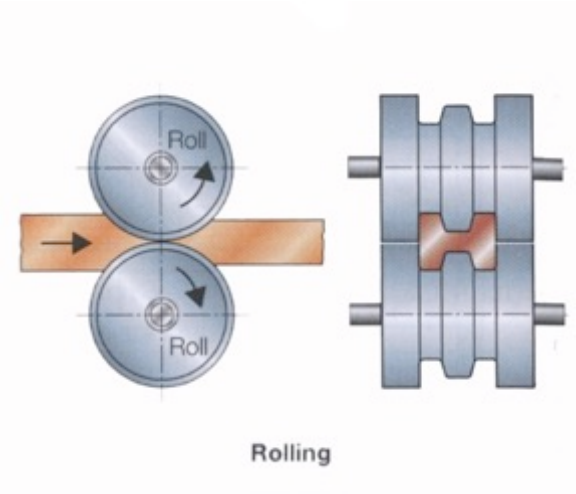
Terminology – Secondary Processing



Forging

Forging

- Can be done cold, warm or hot
- Common for steel, 7XXX aluminum
- Force application can be press, hammer, rollers, etc
- Capital intensive, so expensive



Rolling

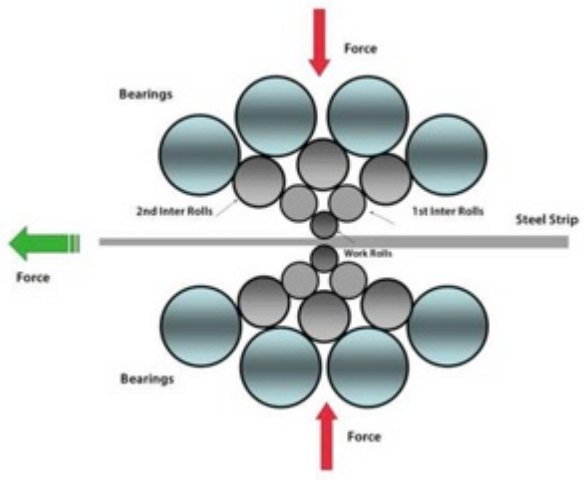
Rolling

- For making long, axisymmetric shapes
- Bars, plates, shapes
- Can be done cold, warm and hot
  - Cold – slower, but stronger product
  - Hot – faster, but weaker product

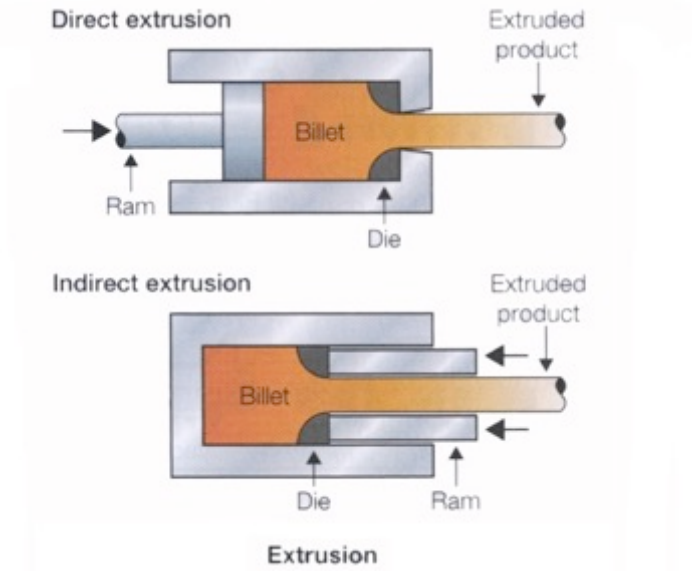
Terminology – Secondary Processing

Rolling

Continuously Rolled Structural Shapes



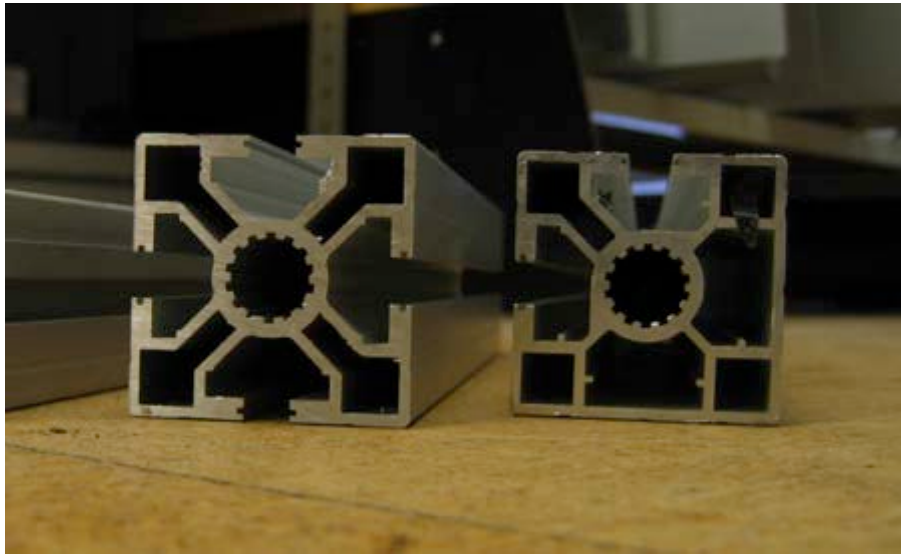
Terminology – Secondary Processing



Extrusion

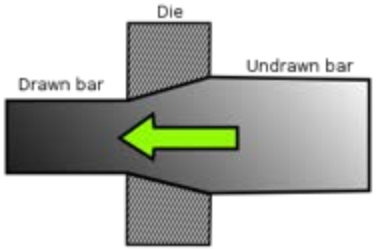
Extrusion – again, Play-Doh

- More common for aluminum, but hot steels
- Direct or Indirect (also drawing)
- Complex shapes possible (open and closed)
- Examples:
  - Ladder side rails
  - 80/20 strut
  - Aluminum water bottles



Terminology – Secondary Processing

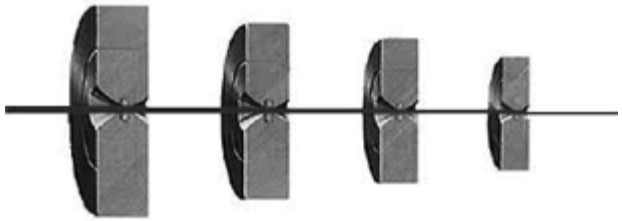
Drawing: Reducing dimensions by thinning and lengthening



- Drawn material is stronger than undrawn
- Defects are critical
  - Can be due to bad metal (inclusions)
  - Can be due to defects in the draw die

- Done in dead-soft state or hot

- Strongest steel ever made – piano wire



Incremental Drawing

Deep Drawn Tubes

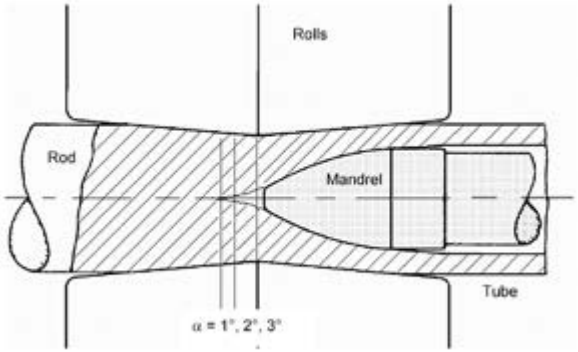
Terminology – Secondary Processing

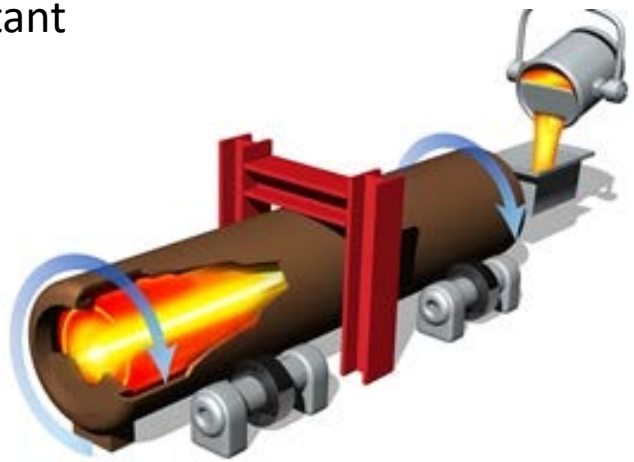
Seamed versus Seamless Pipe:

- Joints typically are points of concern for being weak
  - Joining defects, produced by poor methods, chemical attack, etc.
  - Some critical applications require seamless pipe for safety/performance
    - Higher pressure, corrosive environments

- Some materials can't be formed into a pipe, but must be cast
  - Cast iron sewer and water pipe (**centrifugal casting**)

- Some materials are soft enough that piercing to make seamless is inexpensive
  - Aluminum alloys – rod quality important

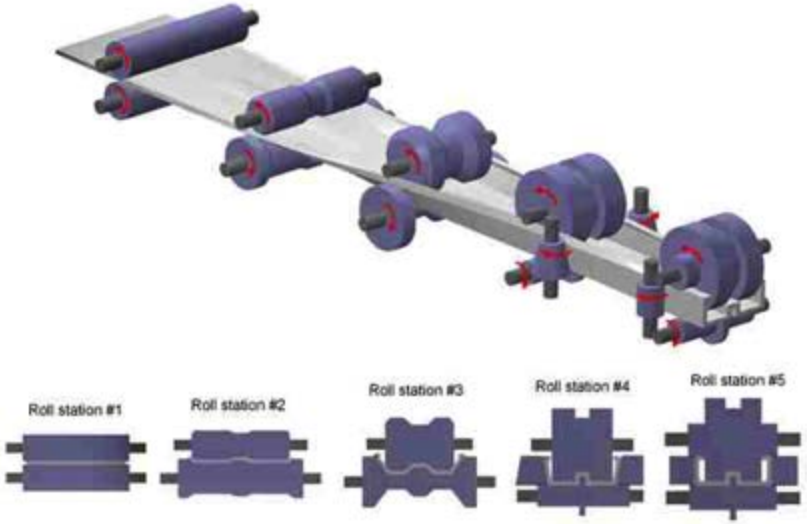


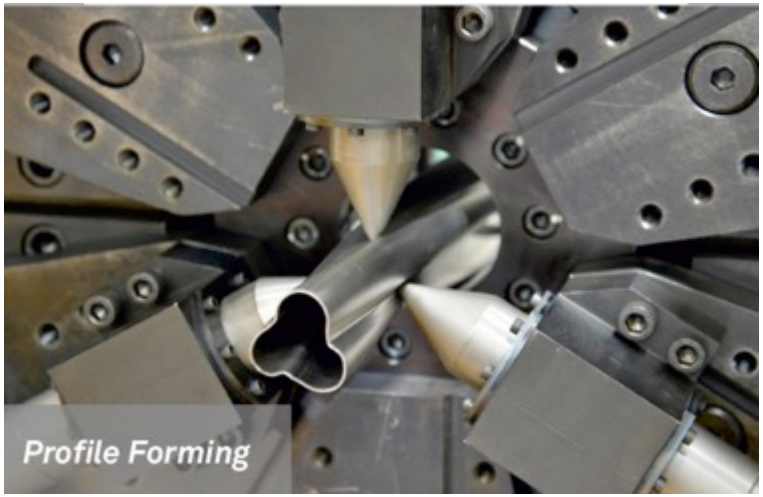


Terminology – Secondary Processing

Forming: Turning sheet metal from a 2D to a 3D shape

- Critical that properties of sheet are known and uniform
- For tubes, may include welding
- Usually done cold, but hot exists (hydroforming)
- **HUGE** in automotive
  - Ductility needed for forming, strength for crash, weldability for assembly

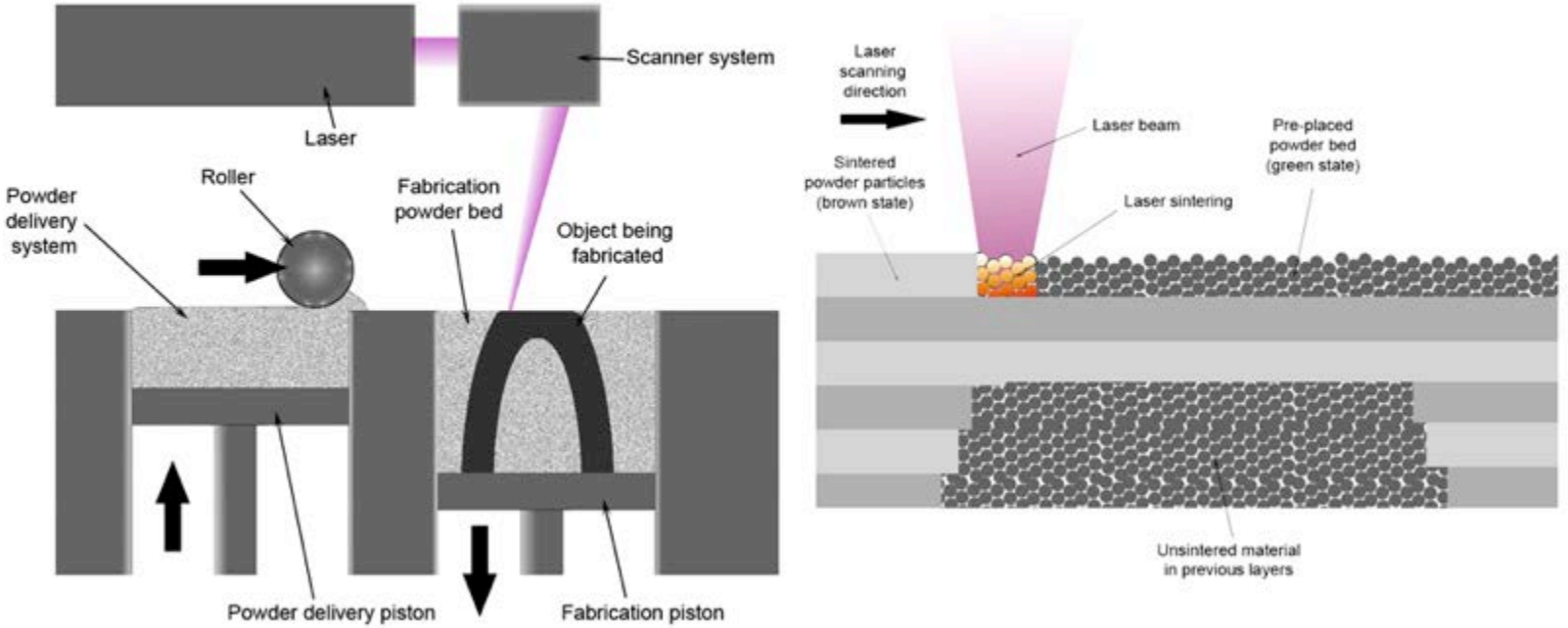




Roll Forming – Combo of rolling + forming

Terminology – Secondary Processing

Additive Manufacturing - Selective Laser Sintering

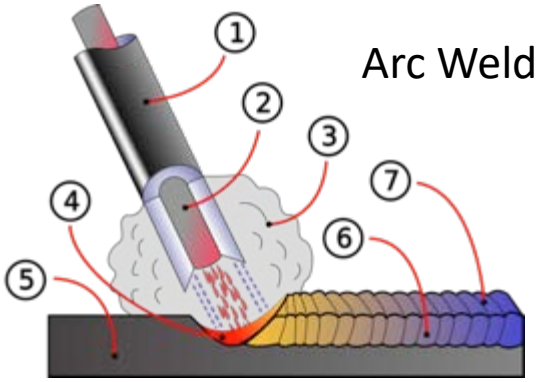


You might get requests on additive powder – most powder proprietary or users are required to buy powder from machine manufacturer to not void warranty

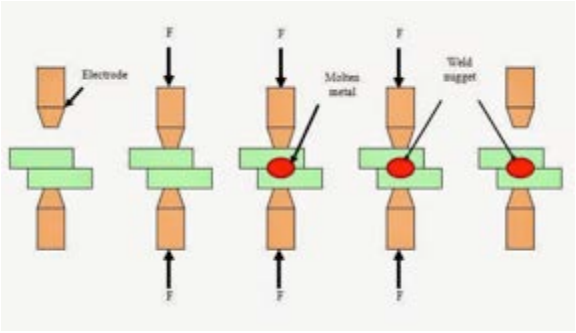
Terminology – Secondary Processing

Additive Manufacturing - Selective Laser Sintering

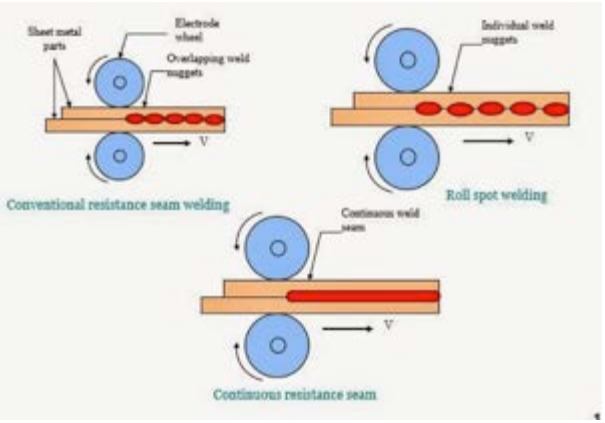
Terminology – Tertiary Processing



Arc Welding



Resistance Welding



Thermite Welding

Terminology – Heat Treatment

- **Heat Treatment** – a series of heating and cooling steps that change the microstructure and therefore the properties
  - Important factors: temperatures, hold times, heating and cooling rates
  - Also important: Part size, atmospheres, batch sizes, uniformity and precision
  - Can be described with words **(Q&T)** or a letter/number designation (ex: **H38**)

- Generally, the more complicated / precise the heat treatment, the higher the cost and difficulty performing it
  - Complicated = large, awkward parts, heating only one location, high temperature holds, etc.

- Can be single step (up-down in temperature), or multistep

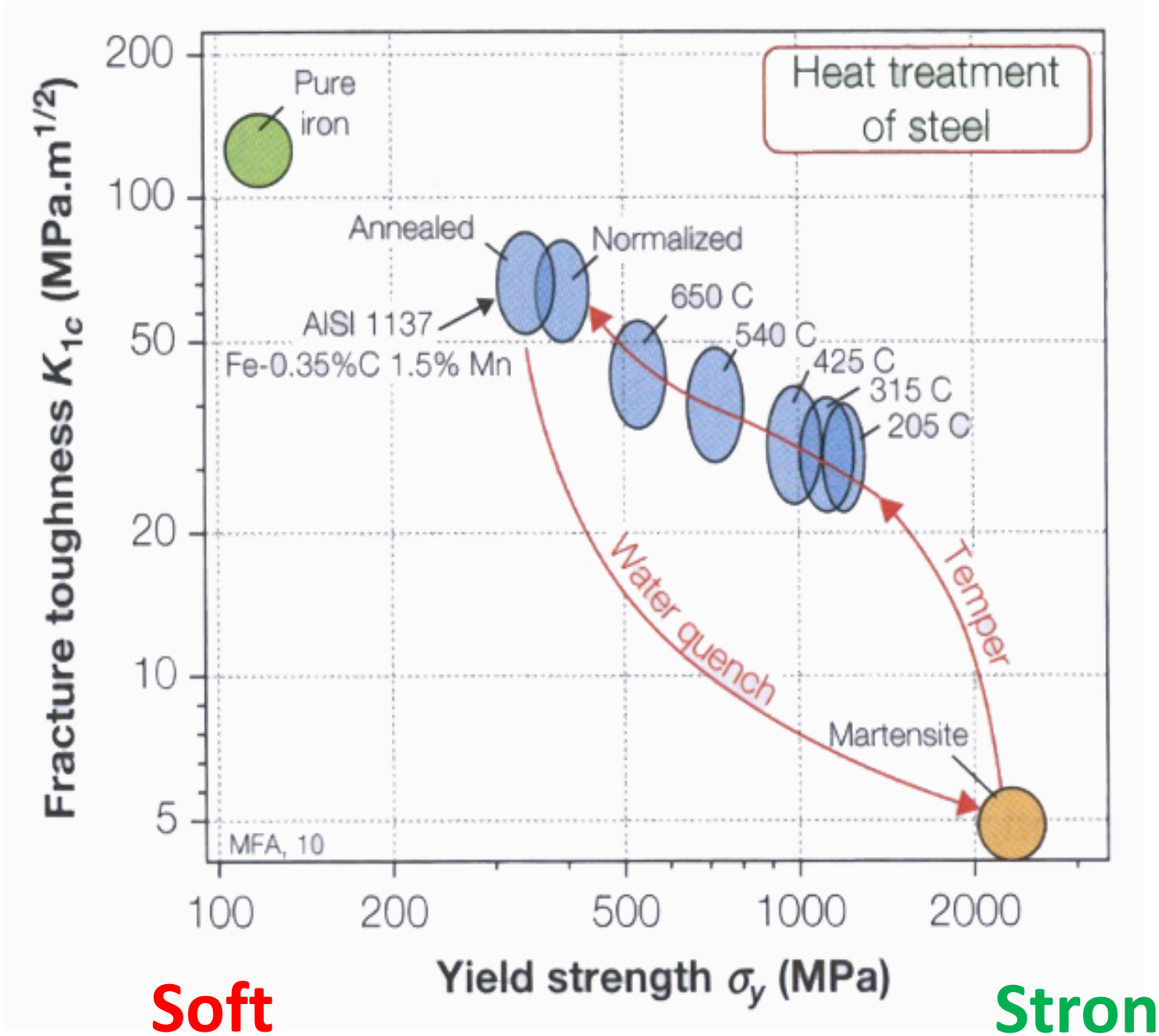
- Steels can change their properties GREATLY with heat treatment

- Aluminum heat treating is more limited, fewer alloys

- Heat treatment is half of overall process envelope called **Thermo-Mechanical Processing**

Terminology – Heat Treatment

Tough



Brittle

Soft

Strong

Terminology – Heat Treatment

- **Annealing** – Heated to a high temperature for a long time such that the internal strength of the material relaxes out
  - At this point, termed "**Annealed**" or "**Dead Soft**"
  - Typically, manufacturing uses dead soft steel/aluminum to shape the part, then sets the properties using a heat treatment

- **Normalizing** – Heating the alloy so as to relax MOST of the strength
  - Material then referred to as "**normalized**"

- **Solutionizing** – Heating **aluminum** to dissolve particles in the microstructure that cause strength
  - Material given a "solutionization heat treatment" might be called "un-aged" or "W"

- **Aging** – Heating up aluminum a bit to allow particles to form and grow
  - Underaged – particles are too few and small
  - Peak aged – particles are just right
  - Overaged – particles are big, fat and ugly (dead soft for heat treatable aluminum)

- **Quenching** – Cooling the metal to lower temperature – can be fast or slow
  - In steel, fast creates different, very strong phases in the microstructure
  - In aluminum, fast locks the alloying atoms in the grains and prevents particles from growing
  - Quenching Medium – what is used to cool the metal
    - Can be air, water, oil, fluidized sand, . . .

Terminology – Heat Treatment

- **Tempering** – Heating steel to white-yellow hot, rapidly quenching, then heating to a red or orange temperature for a while to relax out some of the strength from quenching
  - Makes the part strong and tough
  - Part is thus "tempered" or "quench and tempered"
  - Medium and high carbon steels, alloy steels

- **Hardening** – Quenching a thick part to create high strength / hardness
  - Can be "surface hardened" or "full hardened" / "through hardened"
  - "Hardenability" describes how well it hardens throughout a thick part
    - Low – just the surface is hard
    - High – all the way through

- **Furnace** – Chamber to heat an alloy
  - Can have controlled atmosphere, be any size

- **Stabilized** – The aluminum equivalent of "normalized"
  - Heat it a little, it relaxes a little, isn't quite so "twitchy" in manufacturing

Terminology – Heat Treatment

Aluminum Temper Designations:

F	As fabricated and no mechanical properties specified (F stands alone)
O	Annealed to obtain lowest strength temper (O may be followed by a digit to indicate an annealed condition with special characteristics)
H	Strain-hardened wrought products with or without additional thermal treatment to reduce strength (H always is followed by two or more digits)
W	Solution heat-treated (W is an unstable temper due to natural aging at room temperature after solution heat-treatment)
T	Thermally heat-treated to produce stable tempers other than F, O, or H (T is always followed by one or more digits)

- Set and published by the Aluminum Association
- Essentially, any time anyone finds a new way to process aluminum, they make one of these and sell it

Terminology – Heat Treatment

Aluminum Heat Treatment Designations:

F – "It was that way when we found it" – no specifics – as manufactured

O – Dead Soft

W – Solutionized and quenched, but no anneal. Unstable and uncommon.

H - Series – Work **H**ardened

Softer ↓

H1 – Strain hardened only
H2 – Strain hardened, then partially annealed
H3 – Strain hardened, and stabilized
H4 – Strain hardened . . . and laquered or painted (?)

Nomenclature: H1XY, H2XY, H3XY, H4XY . . .

"X" gives the relative amount of strain work (min = 1, max = 8) – higher number is stronger

"Y" indicates a tweak on the temper for special purpose – registered so people can look up

T-Series: Given some sort of heat **T**reatment (temper)

Temper	Definition
T1	Cooled from an elevated temperature shaping process and naturally aged
T2	Cooled from an elevated temperature-shaping process, cold worked, and naturally aged
T3	Solution heat treated, cold worked, and naturally aged
T4	Solution heat treated and naturally aged
T5	Cooled from an elevated temperature-shaping process and artificially aged
T6	Solution heat treated and artificially aged
T7	Solution heat treated and artificially overaged
T8	Solution heat treated, cold worked, and artificially aged
T9	Solution heat treated, artificially aged, and cold worked
T10*	Cooled from an elevated temperature shaping process, cold worked, and artificially aged

*T10 is designated in ANSI H35.1/H35.1(M) but not in EN 515 or ISO 2107.

Translation to "English"

T1 – Work it hot (below solutionize temp), set it down, and walk away

T2 – Work it hot (below solutionize temp), cool it down, work it "cold", then walk away

T3 – Solutionize, cool it down, work it "cold", then walk away

T4 – Solutionize, remove from oven, set it down and walk away

T5 – Work it hot, then give it an aging heat treatment

T6 – Solutionize, then give it an aging heat treatment

T7 – Solutionize, then give it an aging heat treatment too long or too hot

T8 – Solutionize, cool it down, work it "cold", then perform an aging heat treatment

T9 – Solutionize, give it an aging heat treatment, then work it "cold"

T10 – Work it hot, cool it down, work it "cold", then an aging heat treatment

Digging deeper . . .

T5 – Work it hot, then give it an aging heat treatment

T51 = T5 + stress relief by stretching in a plate

T510 = T5 + stress relief by stretching of box cross-section beam

T52 = T5 + stress relief by compression on a forging

T54 = T5 + stress relief by BOTH compression and tension of a complex shape die forging

To date, there are 531 aluminum alloys and many hundreds of heat treatments

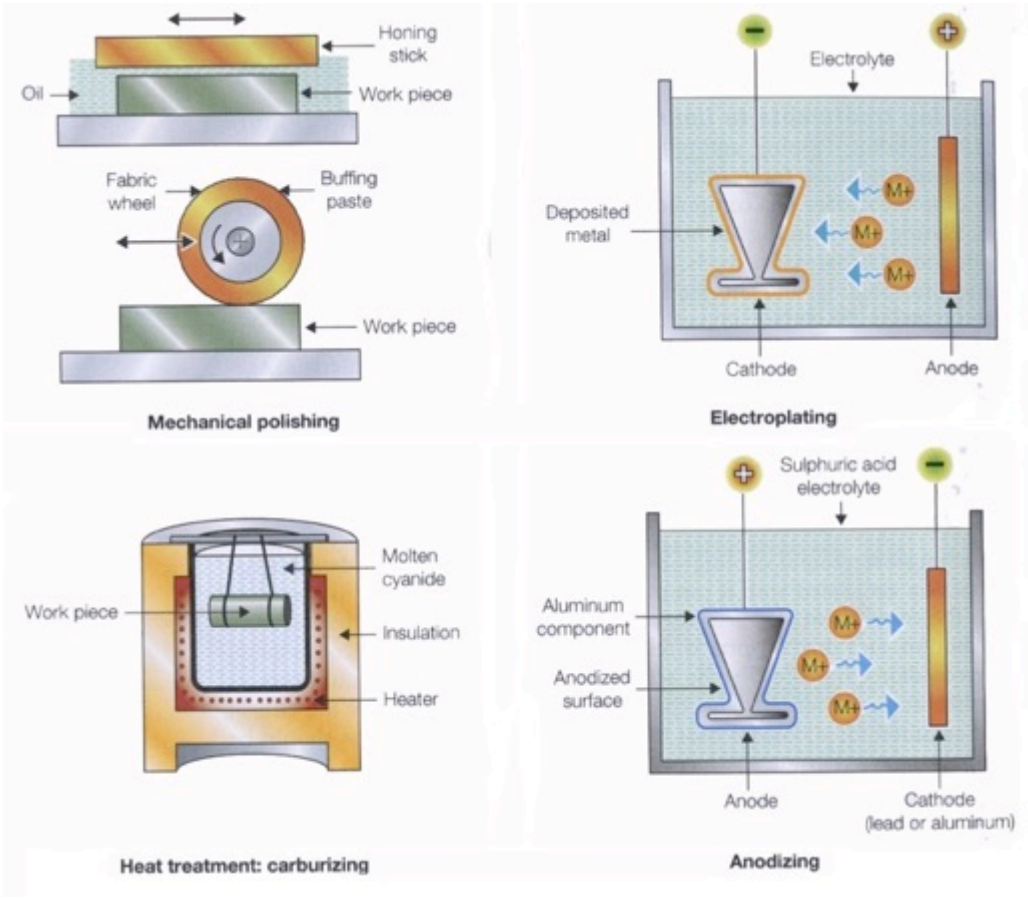
The only way to know if they are specifying the right designation is to be a metallurgist, unfortunately

These heat treatment designations are, by definition, different enough to get their own numbers → they are NOT interchangeable or substitutable

Temper	Designation	T Temper Alloy	Product Forms
F	As Fabricated	All	All
O	Annealed	All	All
O1	Thermally treated at ~time/temperature for solution treatment (ST) and slow cooled to room temperature	All	Products to be machined prior to solution treatment, no mechanical property limits
W	Solution heat treated (unstable temper)	All	All
T	Thermally treated to produce stable tempers other than F, O, or H	All	All
T1	Cooled from an elevated shaping process and naturally aged to a substantially stable condition	6061, 6063, 6105, 6351, 6463	Extruded tube, wire, rod, bar, and profiles
T3	Solution heat treated*, cold worked, and naturally aged to a substantially stable condition	2011, 2014, Alclad 2014, Alclad 2024	Sheet; rolled or cold finished rod, bar, or wire; Drawn tube and extruded tube, wire, rod, bar, and profiles (2024 only)
T31	Solution heat treated*, cold worked ~1%, and naturally aged to a substantially stable condition	2219, Alclad 2219	Sheet; extruded tube, wire, rod, bar, and profiles
T351	Solution heat treated*, stretched a controlled amount for stress relief, and naturally aged (no further straightening after stretching)	2024, Alclad 2024, 2124, 2219	Plate; rolled or cold finished bar (2024 only)
T3510	Solution heat treated*, stretched a controlled amount for stress relief, and naturally aged (no further straightening after stretching)	2024, 2219	Extruded tube, wire, rod, bar, and profiles
T3511	Same as T3510 except minor straightening allowed after stretching to comply with standard tolerances	2024, 2219	Extruded tube, wire, rod, bar, and profiles
T361 (formerly T36)	Solution heat treated*, cold worked ~6%, and naturally aged	2024, Alclad 2024	Sheet and plate
T37	Solution heat treated*, cold worked ~7%, and naturally aged	2219	Sheet and plate
T4	Solution heat treated* and naturally aged	All (with exceptions)	All (most with exceptions)
T42	Solution heat treated in a furnace from annealed or F temper and naturally aged to demonstrate response to heat treatment	All	All
T451	Solution heat treated*, stretched a controlled amount (product dependent) for stress relief, and naturally aged (no further straightening after stretching)	2011, 2017	Rolled or cold finished rod and bar
T4510	Solution heat treated*, stretched a controlled amount for stress relief, and naturally aged (no further straightening after stretching)	6061, 6066,	Extruded tube, wire, rod, bar, and profiles
T4511	Same as T4510 except minor straightening allowed after stretching to comply with standard tolerances	6061, 6066	Extruded tube, wire, rod, bar, and profiles
T5	Cooled from an elevated temperature shaping process and then artificially aged	6063, 6005, 6005A, 6105, 6162, 6351, 6463	Extruded tube, wire, rod, bar, and profiles
T51	Cooled from an elevated temperature shaping process and then artificially aged in underaging conditions to improve formability	6061, 6351	Extruded tube, (6061 only); extruded wire, rod, bar, and profiles
T52	Cooled from an elevated temperature shaping process and then artificially aged to specified minimum and maximum strength levels	6063	Extruded wire, rod, bar, and profiles
T6	Solution heat treated* and then artificially aged	All (with exceptions)	All (with exceptions)
T61	Solution heat treated* and then artificially aged in underaging conditions to improve formability	2018	Forgings and forging stock
T62	Solution heat treated in a furnace from annealed or F temper and artificially aged to demonstrate response to heat treatment	All	All
T63, T64, T65	Solution heat treated* and artificially aged to specified mechanical properties below T6	6101	Electrical conductor products as extruded tube, pipe, rolled or extruded structural profiles, and extruded wire, rod, bar, and profiles
T651	Solution heat treated*, stretched a controlled amount (product dependent) for stress relief, and artificially aged (no further straightening after stretching)	2014, Alclad 2014, 6061, Alclad 6061, 6262, 7075, Alclad 7075, 7178, Alclad 7178, 7475, Alclad 7475	Plate (most with exceptions), rolled or cold-finished rod and bar (most with exceptions)
T6510	Solution heat treated*, stretched a controlled amount (product dependent) for stress relief, and artificially aged (no further straightening after stretching	2014, 6061, 6066, 6162, 6262, 7075, 7178	Extruded tube (except for 6162 and 7178), wire, rod, bar, and profiles
T6511	Same as T6510 except minor straightening allowed after stretching to comply with standard tolerances	2014, 6061, 6066, 6162, 6262, 7075, 7178	Extruded tube (except for 6162 and 7178), wire, rod, bar, and profiles
T652	Solution heat treated*, compressed to a permanent set of 1-5% for stress relief, and artificially aged	2014, 6061, 6151, 7075	Forgings and forging stock
T7	Solution heat treated* and artificially overaged/stabilized to control important properties (rarely used without second digit as below)	7050	Rivets
T72	Solution heat treated* and artificially aged by user from O or F temper (not available from producer)	2024	Sheet
T73	Solution heat treated*, fully overaged artificially to achieve best corrosion resistance with a greater reduction in strength than T74	7049, 7075, Alclad 7075,	Sheet (7075 and Alclad 7075); drawn and extruded tube (7075); extruded wire, rod, bar, and profiles (7075); rolled or cold-finished rod, bar, and wire (7075); rivets (7075); forgings and forging stock (7049 and 7075)
T7351	Solution heat treated*, stretched a controlled amount (product dependent) for stress relief, and artificially overaged to achieve best corrosion resistance with a greater reduction in strength than T74 (no further straightening after stretching)	7075, Alclad 7075	Plate (7075 and Alclad 7075), rolled or cold-finished rod and bar (7075)
T73510	Solution heat treated*, stretched a controlled amount (product dependent) for stress relief, and artificially overaged to achieve best corrosion resistance with a greater reduction in strength than T74 (no further straightening after stretching)	7050, 7075	Extruded wire, rod, bar, and profiles
T73511	Same as T73510 except minor straightening allowed after stretching to comply with standard tolerances	7050, 7075	Extruded wire, rod, bar, and profiles
T7352	Solution heat treated*, compressed to a permanent set of 1-5% for stress relief, and artificially overaged to achieve best corrosion resistance with a greater reduction in strength than T74	7049, 7075	Forgings and forging stock
T74**	Solution heat treated* and then artificially overaged to achieve corrosion resistance and strength level between the T73 and T76 tempers	7050	Forgings and forging stock
T7451**	Solutions heat treated*, stretched a controlled amount for stress relief (product dependent), and then artificially overaged to achieve corrosion resistance and strength level between the T73 and T76 tempers (no further straightening after stretching)	7050	Plate
T74510**	Solution heat treated*, stretched a controlled amount (product dependent) for stress relief, and artificially overaged to achieve corrosion resistance and strength level between the T73 and T76 tempers (no further straightening after stretching)	7050	Extruded wire, rod, bar, and profiles
T74511**	Same as T74510 except minor straightening allowed after stretching to comply with standard tolerances	7050	Extruded wire, rod, bar, and profiles
T7452**	Solution heat treated*, compressed to a permanent set of 1-5% for stress relief, and artificially overaged to achieve corrosion resistance and strength level between the T73 and T76 tempers	7050	Forgings and forging stock
T7454**	Solution heat treated*, stress relieved by restriking cold in finished die, and artificially overaging to achieve corrosion resistance and strength level between the T73 and T76 tempers	7175	
T76	Solution heat treated*, limited overaging to achieve moderate corrosion resistance with some reduction in strength relative to the T79 temper	7075, Alclad 7075, 7178, Alclad 7178, 7475	Sheet; drawn and extruded tube (7075), extruded wire, rod, bar, and profiles (7075 and 7178)
T7651	Solution heat treated*, stretched a controlled amount for stress relief (product dependent), and artificially overaged to achieve moderate corrosion resistance with some reduction in strength relative to the T79 temper (no further straightening after stretching)	7050, 7075, Alclad 7075, 7178, Alclad 7178, 7475, Alclad 7475	Plate
T76510	Solution heat treated*, stretched a controlled amount (product dependent) for stress relief, and artificially overaged to achieve moderate corrosion resistance with some reduction in strength relative to the T79 temper (no further straightening after stretching)	7050, 7075, 7178	Extruded wire, rod, bar, and profiles
T76511	Same as T76510 except minor straightening allowed after stretching to comply with standard tolerances	7050, 7075, 7178	Extruded wire, rod, bar, and profiles
T79	Solution heat treated* with slight overaging to achieve some improved corrosion resistance with slight reduction in strength relative to the T6 temper	No alloy-temper-product standardized	No alloy-temper-product standardized
T8	Solution heat treated*, cold worked, and then artificially aged	2011	Drawn tube, rolled or cold-finished rod, bar, and wire
T81	Solution heat treated*, cold worked ~1%, and then artificially aged	2024, Alclad 2024, 2219, Alclad 2219	Sheet, Extruded tube, wire, rod, bar, and profiles
T851	Solution heat treated*, stretched a controlled amount for stress relief (product dependent), and then artificially aged (no further straightening after stretching)	2024, Alclad 2024, 2219, Alclad 2219	Plate, rolled or cold-finished rod and bar (2024 and 2219)
T8510	Solution heat treated*, stretched a controlled amount (product dependent) for stress relief, and then artificially aged (no further straightening after stretching)	2024	Extruded tube, wire, rod, bar, and profiles
T8511	Same as T8510 except minor straightening allowed after stretching to comply with standard tolerances	2024	Extruded tube, wire, rod, bar, and profiles
T9	Solution heat treated*, artificially aged, and then cold worked	All	All
T10	Cooled from an elevated temperature shaping process, cold worked, and then artificially aged	All	All

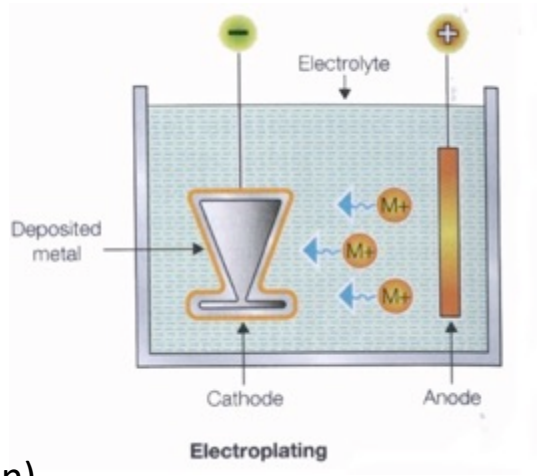
Terminology – Surface Treatments

- Mechanical polishing
  - Makes smooth, shiny
  - Characterized by roughness
- Coating
  - Metal
  - Polymer
  - Oils
  - Characterized by
    - Material
    - Thickness
    - Deposition method
- Other
  - Shot blasting
  - Cladding



Terminology – Surface Treatments

Electroplated: Having another metal chemically deposited on the surface



- Typically done to take advantage of properties of coating:
  - Corrosion resistant
  - Hard
  - Slippery
  - Shiny
  - Etc. . . . .
- Steels typically plated with
  - Zinc, chromium, nickel, cadmium, aluminum (less common)
- Aluminum typically **NOT** electroplated

Galvanized (aka "zinc plated" on form for some reason)

- Iron coated with Zinc for corrosion protection
- Can be electroplated (electro-galvanized)
- Can be dipped into molten zinc (hot dipped galvanized)
- Can be dipped into molten zinc then heated (galvaneal)

- Products: road crash barriers and light poles, nails, ...

Pattern is called "spangle"

Terminology – Surface Treatments

Tin Plate: Same as Galvanizing, but with Tin

- More typical of sheet products ("tin cans") that touch food
- Hot dip or electroplating processes
- Resulting iron or steel material is referred to as "**tinplate** or **tin plate**"

Oils and Greases

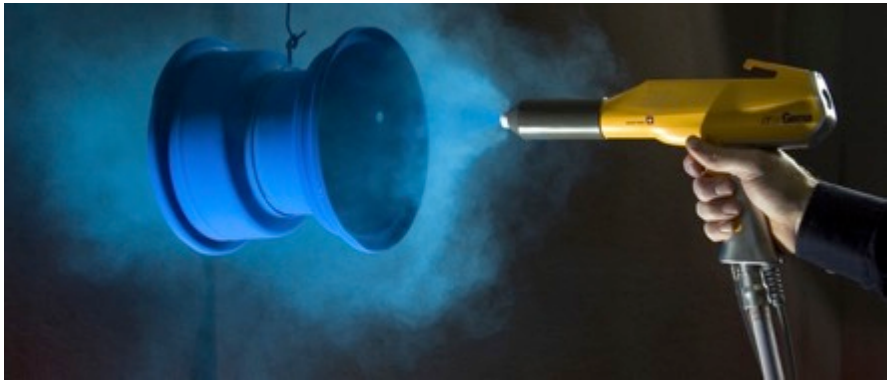
- Put on metals to prevent corrosion due to air, moisture
- Common for imported metals (Cosmolene) carried by ships
- Must be cleaned off to manufacture things

Thermal Spray

- Can be crude (thermal wire spray) or precise (vacuum plasma spray)
- Puts down a lot of coating fast
- Can put down coatings of ceramics (can't plate) or high melting point metals
- Corrosion resistance, wear resistance
    - Crankshafts, hip implants, thermal barrier coatings, . . .

Terminology – Surface Treatments

- **Paint** - a colored non-metallic coating, with a solvent
  - Solvent can be VOC (volatile organic compound) or water
- **Varnish** – a clear coating similar to paint
  - May include polyurethane, acrylic, varnish
- "**Plasticized**" I think means **Powder Coated**
  - Plastic powder given a static charge opposite part
  - Powder sprayed on evenly, baked
  - Typical products – heavily used outdoor equipment, playground stuff
  - Coating is tough, thick, shiny, colored, insulating

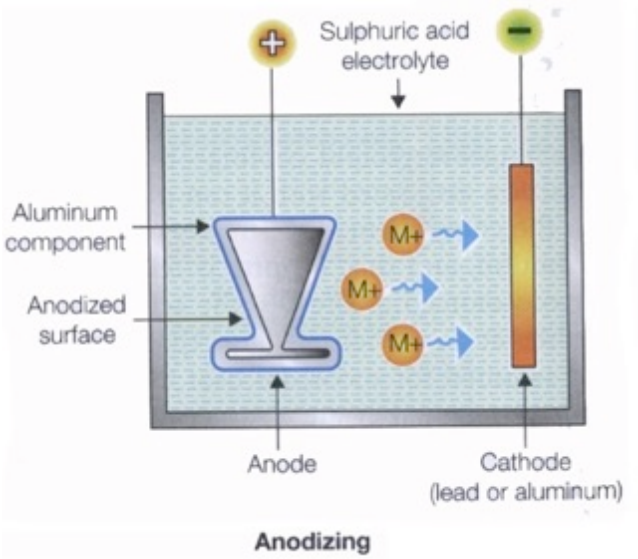


Terminology – Surface Treatments

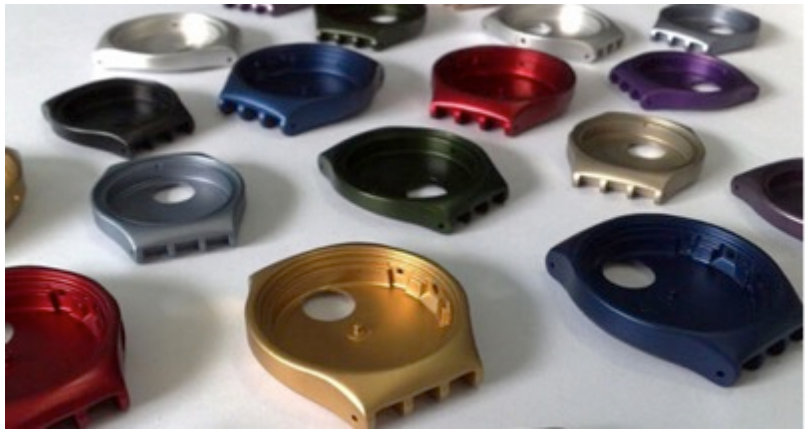
Anodized (can be termed "oxidized")

- Chemically, the opposite of electroplating
- Carefully form a perfect oxide layer
  - Protective, colored
- Commonly used for aluminum parts
- Can be a film on steel parts

- Generally done as an end-step
  - Further manufacturing can damage



Anodizing



Terminology – Surface Treatments

Shot Blasted

- Hit the surface with high speed metal beads (shot)
  - Clean off rust, compressive stress to resist fatigue, texture for powder coating
- Typically done for 3D parts, bars, things that see cyclic loading

Parkerized / Parkerizing

- Like anodizing does oxide layer, parkerizing does phosphate layer on **steel**
- Increases corrosion resistance, wear resistance
- Ex: "blueing" on firearms

Pickled / Pickling

- Chemical cleaning of steel surface, usually before some other treatment
- For stainless steel, removing native protective oxide "heat tint" and lets oxide scale re-form uniformly – nice and shiny everywhere

Clad Product / Cladding

- Metallurgically bonding another alloy on the surface
- Takes advantage of both alloys: performance plus cheap, for example

Terminology – Mechanical Properties

The HTSUS for Steel has ONE strength specification for the categories, and it's fairly useless. However, the customers have MANY mechanical specs for their suppliers, and they are on the waiver request forms. . .

- **Yield strength** - The stress where, if exceeded, results in a permanent change of shape of the metal (yielding). Below this stress, the metal is a spring.
  - This is also called the "proportional limit", "initial yield stress"
  - Designs usually stay well below the yield stress in operation
  - Manufacturing occurs above the yield stress – change shape

- **Tensile Strength** – The maximum stress the metal can hold just before breaking
  - All metals "work harden" – get stronger as you deform them

- **Elongation** - The maximum amount a metal can deform before breaking
  - High elongation is needed to make some products (ex. wire, beverage cans)
  - Elongation and strength usually go in opposite directions (strong = low elong.)

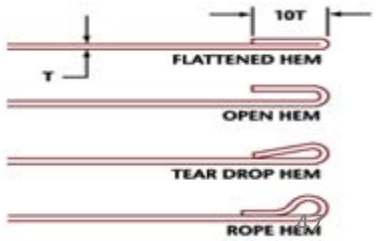
- **Elastic (or Yield) Ratio:** Yield strength divided by tensile strength

Terminology – Mechanical Properties

- **Toughness:** The ability of a material to resist cracking by tearing instead
  - Lead is tough, glass is not
  - One material system can be tough or not: mild steel tough, cast iron not
  - Units are energy (Joules) absorbed while breaking test sample

- **Global Ductility**: The amount a tensile bar stretches before breaking
  - **Elongation %** - (amount it stretched / original length) * 100%
    - Aluminum can range from ~5 – 100%, steel from ~0 – 50%
  - **Reduction in Area:** Another measure of ductility – how much thinner is the test specimen at the point it broke

- **Local Ductility:** Amount the metal can stretch at a special shape feature
  - **Hole Expansion %** - how much you can stretch a hole bigger in a piece of sheet metal before the edge cracks
    - Imagine a drum head with hole in it, now tighten it – at some point it tears
  - **Bendability** – can you make a hem joint
    - More commonly called "hemmability"
    - Depends on both radius of bend and sheet thickness



Terminology – Mechanical Properties

- **Plasticity** – The metal can undergo a permanent shape change. Also called ductility

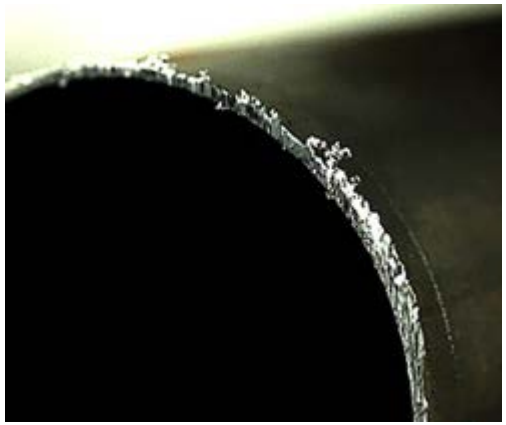
- **Hardness Test** – An almost non-destructive way to measure the strength of a metal . . . sort of
  - Presses an indenter in the surface to make a dent – measure size of dent
  - There are many different types of hardness tests
    - Rockwell B (brass and aluminums), Rockwell C (steels)
    - Vickers, Knoop, microhardness, nanoindentation . . .
    - Are used for screening – measurements are not comparable between materials
      - I.E. is the process still giving a hardness of . . .
  - Commonly used in industry, standardized, but in terms of "real" properties like strength means nothing

- **Hardenability** – Is a term that describes how well you can make an alloy stronger all the way to the center of the part by doing heat treatment
  - Relies on the alloy chemistry to make the correct strong structure
  - Mild steel is not hardenable (only hardens the surface)
  - 4340 high strength steel is very hardenable, and thus is used in things like bolts

Terminology – Mechanical Properties

- **Roughness** - A measure of the surface topography of a metal part (using profilometer)
  - Roughness can be bad for many reasons
    - Ugly – form a car part and paint it, and it's not shiny
    - Friction – the bumps and valleys tend to grab each other, increase friction
  - Roughness can be caused by many aspects of either metal or manufacturing process
  - Very little known about what in an alloy might cause it or make it a problem
  - Measured various ways, expressed as $\mathbf{R_a}$ – average roughness over a length

- **Burr** (if removed – part is "deburred")
  - The ragged edge left on a metal part when cut by shearing
  - Is removed by sanding, de-burring tool (a blade)
  - Why important
    - Parts don't fit
    - Effectively a variation in thickness
    - Can cause failures
  - Some cutting methods avoid making burrs
    - Laser, waterjet, . . .



Terminology – Mechanical Properties

These terms are a bit more subjective and even jargon:

- **Machinability** - Describes the ease with which a metal can be cut into a part
  - Inclusions and bad microstructure can decrease machinability
  - Often, it's just the sense of the machinist whether it's "good"

- **Formability** – Ability of sheet metal to be deformed into a shape without tearing
  - Measurable – "forming limits" in auto industry by stretching a dome

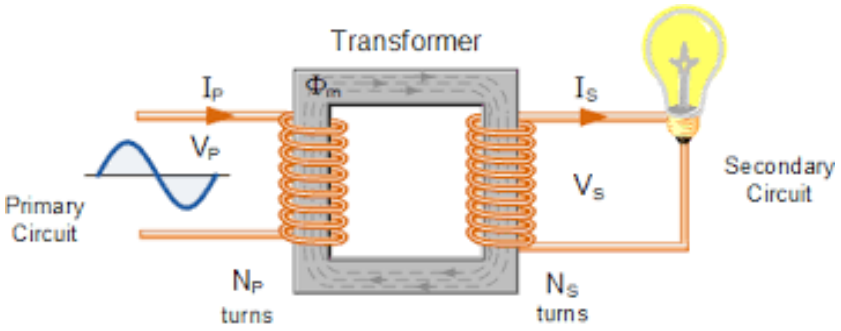
- **Malleability** – "Formability" specifically for hammering and rolling

- **Weldability** - The ease of welding a particular metal
  - Depends on many factors – most importantly chemistry of alloy, clean-ness
  - Every metal is weldable, it's just a matter of how difficult
  - "Low weldability" – it's expensive, a pain, frustrating . . .
  - "High weldability" – anyone could be taught to do it
  - Inclusions and contaminants in metal can greatly affect
    - Ex. if inclusion is an oxide slag particle, it melts and covers metal surface with glass – weld metal doesn't stick.

Terminology – Magnetic Properties

Some steels are used for their magnetic properties in electrical transformers

- **Magnetic Permeability** – How well a metal supports a magnetic field within itself
- Electrical transformers use stacks of steel as the core to reduce voltages
- This type is also called
  - Electrical, lamination, silicon electrical, relay, transformer steels (synonyms)
  - Can also be termed "oriented" or "random" to describe grain structure



Terminology – Specs and Standards

- The complete assemblage of shapes, chemistry and other defined parameters of the product is the **SPECIFICATION (spec)**

- The spec can include anything the buyer and vendor agree upon
  - Buyers include things that affect manufacturability, reliability
  - Vendors want to minimize specs, since they cost $$ to meet
  - Typical: Chemistry, dimensions, mechanical properties (and tolerances)
  - Over-specification leads to waste and increased costs
    - Don't want to specify things that don't matter

- Specifications may or may not include **STANDARDS**

- Standards are **written by industrial committees for themselves** (not imposed by NIST)
  - Many standards bodies (ASTM, ISO, SAE, MIL, AISI, API, DIN, UNS, . . .)
    - Some general, some formed by industrial sector for themselves (Oil = API)
  - Some standards very broad, some very specific – written by committee
  - Cover just about everything (in excruciating detail or maddening vagueness)
    - Ex: MIL-spec for adhesion of labels to condiment bottles sold to DOD
  - Specifications can involve modifications of standards
    - Ex: ASTM F1941 + UTS = 120ksi (Translation: manufacturing specs for high strength bolts, plus a little more strength)

Terminology – Specs and Standards

UNS (Unified Numbering System) for alloys (run jointly by ASTM and SAE)

- A00001 to A99999 - aluminum and aluminum alloys
- D00001 to D99999 – steels with specified mechanical properties
- F00001 to F99999 – cast irons
- G00001 to G99999 – AISI and SAE carbon and alloy steels (not tool)
- H00001 to H99999 – AISI and SAE hot-working tool steels (H-steels)
- J00001 to J99999 – cast steels (not tool)
- K00001 to K99999 – miscellaneous steels and iron alloys
- S00001 to S99999 – stainless steels
- T00001 to T99999 – tool steels, both wrought and cast
- W00001 to W99999 – welding filler materials (rod, wire, etc)

- VERY commonly used in North America
- NOT a complete specification, as it doesn't generally include strength, heat treatment condition, form of the material, nor quality

Terminology – Specs and Standards

ASTM B209:

Industry-authored description of all aluminum alloys sold in plate or sheet form

Includes these requirements:

- Alloy chemistry
- Base mechanical properties
- Mechanical properties as a function of thickness
- How it responds to heat treatment
- Corrosion performance
- Tolerances
- How to inspect upon delivery
- Coatings
- . . . . .

This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

Designation: B209 – 14

Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate[1]

This standard is issued under the fixed designation B209; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This specification[2] covers aluminum and aluminum-alloy flat sheet, coiled sheet, and plate in the alloys (Note 1) and tempers shown in Tables 2 and 3, and in the following finishes:

1.1.1 Plate in all alloys and sheet in heat-treatable alloys: mill finish.

1.1.2 Sheet in nonheat-treatable alloys: mill finish, one-side bright mill finish, standard one-side bright finish, and standard two-sides bright finish.

1.2 Alloy and temper designations are in accordance with ANSI H35.1/H35.1(M). The equivalent Unified Numbering System alloy designations are those of Table 1 preceded by A9, for example, A91100 for aluminum 1100 in accordance with Practice E527.

NOTE 1—Throughout this specification, use of the term *alloy* in the general sense includes aluminum as well as aluminum alloy.

NOTE 2—See Specification B632/B632M for tread plate.

NOTE 3—See Specification B928/B928M for 5xxx-H116 and 5xxx-H321 aluminum alloys containing 3 % or more nominal magnesium and intended for marine service and similar environments. Other alloy-temper products listed in this specification, which do not require the additional corrosion testing/capability called out in ASTM B928/B928M, may be suitable for marine and similar environment applications.

1.3 For acceptance criteria for inclusion of new aluminum and aluminum alloys in this specification, see Annex A2.

1.4 This specification is the inch-pound companion to Specification B209M; therefore, no SI equivalents are presented in the specification.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

[1] This specification is under the jurisdiction of ASTM Committee B07 on Light Metals and Alloys and is the direct responsibility of Subcommittee B07.03 on Aluminum Alloy Wrought Products.

2. Referenced Documents

2.1 The following documents form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards*:[3]

B548 Test Method for Ultrasonic Inspection of Aluminum-Alloy Plate for Pressure Vessels

B557 Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products

B594 Practice for Ultrasonic Inspection of Aluminum-Alloy Wrought Products

B632/B632M Specification for Aluminum-Alloy Rolled Tread Plate

B660 Practices for Packaging/Packing of Aluminum and Magnesium Products

B666/B666M Practice for Identification Marking of Aluminum and Magnesium Products

B881 Terminology Relating to Aluminum- and Magnesium-Alloy Products

B918 Practice for Heat Treatment of Wrought Aluminum Alloys

B928/B928M Specification for High Magnesium Aluminum-Alloy Sheet and Plate for Marine Service and Similar Environments

B947 Practice for Hot Rolling Mill Solution Heat Treatment for Aluminum Alloy Plate

B985 Practice for Sampling Aluminum Ingots, Billets, Castings and Finished or Semi-Finished Wrought Aluminum Products for Compositional Analysis

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E34 Test Methods for Chemical Analysis of Aluminum and Aluminum-Base Alloys

E290 Test Methods for Bend Testing of Material for Ductility

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

E607 Test Method for Atomic Emission Spectrometric

Terminology – Standard Grades

These are the common US-used standards bodies:

- API – American Petroleum Institute
  - API 5 series for tubular goods, for example (drill pipe)
- ABS – American Bureau of Shipping
- LR – Lloyd's Register (UK)
- MIL – US military specification (MIL-SPEC)
- ANSI – American National Standards Institute (includes **ASTM**)
- **AISI – American Iron and Steel Institute**
- **SAE – Society of Automotive Engineers**
- NACE – National Association of Corrosion Engineers)
- **AA – Aluminum Association**

There are non-US standards bodies:

- ISO – International Standards Organization (US is a member)
- BS - British Standards
- EN – European Standards
- JIS – Japanese Standards
- DIN – German Standards
- GB – Chinese steel grades

Terminology – Dimensions

- There are two types of dimensions to think about:
  - Nominal ("standard") dimensions (what is in the specification)
  - Measured ("actual") dimensions (what is delivered)
  - The nominal dimensions have ranges of acceptable that the measured dimensions must fall within

- Typical dimensions:
  - Cut Plate, sheet: Length x Width x Thickness
  - Continuous sheet: Width x Thickness x C (stands for "coil")
  - Pipe/Tube: Outside diameter (OD), Inside diameter (ID), length

- Theoretical weight: calculated from nominal dimensions and density of alloy

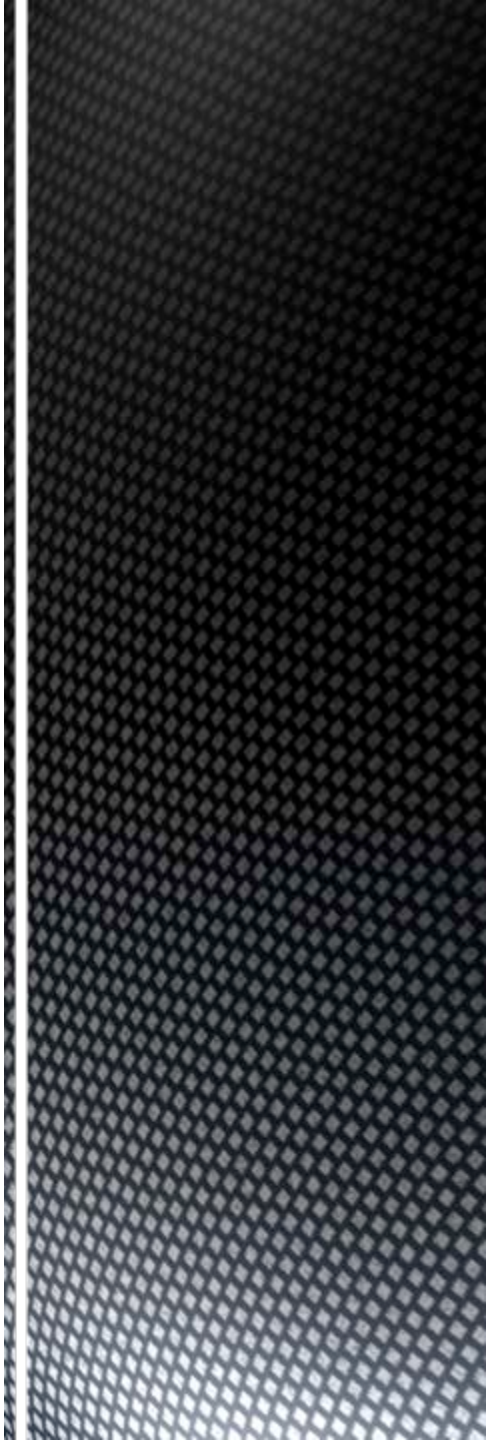
- Specifications for variation – ranges of nominal dimensions
  - Camber – How much the straightness of the edge varies
  - Crown - How much the thickness of the plate varies

Terminology – Shape

- Terminology involved in making a finished product:
  - First Step - Cast(-ing) – Turning the alloy from liquid to solid, using a mold and cooling
    - **Semi-Finished Shapes** include
      - **Slab** – thick plate (wood shape analogy – 1 x 12 board)
      - **Billet** – smaller cross section (4 X 4 board)
      - **Bloom** – large block
    - Continuous casting – casting a long, continuous object (billets and slabs)
  - Second – **Finished Product/Shape** – turning the hot cast object into a more shaped object
    - Shapes include
      - **Strip** – generally less than 4 mm thick (think sheet)
      - **Plate** – generally thicker than 4 mm
      - **Shapes** – **Rods**, **Bars**, **Rounds**
      - **Structural Shapes** – specialty like I-beams, railroad rails
  - Third – Also **Finished Product/Shape** – making the final shape
    - Shapes include but far from limited to:
      - **Sheet** – typically 1-2 mm thick, made by rolling
      - **Bars** and **wire** – made by drawing through a die
      - **Pipe** – bending sheet / plate into a circle and welding together edges
      - **Rounds** – to make seamless pipes

Let's take a 10 minute break

Iron and Steel Overview from HTS Chapters 72 and 73



Outline

- Description of the Various Alloys of Iron and Their Uses
- Primary Cast Products and Shapes
- Wrought Products and Shapes
- Some Definitions You Might Need
- Walking Through HTS Chapter 72: Iron and Steel
- Walking Through HTS Chapter 73: Iron and Steel Products

Steel Chemistry Groups

The Alloys of Iron

- **Pure Iron** – very soft, has relatively few direct uses – starting point for steel

- **Carbon Steel** – Iron + Carbon = Steel
  - Also called “mild steel” or “plain carbon steel” or "non-alloy"
  - Typically, steels contain 0.08% to 1% carbon plus ~1.5% Mn
    - Low carbon steels: 0.08 – 0.25% C
    - Medium carbon steels: 0.25 – 0.55% C
    - High carbon steels: 0.55 – 1% C
  - Can change the mechanical properties a LOT with heat treatment
  - Very utilitarian – you see it everywhere
    - Construction, appliances, autos, . . .

- **Cast Iron** – greater than 2% carbon plus a couple percent silicon
  - Hard, strong and brittle – used in compression
  - Machine tool bases, sewer pipes, stuff that doesn’t move
  - Can get a little better properties by heat treating
    - Get **malleable iron, ductile iron, grey iron, white iron**
  - For some reason, lumped in with **PLAIN STEEL**
  - **NOTE:** some requesters might have break at **1%**, but HTSUS is **2%**

Steel Chemistry Groups

Alloy Steels – More than just carbon

- Alloying elements increase strength and other properties
- Because additions are expensive, price goes up
- Heat treating and manufacturing changes too
- Used in higher performance products
  - Fasteners, pipelines, pressure vessels, engine components
- The HTS definition of Alloy Steels is ***incredibly*** broad

Stainless Steels – Ultimate corrosion resistance

- It is specifically cut out from Alloy Steels
- Add at least 10.5% chromium
- The Cr reacts with air to form thin, hard, protective layer of Cr_2O_3
  - So thin, it's transparent
- Used in food processing, chemical processing, medical equipment

Steel Naming Convention

The SAE (Society of Automotive Engineering) naming convention is commonly used:

SAE10XX – Used for plain carbon (mild, non-alloy) steels

- "XX" refers to 0.XX weight percent carbon
- Thus, 1065 is 0.65% carbon

- 1008 - 1025: Low carbon steel, soft and tough
  - Used in construction and ordinary steel objects
  - Cheap, not very heat-treatable, very machinable and weldable
- 1030 – 1065: Medium carbon steel, strong and less tough
  - Used in higher strength components
  - Costs more, changes strength drastically with heat treatment
- 1070-1100: High carbon steel, very strong and brittle
  - Used in springs, cutting tools, hard surfaces, chisels
  - Costs more, does not respond to heat treatment much
- **If AISI/SAE name starts with "10..", it's "non-alloy steel"**

NOTE: There are also foreign steel naming conventions

Steel Naming Convention

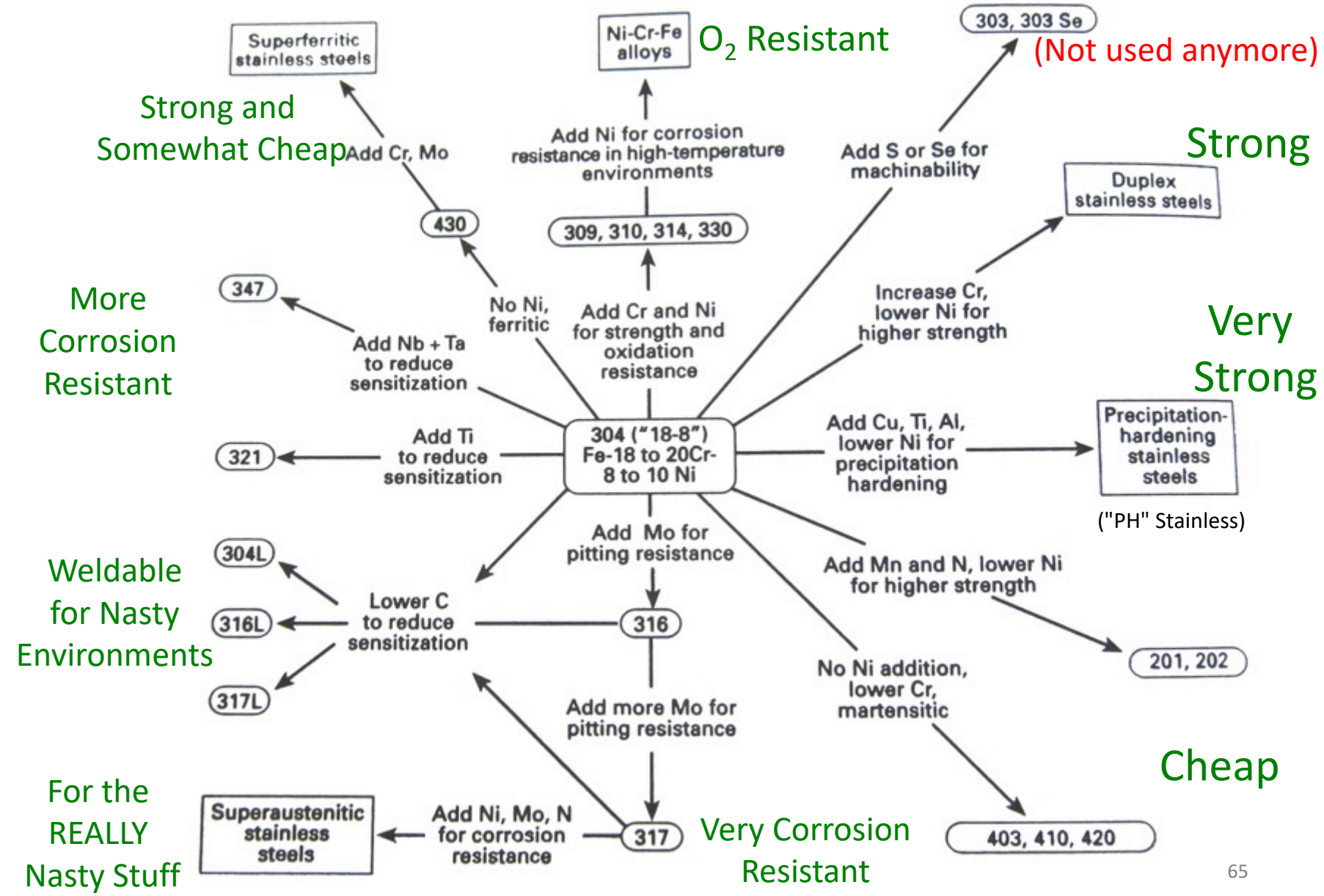
The SAE (Society of Automotive Engineering) naming convention is commonly used:

SAE-YXXX – Used for alloy steels – **If "Y" is not "1", it's an alloy steel**

- The more non-zero digits, the more complex and expensive the alloy

- 2XXX: Nickel steels
  - Maraging steels – unbelievably strong and tough (and $$$$)
  - 23XX and 25XX – cryogenics (liquid nitrogen)
- 3XXX: Nickel – Chromium steels
- 4XXX: Molybdenum steels
  - 4140, 4340: high strength bolts, race engine parts, airframe parts
- 5XXX: Chromium steels
  - Technically stainless steels
- 6XXX: Chromium-Vanadium steels
  - 6118: "High Speed" steel – cheap cutting tools
- 7XXX: Tungsten steels
- 8XXX: Nickel – Chromium – Molybdenum steels
- 9XXX: Silicon – Manganese steels

Stainless Steel Naming Convention



Notes 1(d)

Steel Chemistry Groups

- **Steel** – "Ferrous materials other than those of heading 7203 which (with the exception of certain types produced in the form of castings) are usefully malleable and which contain by weight 2 percent or less of carbon. However, chromium steels may contain higher proportions of carbon."

  Translation:
  - 7203 refers to pure iron. Steels have alloying additions, at least carbon.
  - 2% or less carbon – this is a LOT of carbon. It apparently includes industry definition of many cast irons, which start at 1%.
  - "Usefully malleable" means it doesn't crumble if you try to deform it into another shape – it's somewhat ductile
  - "with the exception of certain types produced in the form of castings" – castings can be not "usefully malleable" depending on how they were made – they can shatter if you hit them with a hammer.

*Essentially, if you have just iron, Mn and up to 2% carbon, the HTS considers it a "**steel**"*

- **Cast Iron** – More than 2% carbon, as defined in HTS Ch 73 intro notes

Steel Chemistry Groups

Notes 1(e)

- **Stainless steel**
  - Alloy steels containing, by weight 1.2 percent or less of carbon and **10.5 percent or more of chromium**, with or without other elements.

Translation:
- This covers every stainless steel you've ever seen. It is a very minimal definition, but sufficient. It is carved out from Alloy Steels below

Notes 1(f)

- **Other Alloy Steel** - Steels not complying with the definition of stainless steel and containing by weight one or more of the following elements in the proportion shown: (omitted here is a laundry list of alloying addition possibilities)

Translation:
- This category is defined by exclusion – it is all steels that are not stainless (at least 10.5% Cr) that have alloying additions besides just carbon. That's a LOT of steels. This is by far the broadest category. ***If you examine the chemistry, and Cr is below 10.5% plus there is some other alloying element besides just carbon, it belongs here.***

Steel Chemistry Groups

Ch. 72, Subheading Notes, 1(a)

Alloy pig iron - Pig iron containing, by weight, one or more of the following elements in the specified proportions:

- more than 0.2 percent of chromium, 0.3 percent of copper, 0.3 percent of nickel, and 0.1 percent of any of the following elements: aluminum, molybdenum, titanium, tungsten (wolfram), vanadium.

Translation:

- This is a higher quality pig iron formed from recycling higher alloy steels
- It is more valuable than regular pig iron

Ch. 72, Subheading Notes, 1(b)

Non-alloy free-cutting steel - Nonalloy steel containing by weight one or more of the following elements in the specified proportions:

- 0.08 percent or more of sulfur, 0.1 percent or more of lead
- more than 0.05 percent of selenium, more than 0.01 percent of tellurium, more than 0.05 percent of bismuth

Translation:

- Also called “free machining steel”, the elements form solid lubricants and chip breakers – it machines really easily and can be left unattended. It costs ~20% more.
- “Nonalloy” steel means it doesn’t have “alloy steel” additions like Cr, Mo, V, W, etc.
- Might be called "SAE13XX" or "AISI13XX"

Steel Chemistry Groups

Ch. 72, Subheading Notes, 1(c)

Silicon electrical steel - Alloy steels containing by weight at least 0.6 percent but not more than 6 percent of silicon and not more than 0.08 percent of carbon. They may also contain by weight not more than 1 percent of aluminum but no other element in a proportion that would give the steel the characteristics of another alloy steel.

Translation:

- These are specialized steels used in laminated cores of electrical transformers. They are vital to the electrical grid. It is the high silicon content that makes them very effective. 2X the cost of plain carbon steel

Ch. 72, Subheading Notes, 1(d)

High-speed steel - Alloy steels containing, with or without other elements, at least two of the three elements molybdenum, tungsten and vanadium with a combined content by weight of 7 percent or more, 0.6 percent or more of carbon and 3 to 6 percent of chromium.

Translation:

- A special one of “tool steels”. They are called “high speed” because you can use them in fast friction contacts without them breaking down.
- They are used in cheap drill bits and other inexpensive cutting tools. Made a lot in China.

Steel Chemistry Groups

Ch. 72, Subheading Notes, 1(e)

Silico-manganese steel - Alloy steels containing by weight:

- not more than 0.7 percent of carbon, 0.5 percent or more but not more than 1.9 percent of manganese, and 0.6 percent or more but not more than 2.3 percent of silicon, but no other element in a proportion that would give the steel the characteristics of another alloy steel.

Translation:

- Another special alloy steel defined by exclusion – if it doesn't fit into any other category, it goes here. This is another version of the electrical steel for transformers from 1(c) that is somewhat more expensive. Used more often in relays and switches.

Steel Chemistry Groups

SPECIAL NOTE: Ch. 72, Additional US Notes, 1(a)

1. For the purposes of the tariff schedule the following expressions have the meanings hereby assigned to them:
(a) **High-strength steel** - Flat-rolled products of a thickness of less than 3 mm and having a minimum yield point of 275 MPa or of a thickness of 3 mm or more and having a minimum yield point of 355 MPa

Translation:

- This was the **only strength specification found anywhere in Chapter 72**
- These strength levels roughly divide steel into that used for ordinary construction from everything else
- These strength levels are not very high

Ch. 72, Additional US Notes, 1(b)

Universal mill plate - Flat-rolled products rolled on four faces or in a closed box pass, of a width exceeding 150 mm but not exceeding 1,250 mm and of thickness of not less than 4 mm, not in coils and without patterns in relief.

Translation:

- This is a stock geometry for what industry regards as simple flat plate
- There is a width range from 6" to 50", and it is at least 4 mm thick
- It is flat plate (not coiled), and not imprinted like diamond plate
- It is rolled on 4 faces (rolled top and bottom, also on sides
    - Makes it nice and straight, and square

Steel Chemistry Groups

Ch. 72, Additional US Notes, 1(c)

Concrete reinforcing bars and rods: Hot-rolled bars and rods containing indentations, ribs, grooves and other deformations produced during the rolling process or twisted after rolling

Translation:

- Also referred to by industry as "rebar"
- Note it can be "bars" (rectangular) or "rods" (round) in cross section
  - Round is by far the most common
- Hot-rolled – it's comparatively soft
- Indentations, ribs, . . . - patterning so the concrete grabs the steel

Ch. 72, Additional US Notes, 1(d)

Razor blade steel – flat rolled products of stainless steel not over 0.25 mm in thickness and not over 23 mm in width, and containing by weight not over 14.7 percent chromium, certified at the time of entry to be used in the manufacture of razor blades

Translation:

- Here is another instance where a steel is broken out into another sub-category by end-use
- These are in the form of coils of thin sheet
- Still a stainless steel, but intended for razor blades
- Note no requirement for any other alloying element
- Commonly produced in Sweden, Germany

Steel Chemistry Groups

Ch. 72, Additional US Notes, 1(e)

Tool Steel: Alloy steels which contain the following combinations of elements in the quantity by weight included:

1. More than 1.2% carbon AND more than 10.5% chromium, OR . . .
2. Not less than 0.3% carbon and between 1.25% and 10.5% Cr, OR . . .
3. Not less than 0.85% carbon AND between 1% and 1.8% manganese, OR . . .
4. 0.9 percent to 1.2 percent, inclusive, chromium and 0.9 percent to 1.4 percent, inclusive, molybdenum, OR . . .
5. not less than 0.5 percent carbon and not less than 3.5 percent molybdenum, OR . . .
6. not less than 0.5 percent carbon and not less than 5.5 percent tungsten.

Translation:

- (1) might be referred to as "high carbon, high chrome" or "D" series tool steels
- (2) might be referred to as "air-hardening" or "A" series tool steels
- (3) might be referred to as "water-hardening" or "W" series tool steels – basically high C, non-alloy steel
- (4) might be referred to as "air-hardening" or "A" series tool steels
- (5) might be referred to as "high speed" or "M" series tool steels
- (6) might be referred to as "high speed" or "M" series tool steels

- Naming convention: Letter + Number – A2, A10, 03, W1, D2 . . . (number up to 10)

- Intended to make tools like drills, hammers, dies, files, etc.

- NOT stainless steels – chromium is always below stainless cutoff of 10.5%

Steel Chemistry Groups

Ch. 72, Additional US Notes, 1(f)

Chipper Knife Steel: Alloy tool steels which contain, in addition to iron, each of the following elements by weight in the amount specified:
(i) not less than 0.48 nor more than 0.55 percent of carbon;
(ii) not less than 0.2 nor more than 0.5 percent of manganese;
(iii) not less than 0.75 nor more than 1.05 percent of silicon;
(iv) not less than 7.25 nor more than 8.75 percent of chromium;
(v) not less than 1.25 nor more than 1.75 percent of molybdenum;
(vi) none, or not more than 1.75 percent of tungsten; and
(vii) not less than 0.2 nor more than 0.55 percent of vanadium.

Translation:

- This is a special air-hardened "A" series tool steel
- ASTM A681
- Used as blades in wood chippers – chomping up tree branches, etc
- Very specific chemical composition window
- Look at the info provided about the company – if "wood" is mentioned, it might belong here

Ch. 72, Additional US Notes, 1(g)

Heat-resisting steel - Alloy steels containing by weight less than 0.3 percent of carbon and 4 percent or more but less than 10.5 percent of chromium.

Translation:

- Another special category breakout from "alloy steels"
- Heat causes it to act like a stainless – protective oxide layer – **but** chromium content below 10.5%
- Cheaper than real stainless, but same performance when hot

Steel Chemistry Groups

Ch. 72, Additional US Notes, 1(h)

Ball-bearing steel - Alloy tool steels which contain, in addition to iron, each of the following elements by weight in the amount specified:

(i) not less than 0.95 nor more than 1.13 percent of carbon;
(ii) not less than 0.22 nor more than 0.48 percent of manganese;
(iii) none, or not more than 0.03 percent of sulfur;
(iv) none, or not more than 0.03 percent of phosphorus;

Translation:

- These are steels to be used for ball bearings
- What is being specified is VERY LOW SULFUR AND PHOSPHORUS
  - Low contamination – higher performance, reliability
- Usually comes in the form of wire or rod, which is headed to a ball, cut, and polished round, then heat treated to make it hard, cleaned and cold ground to exact shape and diameter
- These would be non-alloy steels except lower specification for sulfur and phosphorus

- Essentially, a clean non-alloy steel

Ch 72, Statistical Notes, 1

For the purposes of the tariff schedule, the expression **high-nickel alloy steel** refers to alloy steel containing by weight 24 percent or more of nickel, with or without other elements.

Translation: If there is a ton (over 24%) Nickel, it's this

A Few Useful Definitions . . .

Ch. 72, Statistical Notes, 4:

Tire cord-quality steel wire rod: Rod measuring 5.0 mm or more but not more than 6.0 mm in cross-sectional diameter, with an average partial decarburization of no more than 70 micrometers in depth (maximum 200 micrometers); having no non-deformable inclusions with a thickness (measured perpendicular to the rolling direction) greater than 20 micrometers; and, containing by weight the following elements in proportions:
– 0.68 % or more carbon, less than 0.01 percent of aluminum, 0.040 percent or less, in aggregate, of phosphorus and sulfur, 0.008 percent or less of nitrogen, and not more than 0.55 percent, in the aggregate, of copper, nickel and chromium

Translation:

- A special variety of alloy steel for making thin wires for "steel belted radials"
  - Low junk (sulfur, phosphorus) like ball bearing steel – can make reliable, thin drawn wires
  - Some alloying additions for strength (copper, nickel, chromium)
- Again, broken out by end use away from the chemical definition of "alloy steel"
- Expect this for tire manufacturers, wire manufacturers
- Note small spread of thickness of rod (between 5-6 mm)
  - All the machines that make tire cord use the same size input rod

Ch. 72, Statistical Notes, 5:

Cold Heading Quality (CHQ) - Rod suitable for cold heading, forging, or thread rolling, and meeting standard ASTM F2282.

Translation:

- "**Cold Heading**" is forming a head (hex bolt head, nail head) on a soft piece of rod or wire. You mechanically roll on threads, then heat treat the steel to make it very strong. Cold Heading steel is delivered to the bolt factory heat treated to make it very soft.

A Few Useful Definitions . . .

Ch. 72, Statistical Notes, 6:

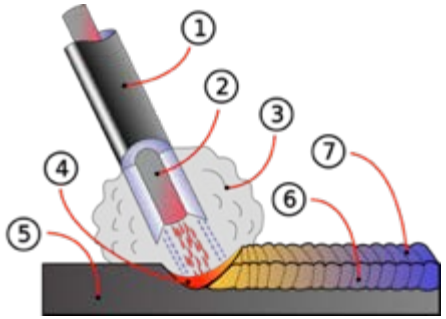
Welding quality wire rod - Rod measuring less than 10 mm in diameter having less than 0.2 percent carbon, less than 0.04 percent sulfur, and less than 0.04 percent phosphorus, suitable for drawing or rolling to final size for use as:

(i) an uncoated or plated or copper coated solid welding wire or rod;
(ii) the core wire or core rod for covered shielded metal arc ("SMAW") welding electrode, or
(iii) the formed jacket of a flux cored welding electrode that is suitable for consumption in the electric arc welding process.

Translation:

- Very clean, fairly low carbon steel rod that is used as filler in welding
- Apparently can be coiled or cut to length
- Can be bare or coated with various things

It's "2" in this picture



Ch. 72, Statistical Notes, 7:

For the purposes of statistical reporting number 7223.00.1005, the term "**spring round wire**" means wire suitable for the manufacture of springs and meeting ASTM standard A313

Translation:

- For a very specific HTSUS 10-digit code, it says that spring round wire MUST meet ASTM A313
- The standard says
  - Required chemistry, proscribed heat treatment, strength requirements, testing requirements
  - For **STAINLESS STEEL**

A Few Useful Definitions . . .

Some other terms found in the HTS that could use some clarification (in no order):

- **Hot rolled** – thinned in a rolling mill at high temperature
  - Cheaper to produce, not as strong
  - Synonym: "hot reduced" – reduced referring to the thickness

- **Cold rolled** – thinned in a rolling mill at low temperature
  - Considerably more expensive, stronger product
  - Synonym: "cold reduced"

- **Coiled** – rolled around itself into a cylinder (sheet) or bundle (rod or wire)
  - Coiling is done for ease of handling and for cheaper transport
  - Coils are un-coiled at the factory and feed the manufacturing equipment
  - HTSUS distinguishes between "rough" and other coils

- **Universal Mill Plate** – plate that is rolled both to thin AND on the sides to establish width

- **Electroslag or Vacuum Arc Remelted** – two ways to process steel that make a cleaner, and more expensive product

A Few Useful Definitions . . .

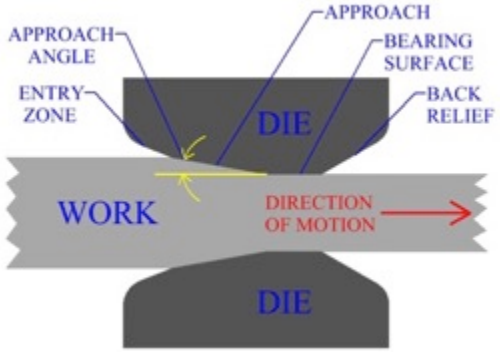
Some other terms found in the HTS that could use some clarification (in no order):

- **Non-alloy steel** – Steels containing only carbon and manganese
- **Galvanized** – Steel coated with Zn to protect against corrosion
- **Sheet Piling** – thick sheet formed for strength and used as retaining walls (below)
- **Pickling** – using acid to remove rust
- **Clad** – putting different metals as outer surfaces to change properties – ex plain steel clad with stainless for cheap corrosion resistant plates in nuclear plants

A Few Useful Definitions . . .

Some other terms found in the HTS that could use some clarification (in no order):

- **Trimmed** – cut to width with a clean, straight edge – helps in manufacturing
- **Hot drawn** – pulled to thin while the metal is hot
  - Not as strong
- **Cold drawn** – pulled to thin while the metal is cold
  - Stronger, more expensive



- **Extruded** – material pushed rather than pulled through die
  - Think Play-Doh Fun Factory
  - Always done hot, can do with steel but much more common with aluminum
- **Tire-Cord Quality** – steel with few if any inclusions (junk defects)
  - So that wire doesn't snap when drawn to tiny diameter
  - More expensive to manufacture
  - Used in steel belted radial tires

A Few Useful Definitions . . .

Some other terms found in the HTS that could use some clarification (in no order):

- **Grain-Oriented Electrical Steel** – specially processed silicon steel, particularly efficient in electrical transformers - more expensive

- **Tempered** – metal given a heat treatment (up and down, at specific heating and cooling rates) to create a microstructure with a particular set of mechanical properties
  - TRIVIA: "Lose your temper" comes from accidentally overheating a tempered cooking pan, ruining it. And making you mad.

- **Drilled** – making a hole with a drill bit (usually thick items)
- **Punched** – making a hole with a punch (usually thin items)
- **Notched** – making a hole on an edge of an item

- **Weight per length** – for complicated shapes with varying dimensions and thicknesses, the "size" is given often as "weight per length". This is very common in shipbuilding – hull plate is specified as "10 pound", which means 10 pounds per square foot, which means ¼" thick. Used because easier to judge weights for cranes.

A Few Useful Definitions . . .

Some other terms found in the HTS that could use some clarification (in no order):

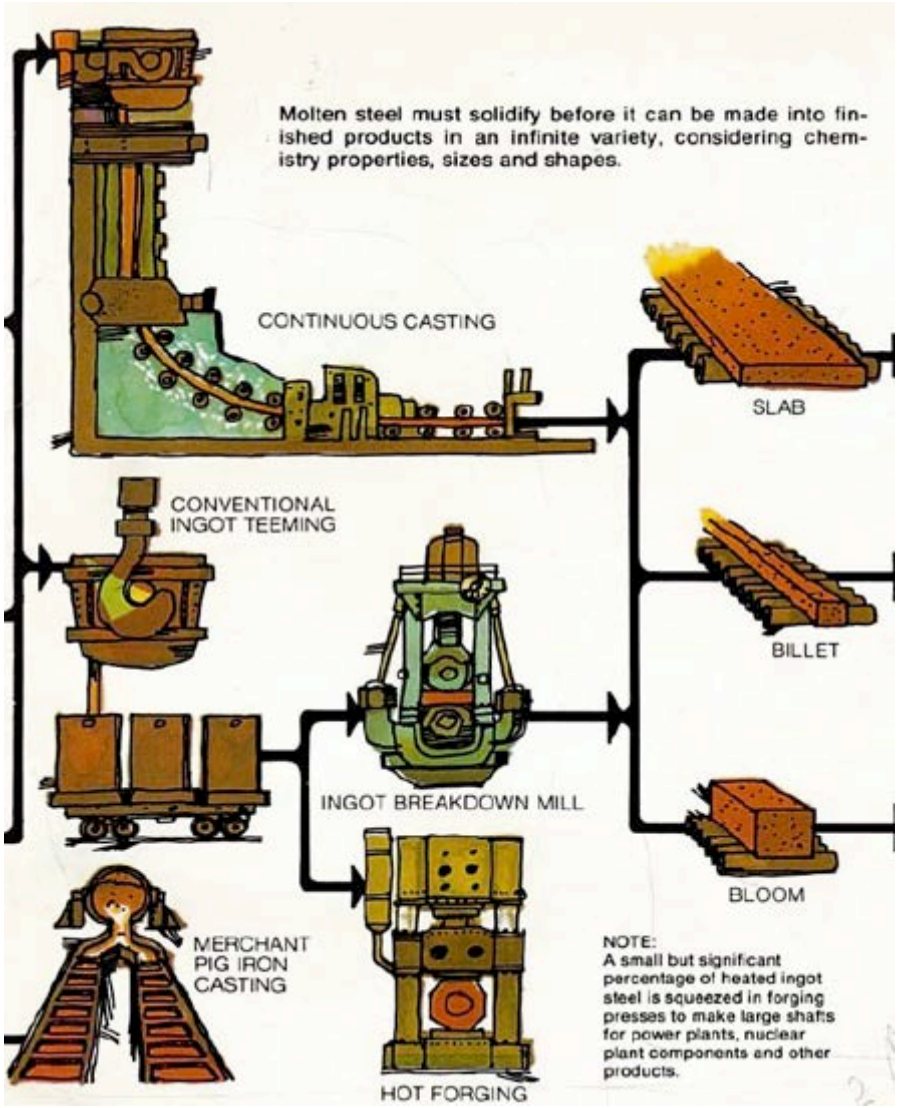
- **Seamless pipe** – not formed by welding a seam. Made by casting, piercing of tube rounds, or extrusion

- **OCTG (Oil Country Tubular Goods)**
  - **Seamless pipes**
    - **Casing pipe** – the outer pipe down a drill hole that keeps it from collapsing
    - **Drill pipe** – the high strength pipe onto which the drill bit is attached and turned – thick, strong
    - **Tubing pipe** – larger diameter and thinner, to collect oil from scattered wells in the field
  - **Pipeline pipe** – larger still, used for pipelines – ***seam welded***

- **Longitudinally welded** – welded along the long direction of the pipe
- **Circumfrentially welded** - welded around the circumference, for joining pipe sections together to make a pipeline

- **Tube rounds** – are formed by piercing a hot round rod with a mandrel, then expanding the opening. They are used to make seamless pipe of stronger steels.

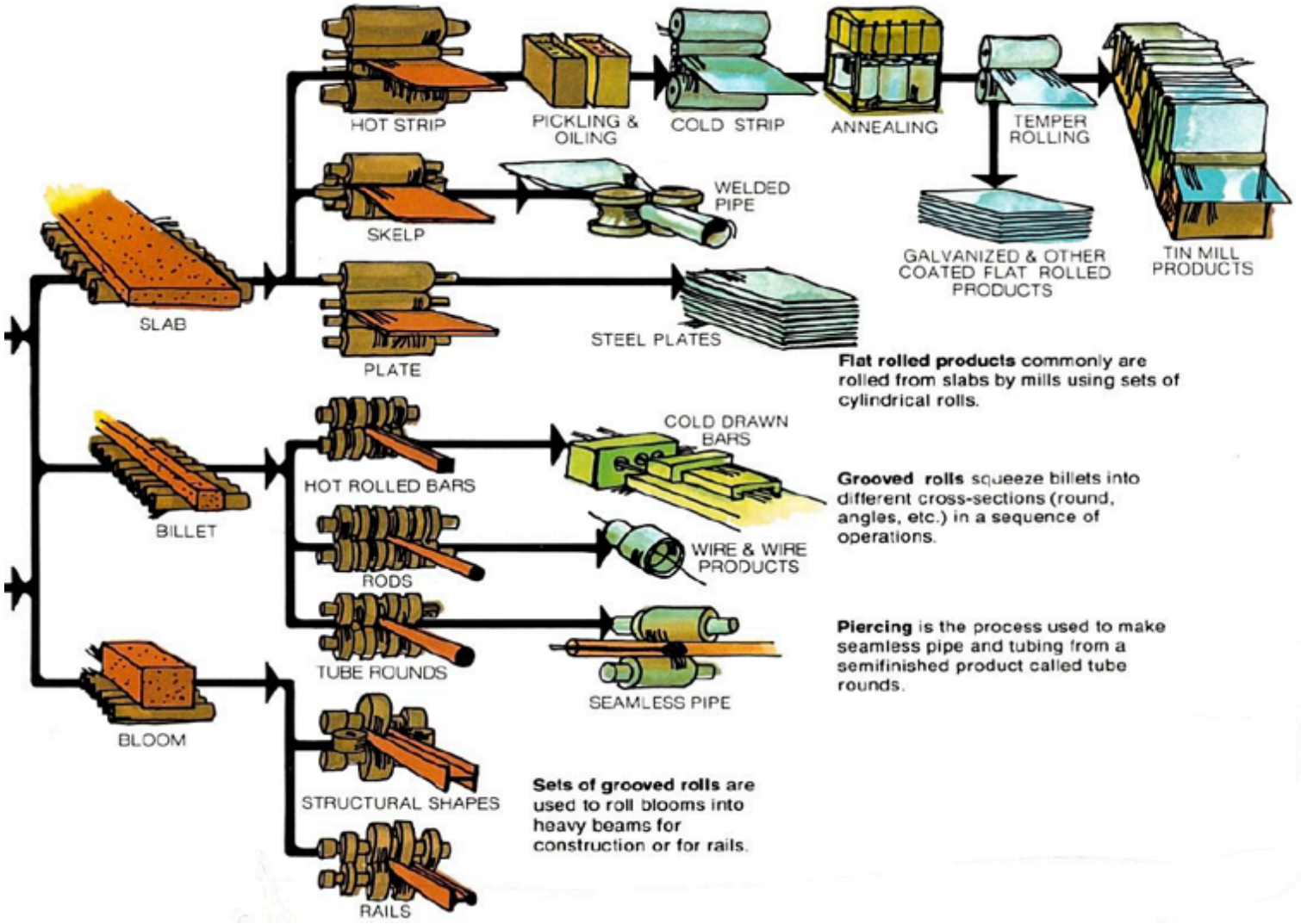
Semi-Finished Products



Chapter 72, Notes 1(ij): **Semi-finished products** - Continuous cast products of solid section, whether or not subjected to primary hot-rolling; and Other products of solid section, which have not been further worked than subjected to primary hot-rolling or roughly shaped by forging, including blanks for angles, shapes or sections. These products are not presented in coils.

Translation: A semi-finished product is anything that was either continuously cast (long, continuous bars and sheets) OR was produced as a single cast piece that has been lightly processed to get it ready for final processing (make it square, straight, or in a rough pre-shape ready to be finally forged into something). These products are too thick to be rolled into a coil. "Solid section" refer to the fact that the products don't have holes in them or are not tubes.

Finished Products



Finished Products

Finished products are actual products – sheet of the correct thickness or wire of the correct diameter to make something out of it without changing those dimensions

Ch. 72, Notes, 1(k):

Flat-rolled products - Rolled products of solid rectangular (other than square) cross section, which do not conform to the definition at (ij) above in the form of:

- coils of successively superimposed layers, or
  - This is a working definition of a coil – layers wrapped around themselves
- straight lengths, which if of a thickness less than 4.75 mm are of a width measuring at least 10 times the thickness or if of a thickness of 4.75 mm or more are of a width which exceeds 150 mm and measures at least twice the thickness.
  - Think cut sheets or plates
- Flat-rolled products include those with patterns in relief derived directly from rolling (for example, grooves, ribs, checkers, tears, buttons, lozenges) and those which have been perforated, corrugated or polished, provided that they do not thereby assume the character of articles or products of other headings.
  - The definition can include sheet or plate that has been textured (ex diamond plate), had holes punched in them, or polished AS LONG AS they do not themselves constitute some other product (like a mirror, for example)
- Flat-rolled products of a shape other than rectangular or square, of any size, are to be classified as products of a width of 600 mm or more, provided that they do not assume the character of articles or products of other headings.
  - If it isn't square or rectangular (say it's rounded), it gets a special definition

Finished Products

Ch. 72, Notes, 1(l):
Bars and rods, hot-rolled, in irregularly wound coils - Hot-rolled products in irregularly wound coils, which have a solid cross section in the shape of circles, segments of circles, ovals, rectangles (including squares), triangles or other convex polygons (including "flattened circles" and "modified rectangles", of which two opposite sides are convex arcs, the other two sides being straight, of equal length and parallel). These products may have indentations, ribs, grooves or other deformations produced during the rolling process (reinforcing bars and rods).

Translation: Fat rod in an ugly coil. This material is used as feedstock to make things like bolts, nails, reinforcing bars for concrete, etc. It can be smooth or have rebar ribs on it. It can have several cross-sectional shapes as described above, but it is solid and coiled (at least roughly).

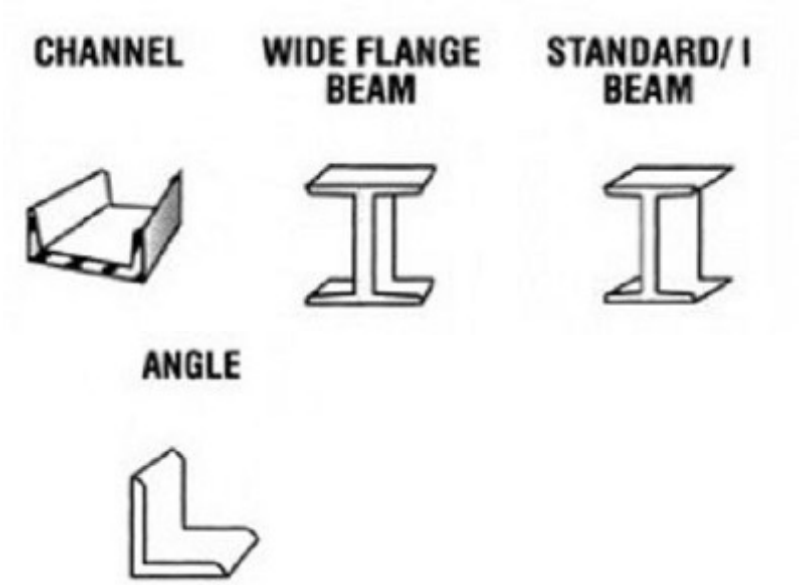
Ch. 72, Notes, 1(m):
Other bars and rods - Products which do not conform to any of the definitions at (ij), (k) or (l) above or to the definition of wire, which have a uniform solid cross section along their whole length in the shape of circles, segments of circles, ovals, rectangles (including squares), triangles or other convex polygons (including "flattened circles" and "modified rectangles", of which two opposite sides are convex arcs, the other two sides being straight, of equal length and parallel). These products may:
- have indentations, ribs, grooves or other deformations produced during the rolling process (reinforcing bars and rods); - be twisted after rolling.

Translation: Rod-like geometries not in an ugly coil. It appears to refer to, as an example, a coil above cut into lengths. It is defined by exclusion – if the product is a solid cross-section material that is not coiled AND NOT a finished sheet or plate AND NOT a semi-finished product, it belongs here.

Ch. 72, Notes, 1(n):
Angles, shapes and sections - Products having a uniform solid cross section along their whole length which do not conform to any of the definitions at (ij), (k), (l) or (m) above or to the definition of wire. Chapter 72 does not include products of heading 7301 or 7302

Translation: Long products like angle iron that aren't any of the solid or flat shapes previously defined. Below are some photos of products that belong in this definition:

These shapes are commonly called by what letter they look like: I, U, H, L, T



Ch. 72, Notes, 1(o):
Wire - Cold-formed products in coils, of any uniform solid cross section along their whole length, which do not conform to the definition of flat-rolled products.

Translation: Wire seems to differ from rod in (l) and (m) in that it has been "cold-formed". This means drawn through a die at room temperature to make it thinner and much stronger. Typically, rod is the starting material for wire. Then it has to be in a coil. Wire is defined in HTS Ch 73 Notes as less than 16 mm in diameter.

Steel HTSUS Ch 72 Classification Numbers

- Non-Alloy – Iron and Plain Carbon Steels
  - 7206 - Ingots
  - 7207 - Semifinished
  - 7208-7212 – Finished – flat rolled
  - 7213-7216 – Finished – long

- Stainless steel – Alloy steels containing, by weight 1.2 percent or less of carbon and 10.5 percent or more of chromium, with or without other elements.
  - 7218 – Ingots and Semi-finished
  - 7219-7220 – Flat rolled
  - 7221-7223 (long)

- Other Alloy
  - 7224 – Ingots and Semi-finished
  - 7225-7226 – Flat rolled
  - 7227-7229 - Long

Steel HTSUS Ch 73 Classification Numbers

7301	**Sheet piling for retaining walls**
7302	**Railroad pieces**
7303	**Cast Iron pipes - sewers**
7304	**Seamless Iron and Steel pipes – MANY MANY uses and types**
7305	**Large iron and steel pipes – gas pipelines**
7306	**Other tubes, pipes and hollow profiles – electrical conduit, etc**
7307	Pipe fittings – plumbing, gas, etc
7308	Prefab structures (not buildings) – bridge parts, towers, masts, etc
7309	Large unpressurized tanks and vats
7310	Small unpressurized tanks and vats – barrels, boxes, etc
7311	Compressed natural gas (CNG) and liquid natural gas (LNG) tanks
7312	Steel wire rope and cable
7313	Barbed and fencing wire
7314	Wire “cloth” – mesh, screen, conveyer belts, etc
7315	Chains
7316	Anchors and grappling hooks
7317	Nails, tacks, pins, staples
7318	Threaded fasteners – bolts, screws, nuts, washers, etc
7319	Sewing needles, crochet hooks, etc
7320	Springs
7321	Non-electric stoves, BBQs, grates, etc
7322	Non-electric radiators and air distribution systems (convective)
7323	Steel and iron kitchen stuff, including steel wool
7324	Sinks and bathtubs
7325	Manhole covers and accessories
7326	Other

Working Down the Table of HTS Ch. 72

7206 **Any Iron and steel cast into ingots** and not rolled or forged in any way

- The ingots can have lots of shapes – doesn't have to look like trapezoidal bar
- Can be pieces of ingots
- Companies buy to re-melt and cast themselves into smaller shapes

7207 **Semi-finished products** – slabs, bars, pre-forgings – of iron or nonalloy steel. Initially shaped but far from a finished product

- Can have several shapes
- Roughly shaped
- Companies buy to cut to length, roll or forge into rough products

Working Down the Table of HTS Ch. 72

7208 **Flat-rolled products** of iron or nonalloy steel, of a **width of 600 mm or more**, **hot-rolled**, not clad, plated or coated

- Iron or non-alloy: **no alloy or stainless steels**
- 600 mm wide or more: not narrow strips, wires, bars – wide plate and sheet
- **Hot** rolled – softer condition
- Not clad – no protective layer of other metals
- Not plated – no protective metal layer electroplated (ex not galvanized with Zn)
- Not coated – not painted. Not sure if this means no oil or grease?

7209 **Flat-rolled products** of iron or nonalloy steel, of a **width of 600 mm or more**, **cold-rolled**, not clad, plated or coated

- All of 7208, but **cold** rolled and thus stronger. Harder to make so more expensive

7210 **Flat-rolled products** of iron or nonalloy steel, of a **width of 600 mm or more**, **clad, plated or coated**

- All of aspects of 7208 and 7209, but additionally painted, plated or coated in some way
- Lots of different coatings, but most common is **galvanized** – put on a zinc film that corrodes in place of steel to protect it. Can be put on by electroplating or by dipping the steel in molten zinc.
- Other names include galvanneal, electro-galvanneal, electrogalvanized.

Working Down the Table of HTS Ch. 72

7211 Flat-rolled products of iron or nonalloy steel, of a width of **less** than 600 mm, not clad, plated or coated

- This is 7208 and 7209 aspects together, but for sheet and plate narrower than 600 mm. Note it doesn't distinguish between hot-rolled and cold-rolled for narrow stuff. That's likely because the cost difference is small.

7212 Flat-rolled products of iron or nonalloy steel, of a width of **less** than 600 mm, **clad, plated or coated**

- This is 7211 plus a coating

7213 **Bars and rods, hot-rolled**, in irregularly wound coils, of iron or nonalloy steel

- Continuous rod of iron or plain steel roughly wound into a coil, as previously described. Used to make re-bar, cheaper bolts, nails, wire etc.

7214 **Other bars and rods of iron or nonalloy steel**, not further worked than forged, hot-rolled, hot-drawn or hot-extruded, but including those twisted after rolling

- Essentially, the continuous coil from 7213 but **chopped up into individual bars.** No further work is allowed other than chopping, but they can be twisted at some point in the process.

Working Down the Table of HTS Ch. 72

7215 Other bars and rods of iron or nonalloy steel

- You could call this “other” for iron and plain steel solid shape rods and bars
- Free-machining is under this one

7216 Angles, shapes and sections of iron or nonalloy steel

- Now iron or plain steel, but they come out of equipment not as a solid shape but a more complicated one (U, H, I, T, L cross sectional shapes)
- Sub-sections depend on dimensions of various thicknesses of shape
- Some sub-sections refer to material hot processed out of rolling mill, drawing die or extruder
- Some sub-sections refer to material made into a shape by cold rolling them from a flat sheet (like bending to make an “L”)
- Some sub-sections refer to first hot processing, THEN cold processing
- You need to know something about how the shape was made to select the right designation

Working Down the Table of HTS Ch. 72

7217 **Wire** of iron or nonalloy steel

- Wires made from plain iron or plain steel
- Used for binding, to make cheap cables, other things (cheap)
- Shapes include flat and round
- Heat treated or not (to change the strength)
- Four main sections on coatings: none, zinc (galvanized), other metal, plastic

7218 **Stainless steel** in ingots or other primary forms; semi-finished products of stainless steel

- Now shift gears to stainless steel
- Lumps ingots and semi-finished together (were separate for iron and plain steel)

7219 **Flat-rolled products of stainless steel**, of a width of 600 mm or **more**, not further worked than hot rolled, in coils

- Coils of wide stainless steel as they emerged from the first rolling mill
- Sorted by dimensions (thickness, width), chemistry
- LOTS of sub categories, because stainless steel is expensive and cost varies a lot with alloying and processing

Working Down the Table of HTS Ch. 72

7220 **Flat-rolled products of stainless steel**, of a width of **less** than 600 mm, not further worked than hot rolled

- **Narrow stainless steel** as they emerged from the first rolling mill
- Does not need to be coils
- Sorted by dimensions (thickness, width), chemistry
- LOTS of sub categories, because stainless steel is expensive and cost varies a lot with alloying and processing

7221 **Bars and rods**, hot-rolled, in irregularly wound **coils**, of **stainless steel**

- Thick continuous rods for making stainless steel bolts and other long objects
- Also feed wire for stainless wire drawing, can be cut into steel wool

7222 **Other** bars and rods of **stainless steel**; angles, shapes and sections of stainless steel: Bars and rods, not further worked than hot-rolled, hot-drawn or extruded

- This seems to lump together solid rod cut into individual bars AND stainless steel shapes like I, H, T, L, U

7223 Wire of stainless steel

- Fairly self explanatory

Working Down the Table of HTS Ch. 72

7224 **Other alloy steel in ingots or other primary forms**; semi-finished products of other alloy steel

- "Other" seems to mean "not stainless steel"
- There are a LOT of "other alloy steels"
- Ingots, slabs, continuous and cut rough bars, rough forgings
- Breaks out by chemistry and a little by shape

7225 **Flat-rolled products of other alloy steel**, of a width of 600 mm or **more**

- Wide finished plate or sheet
- Breaks out specific alloy steels like electrical and tool for special treatment
- In this category, 98% of alloy steels will be in "other" someplace
- Coiling doesn't apply

7226 **Flat-rolled products of other alloy steel**, of a width of **less** than 600 mm

- Narrow finished plate or sheet
- Breaks out specific alloy steels like electrical and tool for special treatment
- In this category, 98% of alloy steels will be in "other" someplace
- Coiling doesn't apply

Working Down the Table of HTS Ch. 72

7227 Bars and rods, hot-rolled, in irregularly **wound coils**, of **other alloy steel**

- Continuous rod in an ugly cool, this time of alloy steel (not iron, not plain steel, not stainless essentially)
- Used to make high strength bolts for construction, racing engines, cheap cutting tools, precursor bars for forging hand tools and other strong steel items

7228 **Other bars and rods of other alloy steel;** angles, shapes and sections, of other alloy steel; hollow drill bars and rods, of alloy or non-alloy steel

- Non-solid shapes of alloy steels
- ALSO hollow drill bars and rods, but they can be non-alloy steel
  - Drill bar/rod – used to make drills like you use in your garage
  - NOT drill pipe used for oil drilling
- Kind of a catch-all for alloy steel, plus drill bars for some reason

7229 Wire of other alloy steel

- Wire made from alloy steel – that is to say not iron, plain steel, or stainless

Working Down the Table of HTS Ch. 73

7301 **Sheet piling** of iron or steel, whether or not drilled, punched or made from assembled elements; welded angles, shapes and sections, of iron or steel

- Components to make sunken retaining walls, previously defined

7302 **Railway or tramway track construction material of iron or steel**, the following: rails, check-rails and rack rails, switch blades, crossing frogs, point rods and other crossing pieces, sleepers (cross-ties), fish-plates, chairs, chair wedges, sole plates (base plates), rail clips, bedplates, ties and other material specialized for jointing or fixing rails

- All the pieces you need to build a railway

7303 **Tubes, pipes and hollow profiles, of cast iron**

- The notes here define cast iron as having **carbon over 2%**
- Sewer pipe, drain pipes

7304 **Tubes, pipes and hollow profiles, seamless, of iron (other than cast iron) or steel**

- Pipes made from ANY type of steel but not cast iron
- Used in petrochemical, chemical, food, bio industries
- HUGE category
- Broken down by steel chemistry, geometry, usage, even end fittings
- Seamless – not welded from a curved plate. Cast or extruded steel.

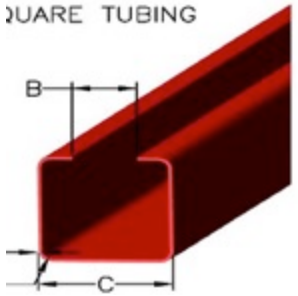
Working Down the Table of HTS Ch. 73

7305 **Other tubes and pipes** (for example, welded, riveted or similarly closed), having circular cross sections, the external diameter of which **exceeds 406.4 mm**, of iron or steel

- Large pipes that are not seamless, but held together with longitudinal (along the length) welds or other fasteners
- Used in oil and gas pipelines

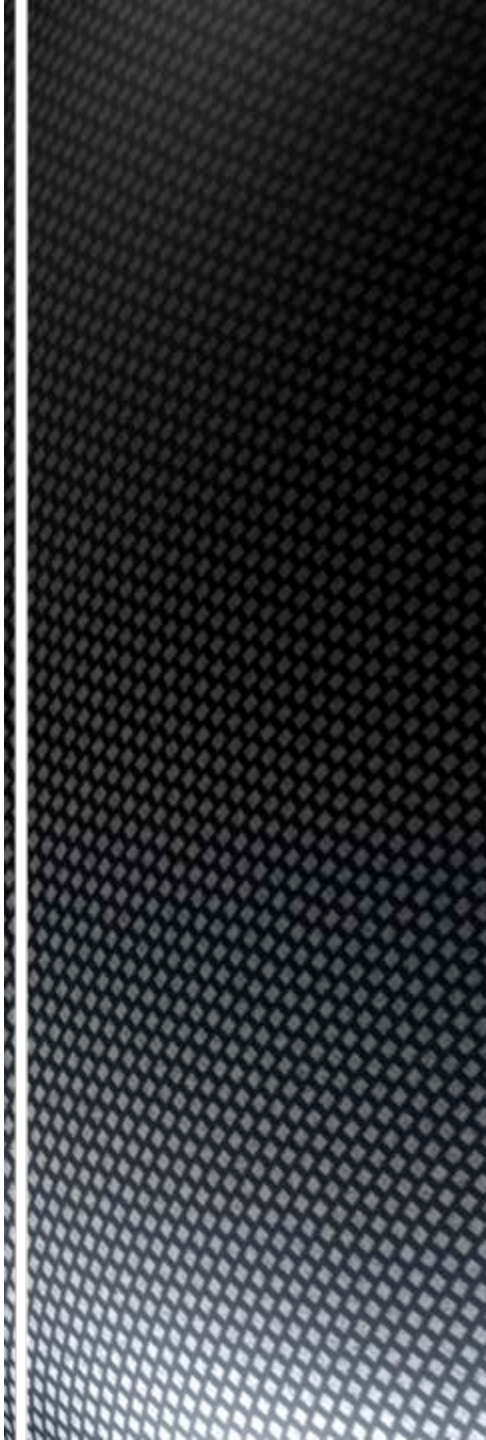
7306 **Other tubes, pipes and hollow profiles** (for example, open seamed or welded, riveted or similarly closed), of iron or steel

- A catch-all for thinner pipes – open seamed means it has an opening along one side - conduit



Let's take a 5 minute break

Aluminum Overview from HTS Chapter 76



Outline

- Description of the Various Alloys of Aluminum and Their Uses
- Walking Through HTS Chapter 76: Aluminum and Articles Thereof

NOTE: This training relies on the definitions in the training for iron and steel Chapters 72 and 73 for shapes, etc.

Aluminum Alloys

- Compared to steel chemistry, aluminum is much simpler
- Relatively few elements are in aluminum alloys
- Only aluminum crystals, plus particles in the microstructure
- Most aluminum alloys are 90+% Al
- Strengths can range from extremely soft to a medium strength steel
- Aluminum can be processed in many of the same ways as steel
- Only certain alloys can be heat treated to increase strength
  - These are the more expensive ones

Aluminum Alloys

1XXX series – Commercially-pure aluminum (99+% Al)

- Excellent thermal and electrical conductor
- Uses:
  - 1100: disposable aluminum cooking pans
  - 1145, 1199: aluminum foil
  - 1350, 1370: Power transmission lines

2XXX series – Aluminum + Copper

- Can be heat treated to very high strengths, decent toughness
- Atmospheric corrosion a problem – typically clad with 1XXX or 6XXX
- Uses:
  - 2014, 2024: skins on jet airliners
  - 2195: Space Shuttle and Space-X external fuel tanks
  - 2519: Layered lightweight armor plate on jet fighters

3XXX series – Aluminum + Manganese + Magnesium (almost pure Al)

- Very ductile, can be shaped very thin and intricately
- Uses:
  - 3003, 3004: the sides of beverage cans

Aluminum Alloys

4XXX – Aluminum – Silicon

- Uncommonly used as wrought product, high Si levels used as casting
- Casting alloys have 3 digits (ex. A356) – are more brittle than wrought
- Corrosion resistant
- Uses:
  - Cast aluminum housings on engine parts, statues
  - 4017: Cooking utensils, truck bodies, signage, outdoor stuff

5XXX – Aluminum – Magnesium – Manganese

- Jack of all trades, cheaper, strong-ish aluminum
- Not heat treatable
- Uses:
  - 5052, 5083, 5086: boat hulls and fittings, welding rod
  - 5754: automotive frame components, bumpers

6XXX – Aluminum – Silicon – Magnesium – Manganes

- Strong, heat treatable, ductile, versatile
- Uses:
  - 6022: automotive frame and skin components
  - 6061: boats and canoes
  - 6463: extruded ladders

Aluminum Alloys

7XXX – Aluminum – Zinc – Magnesium – Copper

- The strongest aluminum alloy
- Heat treatable, extrudable, weldable
- Uses:
  - 7005 – high strength extruded shapes (bikes)
  - 7039 – armor on fighter planes
  - 7068 – strongest alloy – military aircraft structures, guns
  - 7075 – Boats, car parts, bikes, M-16s, Leki trekking poles
  - Special 7XXX – iPhone case

8XXX – Aluminum – Iron – Other

- Mostly developmental/prototype alloys
- Uses:
  - 8090: Has lithium, 8% less dense than aluminum, aerospace
  - 8176: High strength wires

Aluminum End Uses

Table 4: World consumption of aluminum wrought products by major end-use sectors, 2015

End-use sector	1,000 mt	Percent
Construction	20,515	34
Electrical	10,185	17
Transport	7,318	12
Packaging	6,200	10
Foil stock	6,172	10
Machinery and equipment	5,475	9
Consumer durables	2,404	4
Other	1,252	2
Total	59,522	100

Source: CRU Group and USITC Pub 4703 (June 2017) at App L page 589.

A Walk Through HTS Chapter 76

Some Definitions:

- In this chapter, they refer to "**profiles**" – in steel they were called "shapes"
  - L, I, T, H, U cross-sections on finished products
- Flat stock has been described as plate and sheet. Now we add "**foil**"
- **Unalloyed Aluminum** - Aluminum with no more than 1% (iron plus silicon), up to 0.1% of Cr, Mg, Mn, Ni, Zn, and up to 0.2% Cu
  - Iron and Silicon are hard to remove from aluminum
- **Aluminum Alloy** – basically unalloyed Al plus more additions
  - At least 1% of something besides Fe and Si
- **Aluminum wire** is defined as no bigger than 6mm in diameter
  - Steel is 16 mm
- **"Aluminum Can Stock"** is defined chemically as having magnesium as the main alloying addition, and prescribes the thickness
  - The strengths of the can body and lid are given

A Walk Through HTS Chapter 76

7601 – Unwrought aluminum

- This is aluminum that has been cast into bars and slabs
- Breaks out alloyed versus not alloyed

7602 – Aluminum Waste and Scrap

- Includes beverage cans
- Aluminum waste from manufacturing typically kept sorted by alloy – makes it MUCH easier to recycle
  - Aluminum alloys VERY hard to clean during recycling, unlike steel

7603 – Aluminum Powders and Flakes

- Flakes are made by rolling powder – less inhalation hazard than powder
- "Lamellar structure" means flakes

7604 – Aluminum Bars, Rods and Profiles

- Unlike steel, all shapes and profiles lumped together
- It refers to "hollow profiles", but "tubes" are in a different section

A Walk Through HTS Chapter 76

7605 – Aluminum Wire

- Unalloyed and alloyed
- Conflict: says “wires” of over 7mm, which conflicts with notes definition of “wire”

7606 – Aluminum plates, sheets and strips, of thickness exceeding 0.2 mm

- Essentially, anything that is flat but not foil
- Includes special callout for “circles and discs”

7607 – Aluminum foil

- Appears to include foil-covered paper packaging material
- Also capacitor foils – used in microelectronic devices

7608 – Aluminum Tubes and Pipes

- Both seamless (extruded) and “other” (bent and welded or crimped)

7609 – Aluminum Tube Fittings

- Elbows, T-junctions, valves, etc

A Walk Through HTS Chapter 76

7616.99.51.60 – Other articles of aluminum - Castings

- This is a deceptively large sub-sub-sub category
- Can be engine blocks, Bundt pan unfinished castings, lots of different rough, unfinished castings
- Keywords to look for: aluminum casting(s), rough aluminum castings, unfinished aluminum castings

7616.99.51.70 – Other articles of aluminum – Forgings

- Again, rough forgings of aluminum
- Automotive wheels, rotor rough forgings
- Keywords to look for: aluminum forging(s), rough aluminum forgings, unfinished aluminum forgings

I thought it would be helpful to walk through reading a CURRENT submission . . .

(b) (5), (b) (4)

(b) (4), (b) (5)

(b) (4), (b) (5)

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