Stainless Steel (S. St)

- Steel alloy that is highly resistance to Corrosion in a variety of environments.
- Alloysing elements (Cr > 11%, Ni, Mo, Al, Cu, Si, Cb).

\[
\text{Cr} + \text{O}_2 \rightarrow \text{Cr}_2\text{O}_3 \quad \{\text{Stable oxide film} \quad \text{thin} \quad \text{adherent}\}
\]

Serves to protect (insulate) the surface from further corrosion reaction (Oxidation) this process is referred as (Passivation).

**Classification of Stainless Steel:**

<table>
<thead>
<tr>
<th>No.</th>
<th>Stainless St. Type</th>
<th>%C</th>
<th>%Mn</th>
<th>%Cr</th>
<th>%Ni</th>
<th>%Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Austenitic S. St (γ. S. St.)</td>
<td>&lt; 0.25</td>
<td>&lt; 10</td>
<td>11 - 24</td>
<td>3 - 22</td>
<td>Mo, Ti, Si, Nb</td>
</tr>
<tr>
<td>2</td>
<td>Martensitic S. St (M. S. St)</td>
<td>&lt; 0.2</td>
<td>&lt; 1</td>
<td>11 – 18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Ferritic S. St. (α. S. St.)</td>
<td>&lt; 0.2</td>
<td>&lt; 1</td>
<td>14 – 27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Precipitation Hardening S. St.</td>
<td>&lt; 0.12</td>
<td>&lt; 0.75</td>
<td>15 - 17</td>
<td>4 – 10.5</td>
<td>Si (0.4 – 0.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Al (1.15)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cu (3.6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cb (0.25)</td>
</tr>
</tbody>
</table>
# System Identify Stainless Steel:

<table>
<thead>
<tr>
<th>No.</th>
<th>Series Designation</th>
<th>Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2XX</td>
<td>γ. S. St. (Cr – Ni – Mn) non - hardenable, non – magnetic.</td>
</tr>
<tr>
<td>2</td>
<td>3XX</td>
<td>γ. S. St. (Cr – Ni) non - hardenable, non – magnetic.</td>
</tr>
<tr>
<td>3</td>
<td>4XX</td>
<td>M. S. St. (Cr) hardenable + magnetic.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>α. S. St. (Cr) non - hardenable + magnetic.</td>
</tr>
<tr>
<td>4</td>
<td>5XX</td>
<td>(Cr + low c) heat resisting.</td>
</tr>
</tbody>
</table>
Stainless Steel (S. St)

Austenitic Stainless Steel (γ. S. St):

- Steel alloy that is highly resistant to Corrosion in a variety of environments.
- The alloying elements are (Ni + Cr) > 23%.
- They are not hardenable by H. T, they may be C. W to develop a wide range of T. S (ex. 350,000 psi).
- The Phase diagram is illustrated in fig. (28).

Fig. (28) Fe – Cr – Ni (Ternary Phase diagram)
Stainless Steel (S. St)

Austenitic Stainless Steel (γ. S. St):

- Type (302, 304, 316) are the basic alloys. They are susceptible to inter-granular corrosion (along the grain boundaries, this attack can take place when (α. S. St) sensitized by heating at °T (427 – 871) for sufficient period of time....... 

During this process: Cr – Carbide precipitate at the grain boundaries depleting the Cr content (concentration in the matrix (Cr < 12%).

- The remedies are:

  1. Using lower %C (C < 0.02%).
  2. Using such element have stronger Carbide – forming tendency than Cr (Mo, Ti).
  3. By solution treatment (thermal treatment) called Stabilization treatment consist of:

     a. Heating to a °T (1000 - 1150 °C for a period of time sufficient to dissolve Car bide.
     b. Cooling rapidly (Quenching).
Stainless Steel (S. St)

Ferritic Stainless Steel (α. S. St):

- They don’t respond to Heat Treatment because these alloys are Ferritic.
- Type (405, 430, 446) are the most type of (α. S. St.).
- Fig. (29) shows phase diagram which indicate that these steels fall outside (γ) loop.
- They are magnetic & can be C.W & H.W.
- The strength of (α. S. St) is 50% higher than Carbon St. if they are in the annealed condition.

Fig. (29) Fe – Cr Phase diagram
Stainless Steel (S. St)

Ferritic Stainless Steel (α. S. St):

- Heat Treatment of (α. S. St.) is annealing to relieve welding and C. W stresses:
  - They annealed at \( \theta T > 850 < \theta T \) at which (γ) is formed.
  - They are not tempered since:
    - a – The amount of (M) formed are negligible.
    - b – Because of possible embrittlement.
    - c – Cooled slowly.

Martensitic Stainless Steel (M. S. St):

- Types (410, 416) are the most popular alloys, they are used for turbine blade.
- They are magnetic, can be C. W and are easily H. W., their corrosion resistance are < (α & γ S. St.).
Stainless Steel (S. St)

Martensitic Stainless Steel (M. S. St):

- **Heat Treatment of (M. S. St.):**
  - Heating above transformation range **1850 oF**.
  - Cooling in air or oil.
  - Time at °T is held to a min. to prevent:
    - a – The decarburization.
    - b – Grain growth.

- Tempering of these alloys should not be done in the range *(750 – 950)* °F because of drop in impact strength so it is usually done above **1100 °F** which is the higher Temp. cause reduction in corrosion resistance.

- Alloys type *(501, 502)* have excellent resistance to oxidation and better corrosion resistance than ordinary steel.

- These steels hardened by oil Quenching, their mechanical properties are really intermediate between *[Cr – Steel & M. S. St.]*, they have used for Petroleum refining equipments.
Stainless Steel (S. St)

Precipitation hardening Stainless Steel (PH. S. St):

- They are utilized in applications that require:
  a) High strength.
  b) Corrosion resistance < (γ. S. St.).

- They are made either Martensitic
  by varying Cr/Ni ratio:
  Austenitic

  Semiaustenite

Cr: Ferritic stabilizer.
Ni: Austenite (γ) stabilizer.

If Cr/Ni ratio
Austenitic Condition.

If Cr/Ni ratio
Martensitic Condition.
Precipitation hardening Stainless Steel (PH. S. St):

- Addition of (Al, Cu, Ti, Mo) → Precipitation Hardening.
- Heat Treatment for (ex. Alloy 17 – 7 ph. S. St) as following:
  - # Solution treated at about 1050 °C → dissolve coarse precipitates + obtain uniform (γ) solid solution.
  - # Cooled rapidly (Quench) to RT → supersaturated solid solution.
  - # Aging at 510 °C → fine, inter-metallic compound which strengthen the steel ($\sigma_T = 200 - 300 \times 10^{-3}$ psi).