Case Studies

Corrosion of a Stainless Steel Water Filter After Welding

Background

- Water filter made of a perforated tube with a diameter of 200 mm
- End of tube welded to a short screwed section
- Used to couple the filter to a length of ordinary non-perforated pipe
- Components made from AISI 304 stainless steel

Background

- Perforated tube made by assembling a tubular cage of steel rods and welding the ends of each rod to a screwed coupling
- A helix of steel wire was then wound around the outside of the cage to complete the perforated wall
- Wire fixed to the support rods by electrical resistance spot welding
- An extra weld made on the outside of the coupling
- Weld and adjoining helix levelled by grinding

Background

- Filters transported to their destination by sea
- When unloaded noticed that some of the repair welds had corroded
- Thin uniform layer of red rust apparent on weld bead and parts of helix which had been ground flat
- Does the steel have the correct composition?

Schematic of water-filter

Exterior view

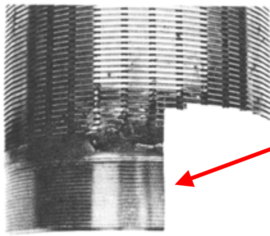


FIG 24.1 Exterior view of part of the water filter.

Perforated tube

Short screwed section

Interior view

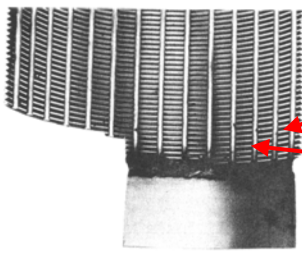


FIG 24.2 Interior view of part of the water filter.

Steel wire wound around cage

Steel rods

Schematic of water-filter

Exterior view

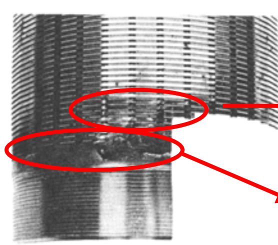


FIG 24.1 Exterior view of part of the water filter.

Rusting apparent on helix which had been ground flat

Rusting apparent on weld around outside of the coupling

Interior view

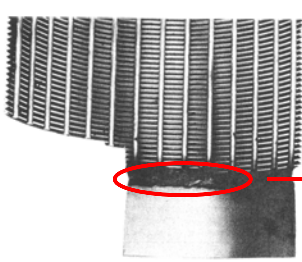


FIG 24.2 Interior view of part of the water filter.

Rusting in HAZ seen as a thin dark line on inside of coupling

Relative permeability measurements (304)

Reduction in thickness $(t_o-t)/t_o$	Vickers hardness, HV	Relative permeability for H = 4000 A/m	Relative permeabiltiy for H=16000 A/m
0	175	1.0037	1.0040
0.14	218	1.0048	1.0050
0.32	315	1.0371	1.062
0.65	390	1.540	2.120
0.85	437	2.200	4.750

Chemical composition of 304

Element	AISI 304
Carbon	0.08 max
Silicon	0.75/1.00 max
Manganese	2.00 max
Sulphur	0.03 max
Phosphorus	0.045 max
Chromium	18.0-20.0
Molybdenum	-
Nickel	8.0-10.5
Titanium	-
Niobium	-

Shaeffler diagram

Cr equivalent = Cr + Mo + 1.5Si + 0.5 Nb

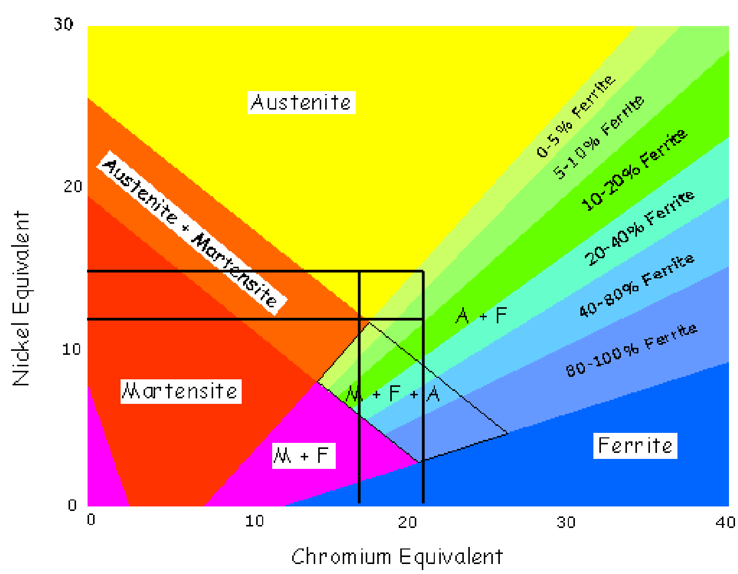
18 – 21.5

Ni equivalent = Ni + 30C + 0.5 Mn

11.4 – 13.9

Bottom of austenite field

Shaeffler diagram



Depending on precise composition
304 could be unstable at room
Temperature

Cold work could trigger a displacive
Transformation where some of the
austenite forms martensite

Testing samples from filter

Component	Vickers hardness, HV	Magnetic attraction
Coupling	180	Very weak
Rod/wire	350	Weak
Rod/wire	430	Strong

→ filter austenite and martensite

Did filter experience weld decay?

- Stainless steels held in the temperature range 550 to 850°C
- Carbon reacts with chromium to produce chromium carbides ($Cr_{23}C_6$)
- ppt at grain boundaries and reduce the concentration of dissolved Cr
- Composition of steel 0.03-0.04 %C

Kinetics of sensitization

Wt % C in steel	Temp. (°C) for fastest sensitization	Sensitization time (min)
0.08	800	0.5
0.06	730	2
0.05	660	10
0.04	620	60
0.03	600	600

Why did filter corrode?

When filters unloaded from containers, running with condensation

Film of condensed water saturated with air and Cl ions

Ideal solution for corrosion

Why did filter corrode?

During welding high temperature oxide forms – High temperature oxides offer less corrosion protection

Corrosion occurred at main attachment weld

Solution: Remove oxide with a pickling solution of nitric and hydrofluoric acids

Produces clean surface which can passivate in air naturally

Why did filter corrode?

What about outside of filter where the oxide layer had been ground off?

Rough cold worked surface produced by grinding is more liable to corrode than a smooth stress-free one

Solution: Stainless steel required for critical applications is often cleaned through "electroploishing"

Dissolves away cold worked layer