

Prevention of the Material Degradation of Boilers

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In refineries , boilers are the important component for supply of power and steam. In the worst case, shutdown of steam and power system can results in emergency shutdown of the refining plants.

During emergency shutdown, flare gas is released and the inner oil is drained out. This will increase CO₂ emission from flare and the bad odor from the drained oil.

It is very important to improve reliability of boilers for the preservation of the environment as well as plant safety.

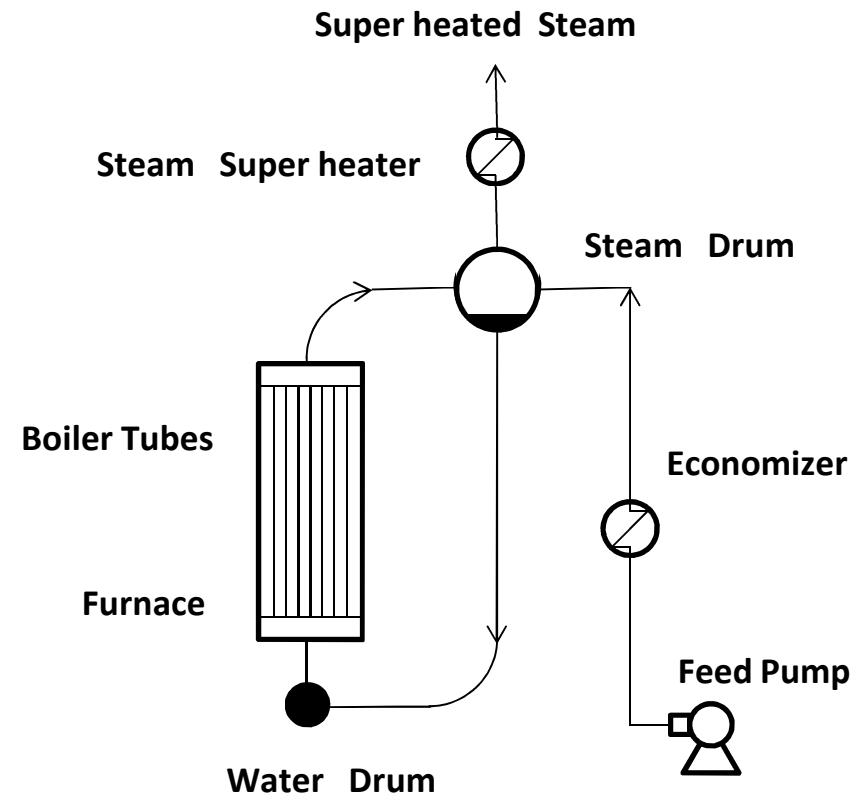
Introduction

A circulation boiler consists of a drum and many water tubes .

The feed water pump increases the pressure of the boiler feedwater.

Then, an economizer exchanges heat up the feedwater temperature with exhaust gas. The boiler water is injected into a steam drum, guided to boiler tubes through a downcomer, and steam is generated.

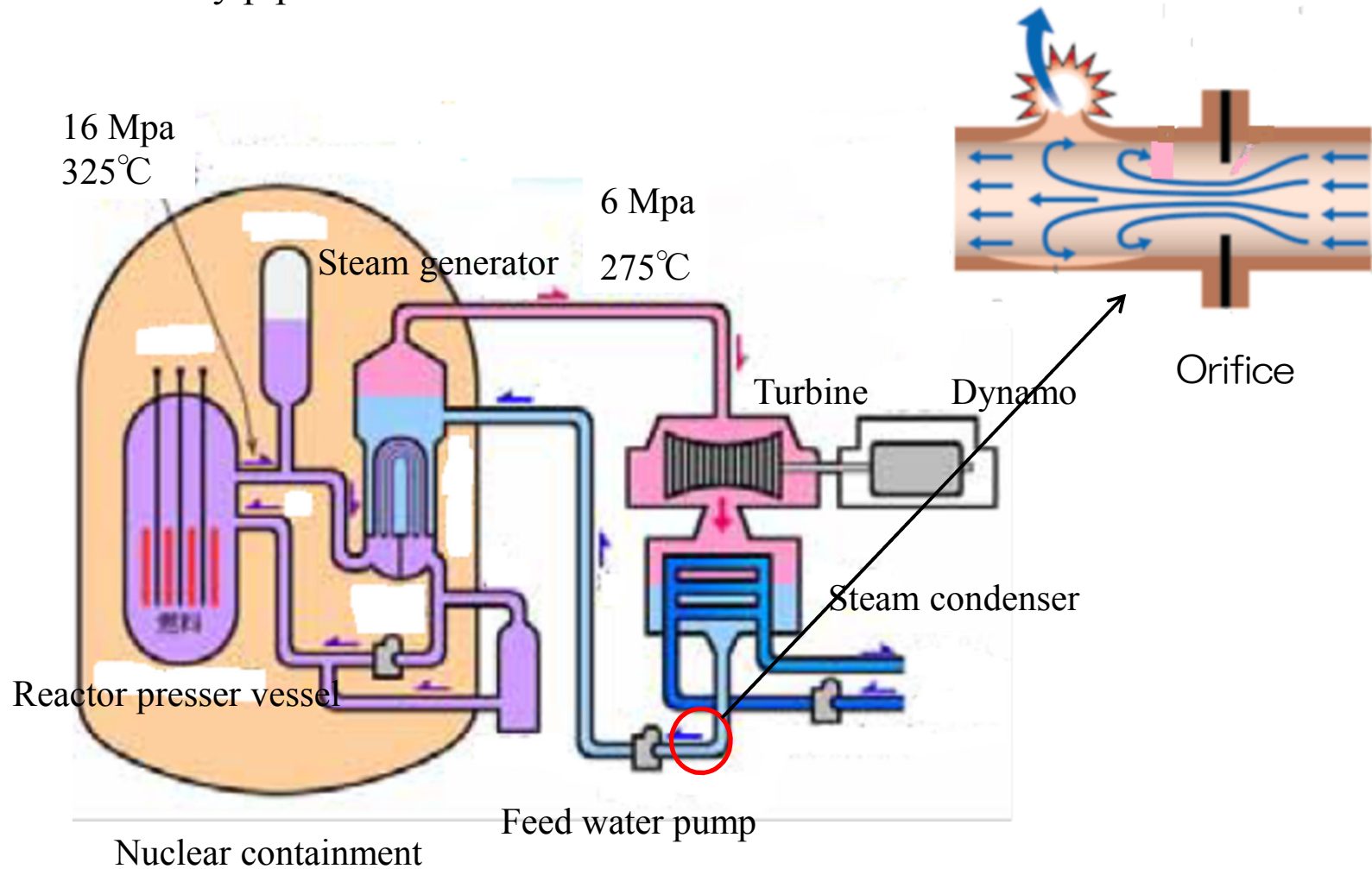
The generated steam is separated into steam and mist in a steam drum, and the steam becomes superheated steam in a super heater.



schematic illustration of water circulation in a boiler

What is FAC ?

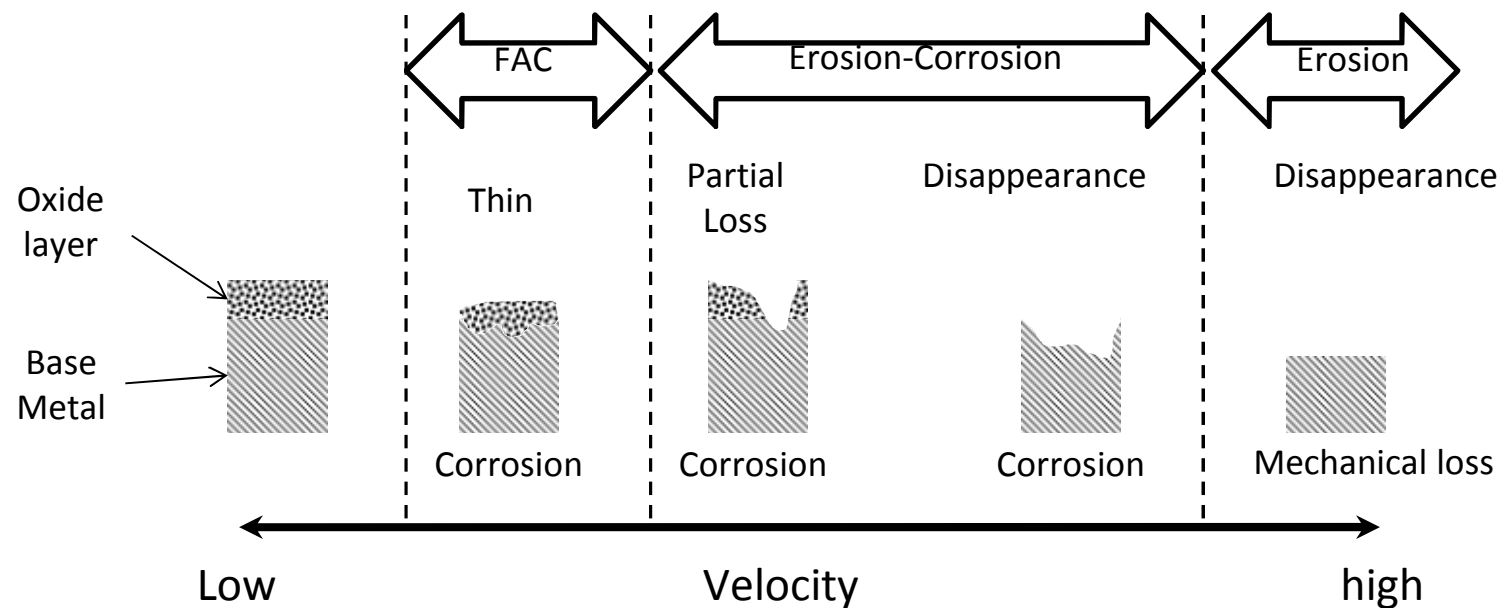
Significant piping failures caused by flow-accelerated corrosion (FAC)
at unit 3 secondary pipe of Mihama Power Station in 2004.



What is FAC ?

FAC is the chemical dissolution of surface oxide and metal. There are no physical or microstructural changes in steel.

- ☐ Static or low velocity : The oxide layer is stable and Corrosion rate is low.
- ☐ High velocity : The oxide layer is removed mechanically. Extend and location of oxide layer removal can be changed as increasing velocity.
- ☐ FAC: As increasing velocity, the corrosion rate increases. Because the diffusion speed of the ferric ion increases and the corrosion reaction is promoted.



Relationship between Velocity and Damages

What is FAC ?

FAC is affected by many factors..

pH: The corrosion rate decreases as the PH increases.

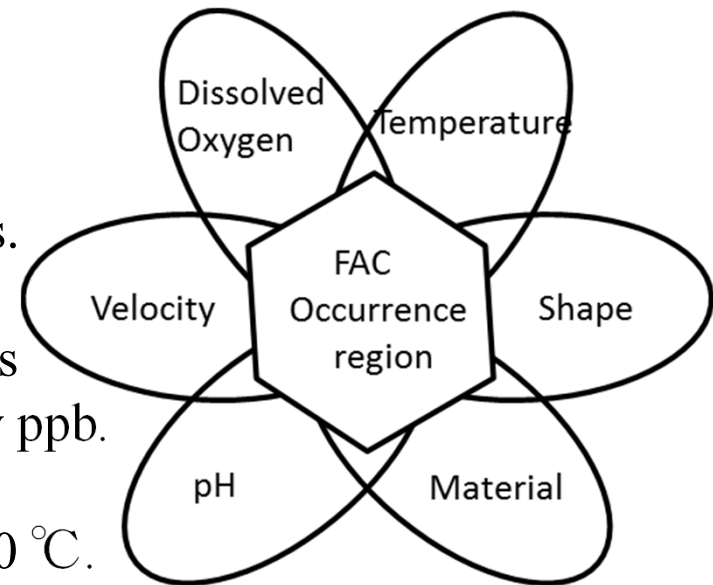
Dissolved oxygen (DO): The corrosion rate increases when DO becomes less than a few ppb.

Temperature: The corrosion rate is maximized at 150 °C.

Material: The corrosion rate decreases as the Cr content increases.

Velocity: Corrosion rate increases as the flow rate increases.

Shape: Corrosion rate increases depending on piping geometry
Corrosion rate increases in areas of turbulent flows.



Experience of FAC damage

In shutdown inspection, the localized thinning found BFW piping.

① Operating Conditions

Temperature: 165 °C

Pressure: 16.14 MPa

Velocity : 4.1 m/s

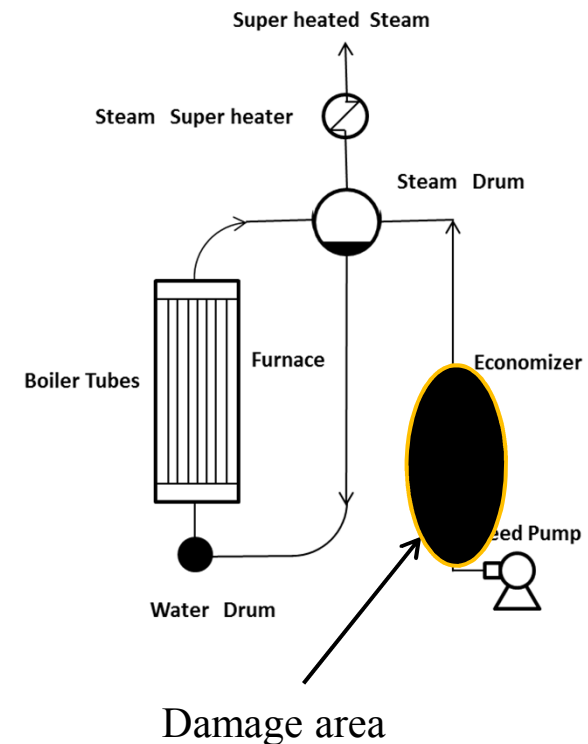
② Material & Others

Material : Carbon steel(ASTM A106Gr.B)

Damage Location : From feed pump to
outlet of economizer

Pipe Diameter : 8 inches

Thickness : 23 mm



Experience of FAC damage

(1) Visual observation of damaged piping

- Reddish scales are observed in some spots inside of the elbows.
- Thickness of the Reddish scale areas were thinner than the black area.
- Tiger skin stripe pattern was observed there.



Sample elbow



Color changed area of inside piping



Enlarged view

Experience of FAC damage

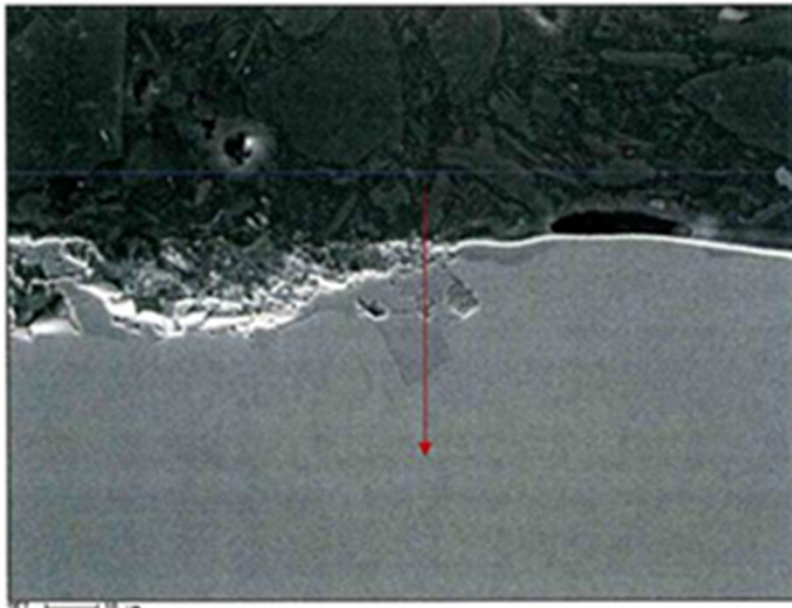
(2) Destructive test of piping

① Microscopic observation of cross section

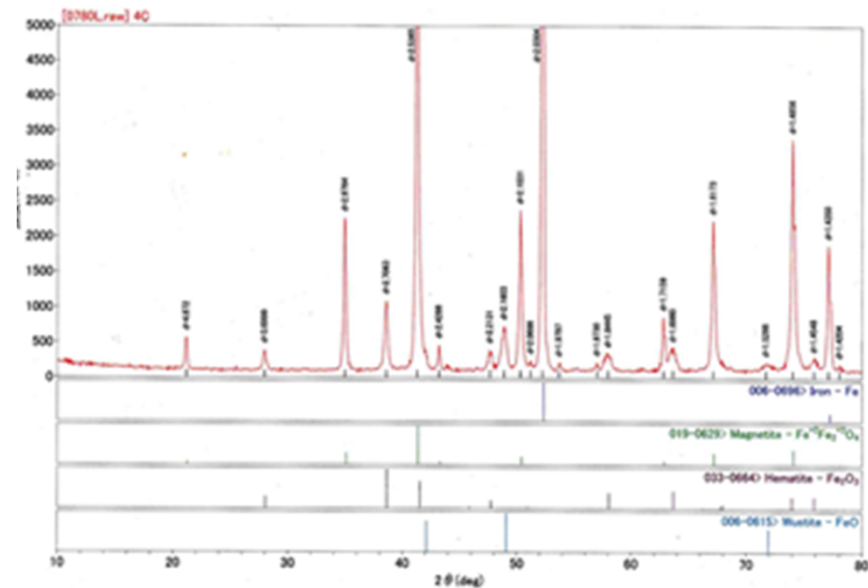
The thin oxide layer was observed on the surface of base metal.

② X-ray diffraction pattern analysis

The scales are consist of magnetite(Fe_3O_4), Hematite (Fe_2O_3) and Wustite (FeO).



Cross section of damage pipe

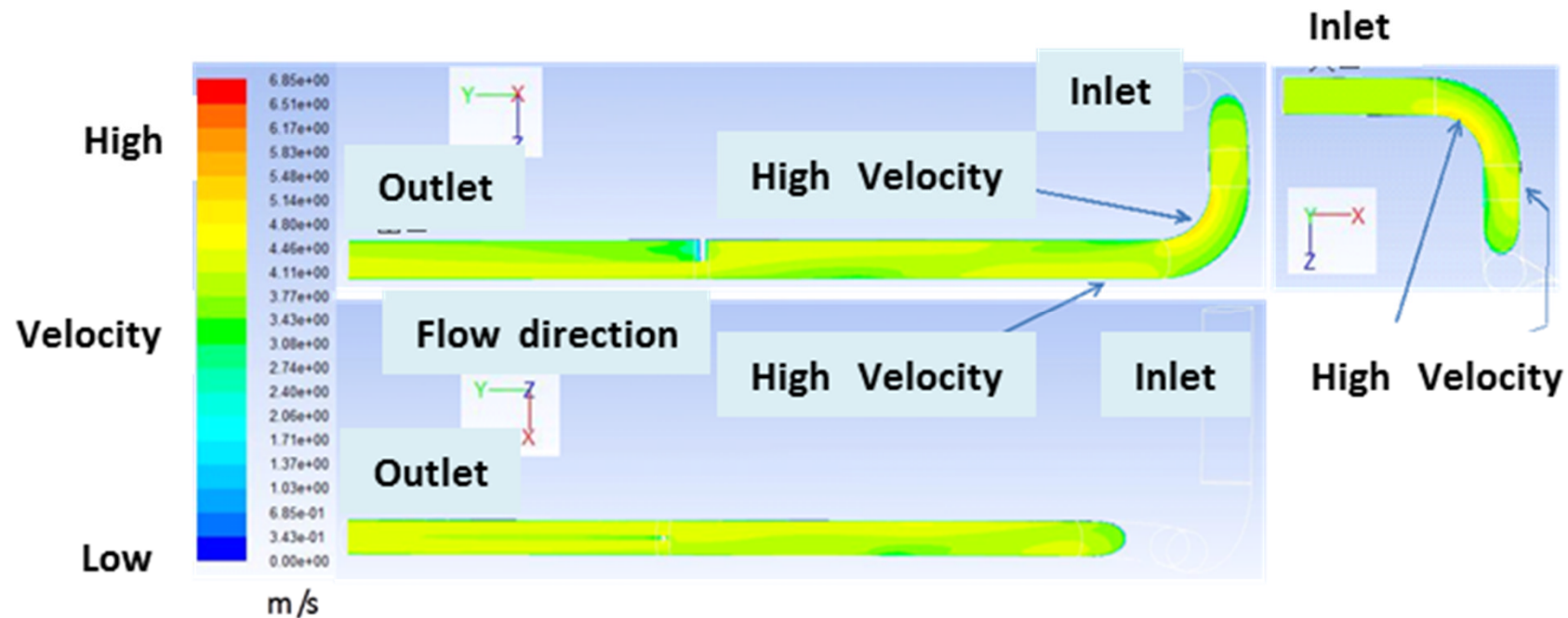


Result of X-ray diffraction

③ Analysis of flow

Recently the capability of steam generation was increased up to about 10%.

The average velocity of the boiler feedwater was 4.1 m/s, it reaches 5 m/s in some spots. The velocity is high in elbows.

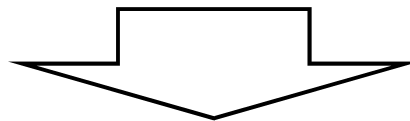


Result of the computation fluid dynamics

There are several measures against FAC.

- Temperature changes
- Velocity
- Material

⋮



difficult to take all measures

Two factors in BFW quality are changed to prevent FAC.

	pH	Do
Before	$8.5 < \text{pH}$	$< 7 \text{ ppb}$
After	$9.0 < \text{pH}$	a few ppb

1. It is important to periodically inspect and keep track of conditions of facilities.
2. The FAC can be caused by slight changes in operating conditions by increasing the capability of steam generation.
3. Fortunately, the thickness reduction was found in an early phase, and the prevention measures were implemented in our unit.
The system is properly operating today.
4. It is important to prevent these problems proactively before they occur.