



Water Hammer at San Onofre

Section 7.3

What is Water Hammer?

A pressure transient which creates fluid shock waves in piping systems due to changes in fluid velocity or pressure.



Learning Objective 1

Describe three types of water hammer and their causes.

Learning Objective 2

Describe corrective actions that were taken to prevent previous steam generator water hammer problems.

Learning Objective 3

Describe the damage caused by the water hammer event at San Onofre Nuclear Generating Station Unit 1 (SONGS-1).

Learning Objective 4

Describe how multiple check valve failures contributed to the initiation of the water hammer at SONGS-1.

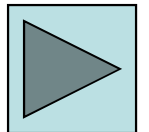
Learning Objective 5

Discuss how check valve testing required by the American Society of Mechanical Engineers Boiler and Pressure Vessel code could have prevented the SONGS-1 water hammer incident.

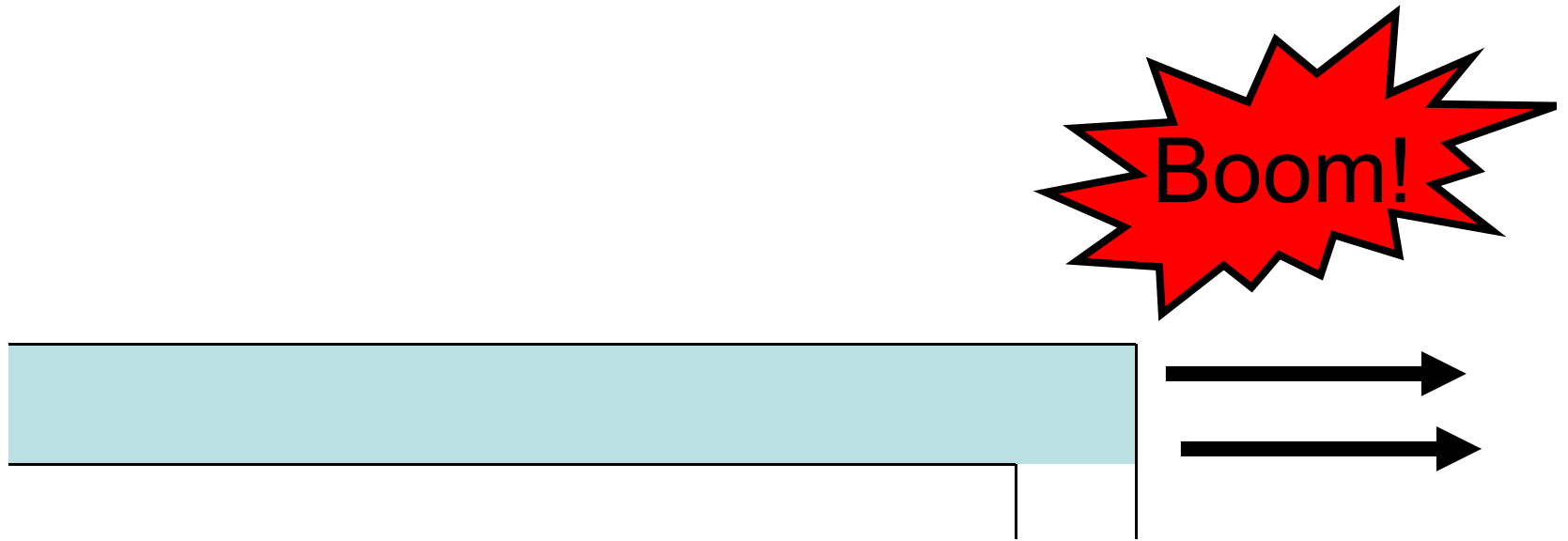
Types of Water Hammer

(Section 7.3.2)

- Classical water hammer
- Condensation induced water hammer
- Steam Generator water hammer

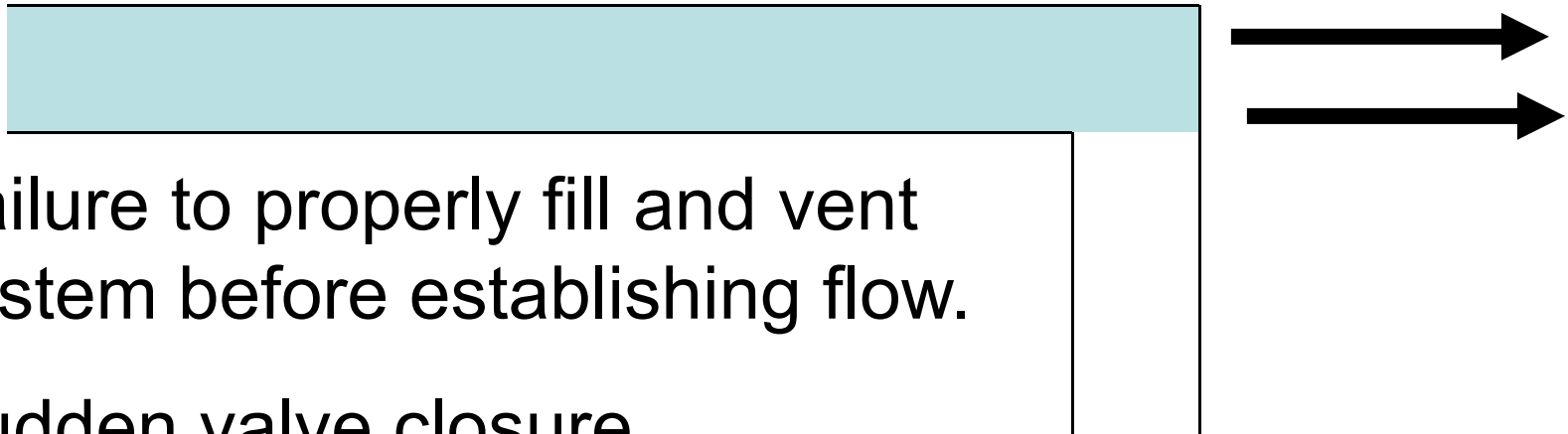


Classical Water Hammer



- ❖ Generally a shock wave created by a moving fluid column suddenly stopping. Usually accompanied by noise.

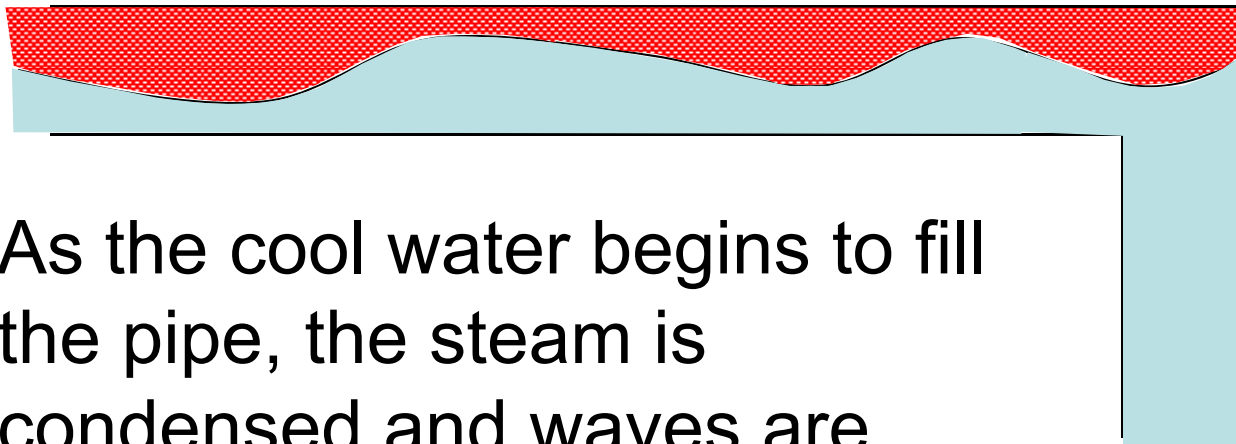
Classical Water Hammer - Common Causes



- ❖ Failure to properly fill and vent system before establishing flow.
- ❖ Sudden valve closure.

Condensation-induced Water Hammer

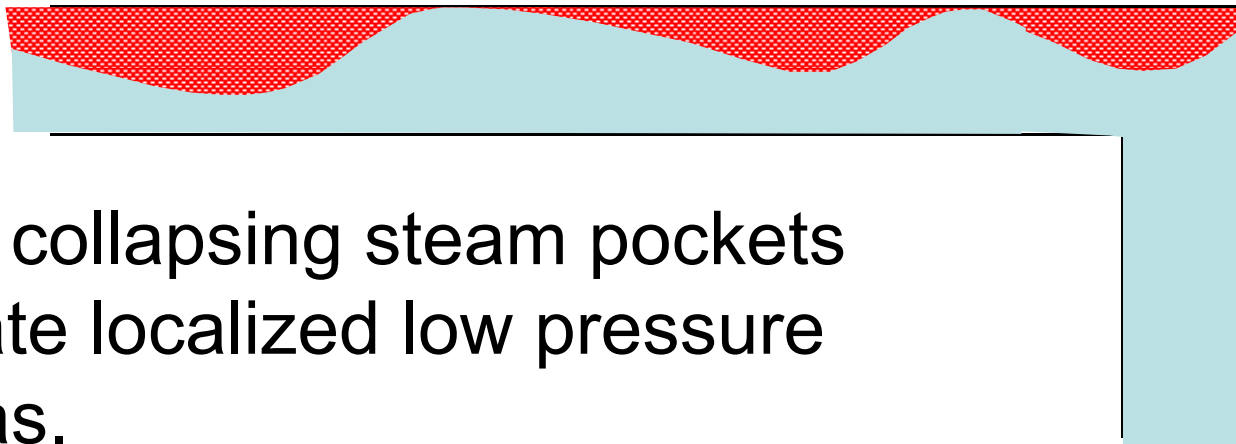
- ❖ Begins w/ a long horizontal steam filled pipe being filled by relatively cool water (AFW).



- ❖ As the cool water begins to fill the pipe, the steam is condensed and waves are formed.

Condensation-induced Water Hammer

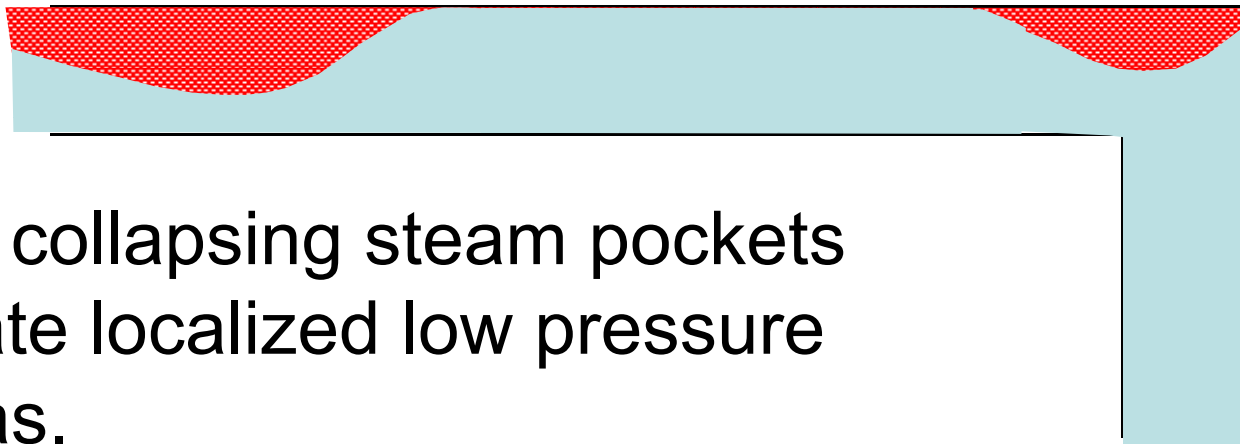
As the water level & waves increase, a volume of steam can be trapped, where it will condense rapidly.



The collapsing steam pockets create localized low pressure areas.

Slugs of water accelerate towards the low pressure areas.

Condensation-induced Water Hammer



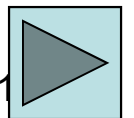
The collapsing steam pockets create localized low pressure areas.

Slugs of water accelerate towards the low pressure areas.

S/G Water Hammer is condensation-induced water hammer in a feedwater line.

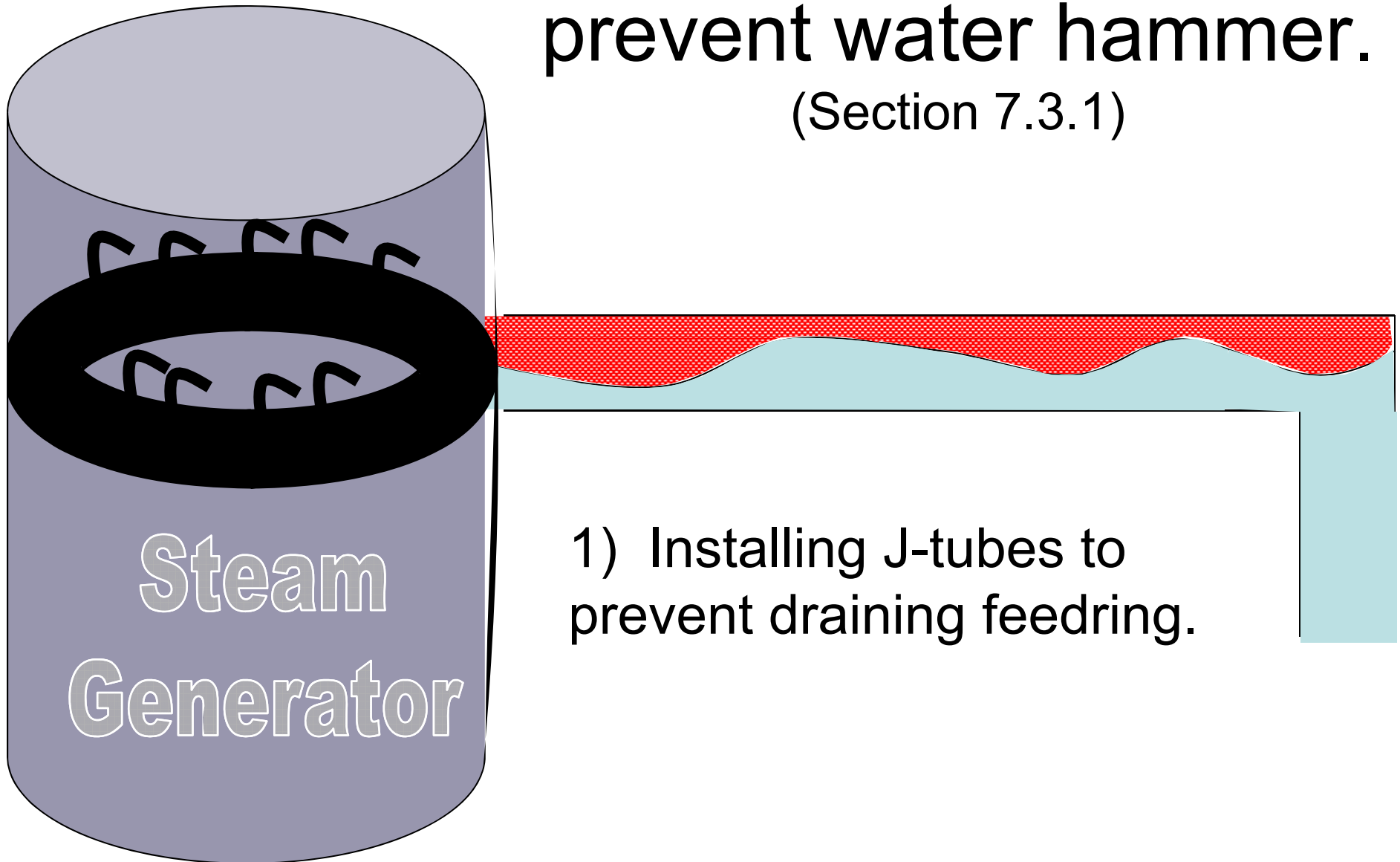
Causes are generally the

Damage is generally in S/G feedring and its supports, the FW nozzle, and FW piping snubbers & supports.



3 Modifications to prevent water hammer.

(Section 7.3.1)

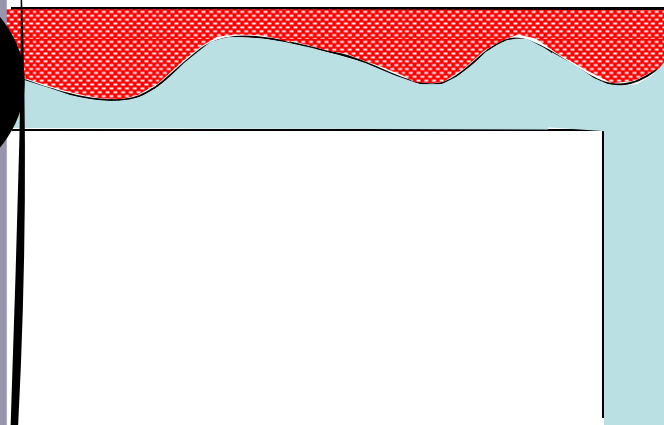
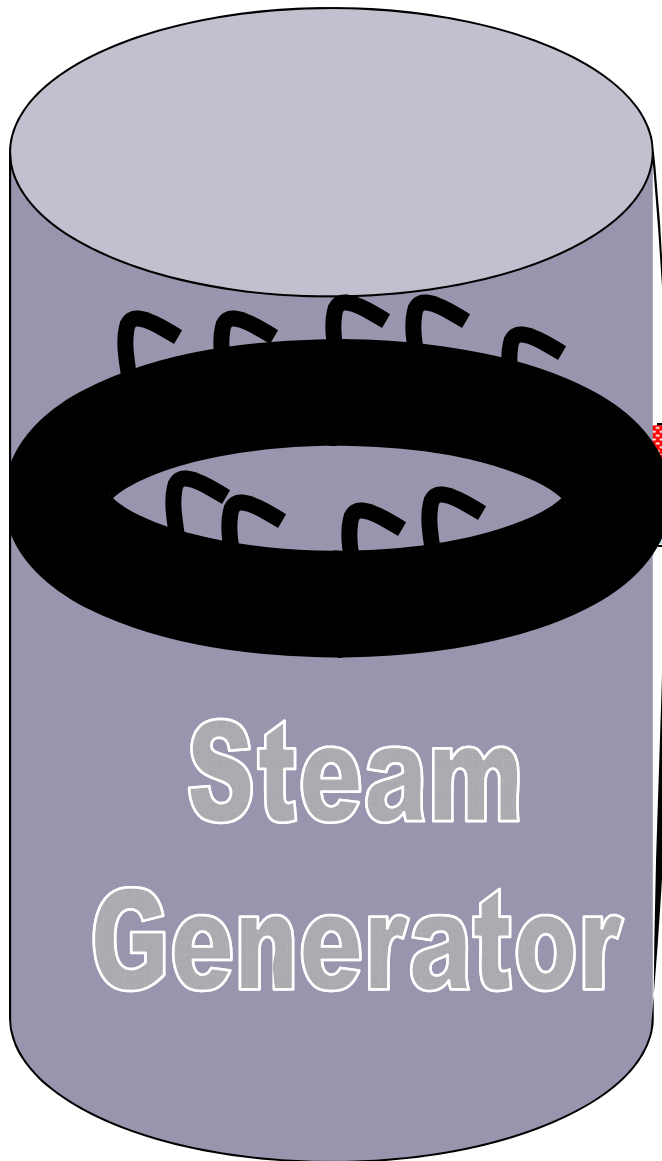


- 1) Installing J-tubes to prevent draining feedring.

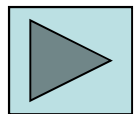
3 Modifications to prevent water hammer.

(continued)

2) Shorten Horizontal runs of FW piping adjacent to S/Gs.

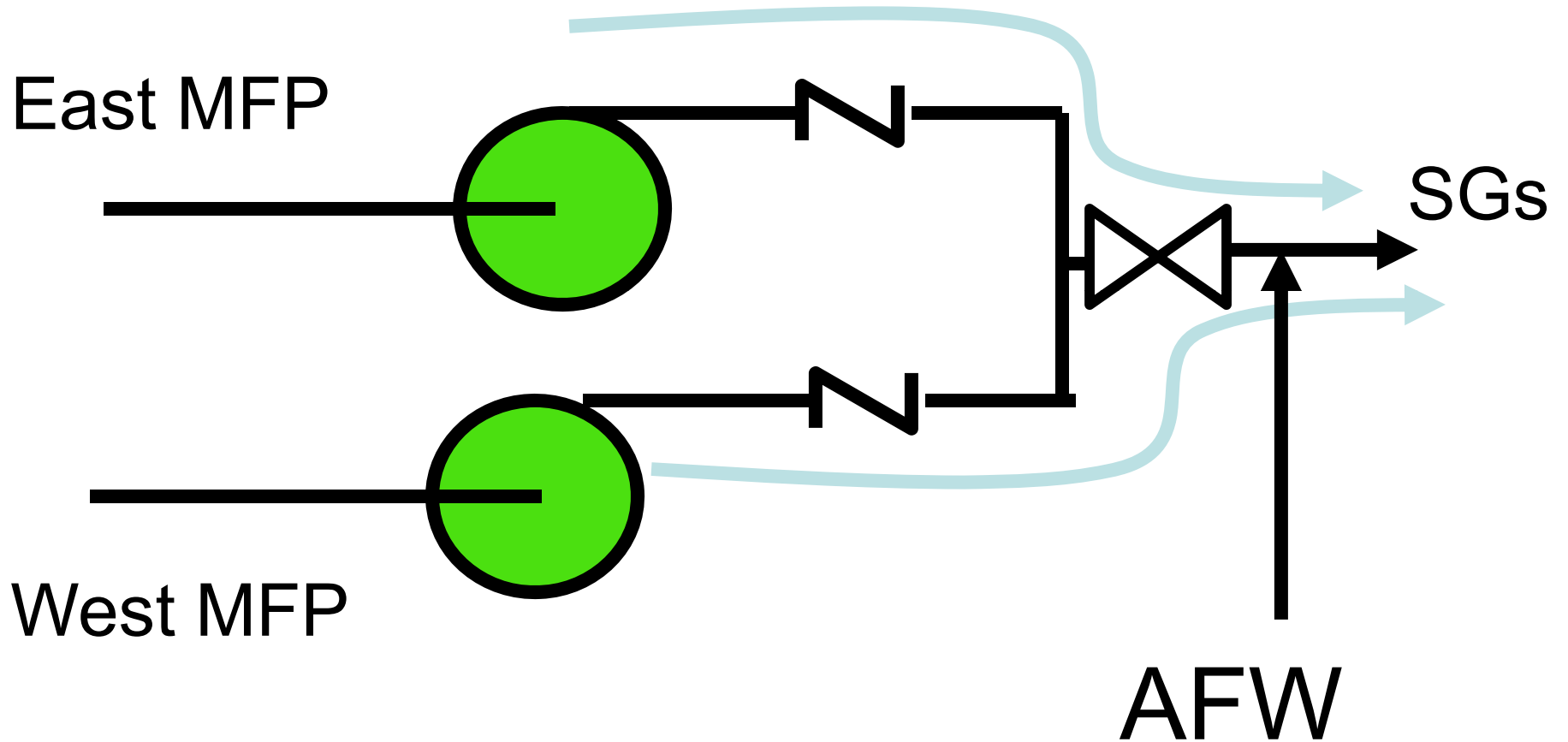


3) Limit AFW flow to avoid rapid refill of horizontal runs of FW piping.

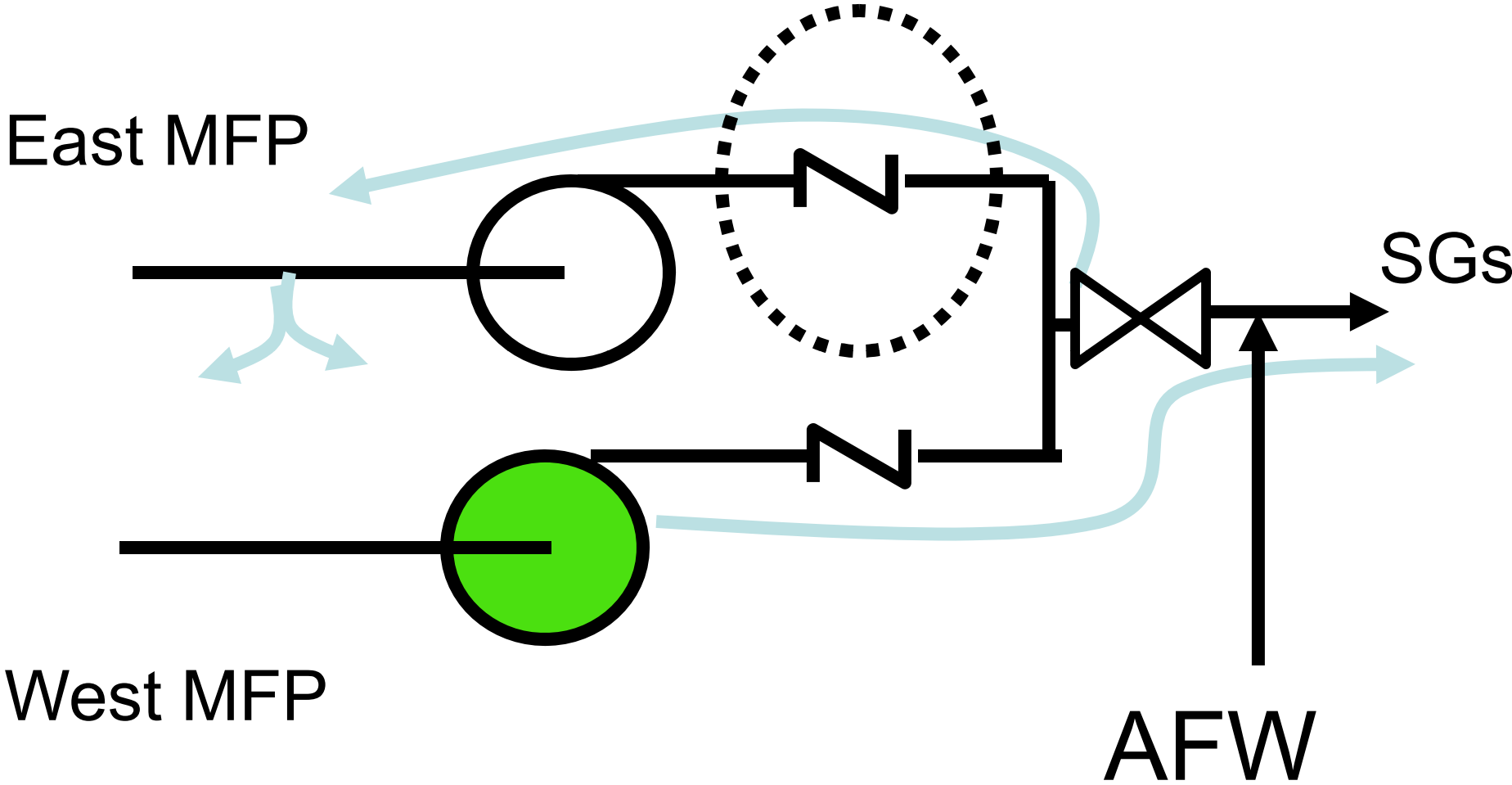


SONGS –1 Water Hammer

(Sections 7.3.3 & 7.3.4)



E-MFP lost due to Aux Transformer problem.

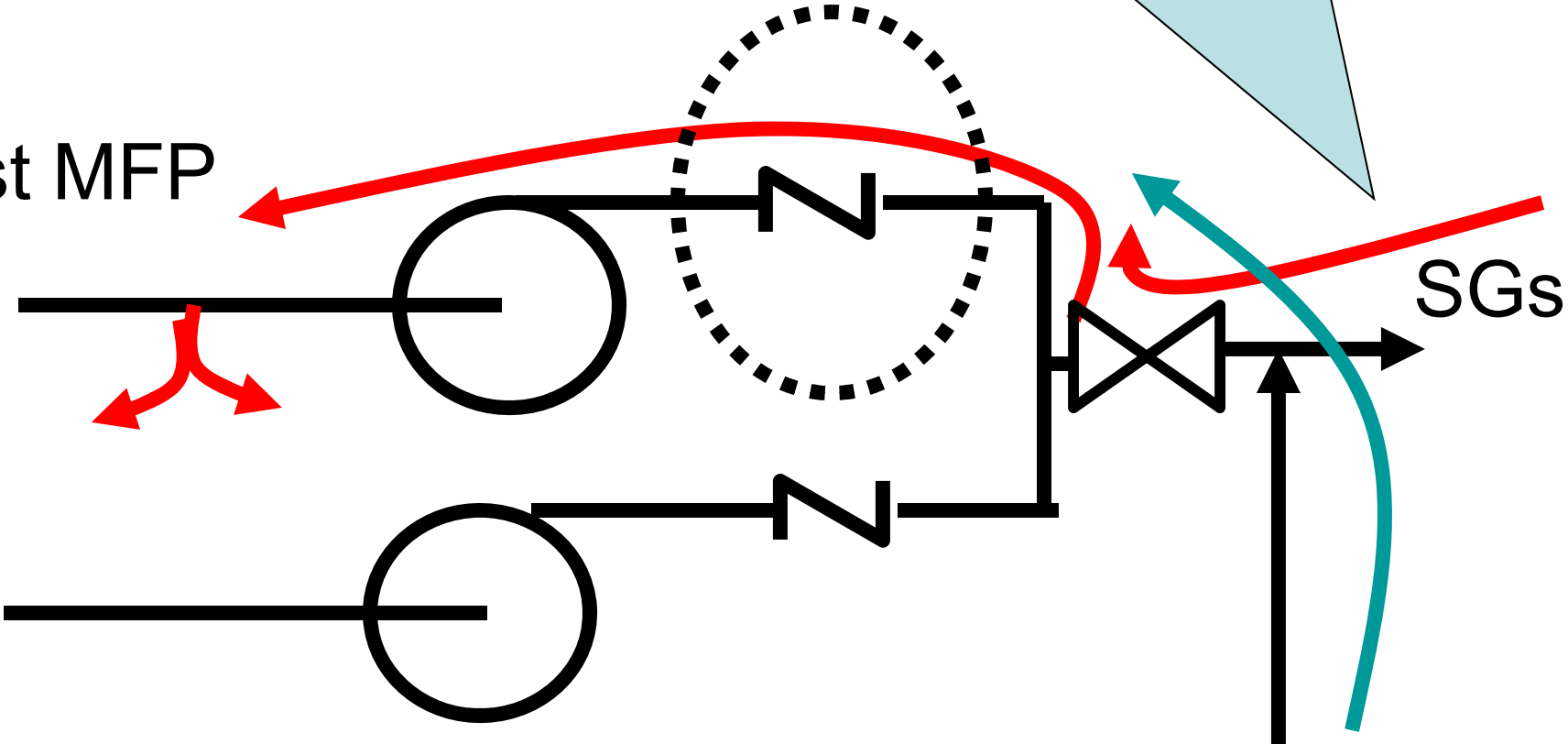


MFP Check Valve

MFP Check Valve As Found

Check valve downstream of FRV was leaking too.

East MFP



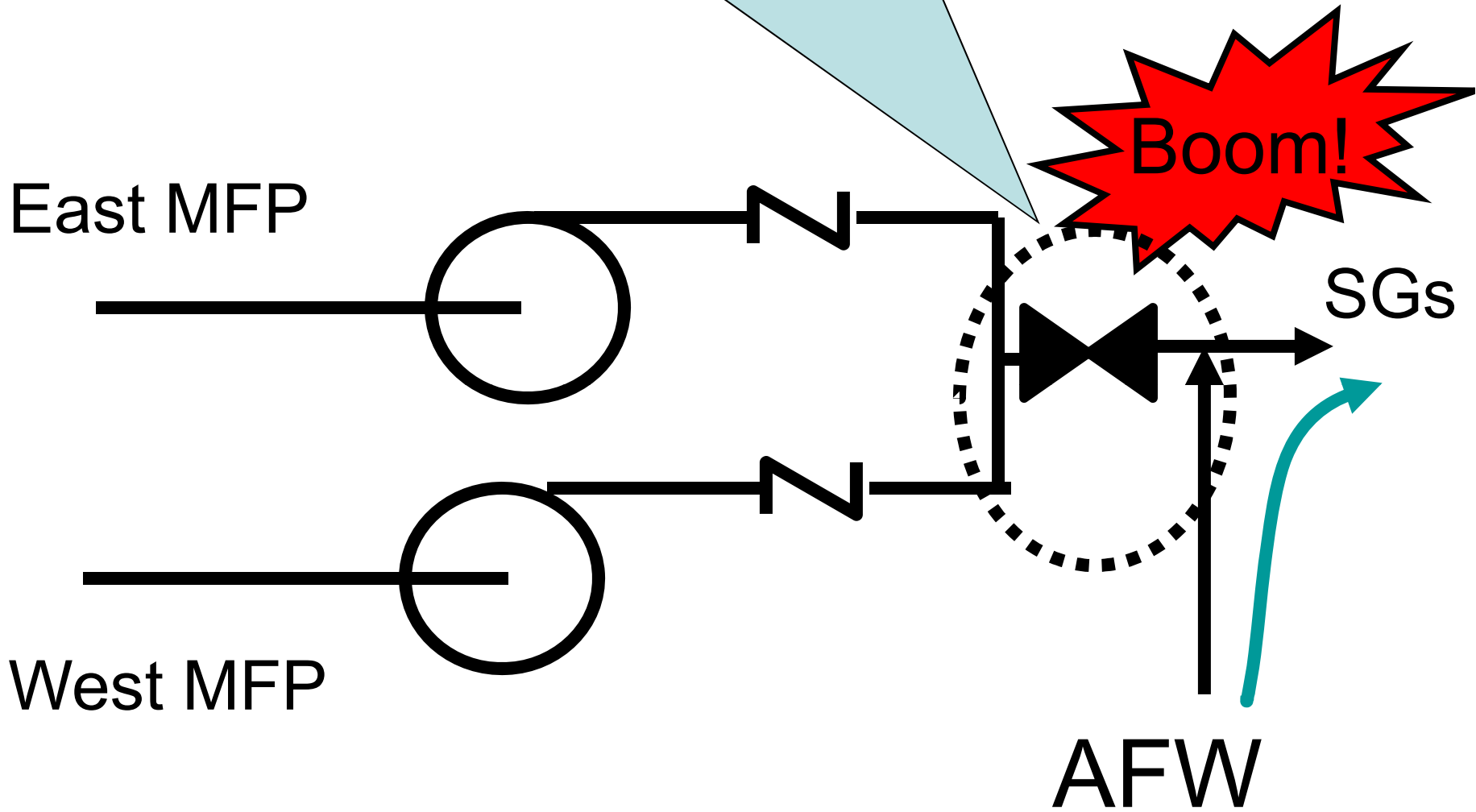
West MFP

SGs

AFW

FRV Check Valve As Found

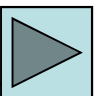
Operators closed FWIS valves.



Consequence / Damage

(Section 7.3.5)

- Cracked feedwater pipe.
- Several damaged pipe supports.
- Several damaged valves.



CAUSES

Failure of 5 safety related check valves.

Inadequate check valve testing.

Questions



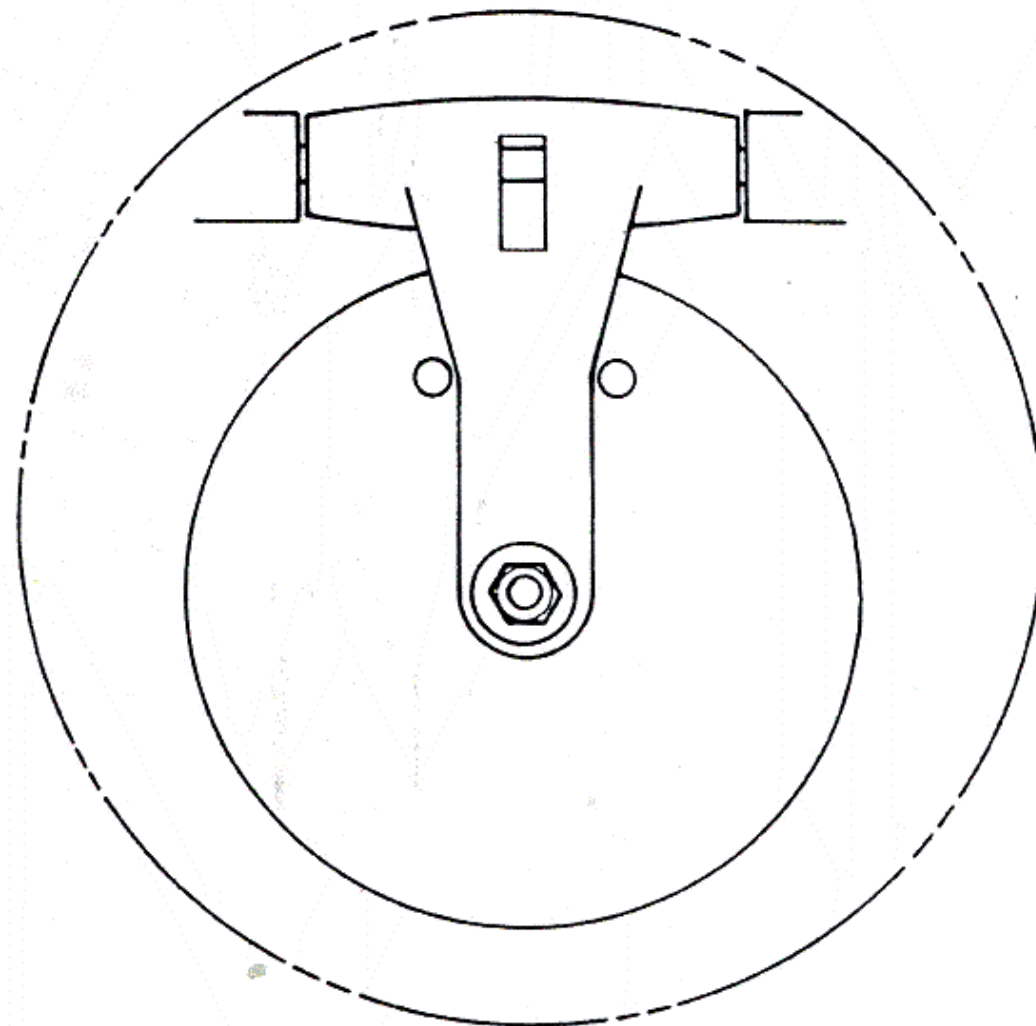
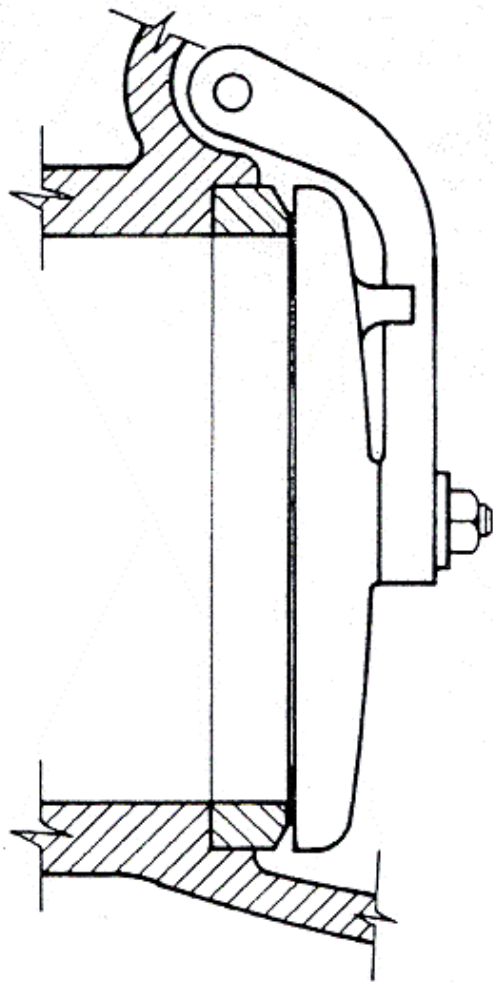
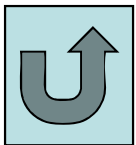


Fig. 7.3-13
MFP Discharge Check Valve Fully Assembled



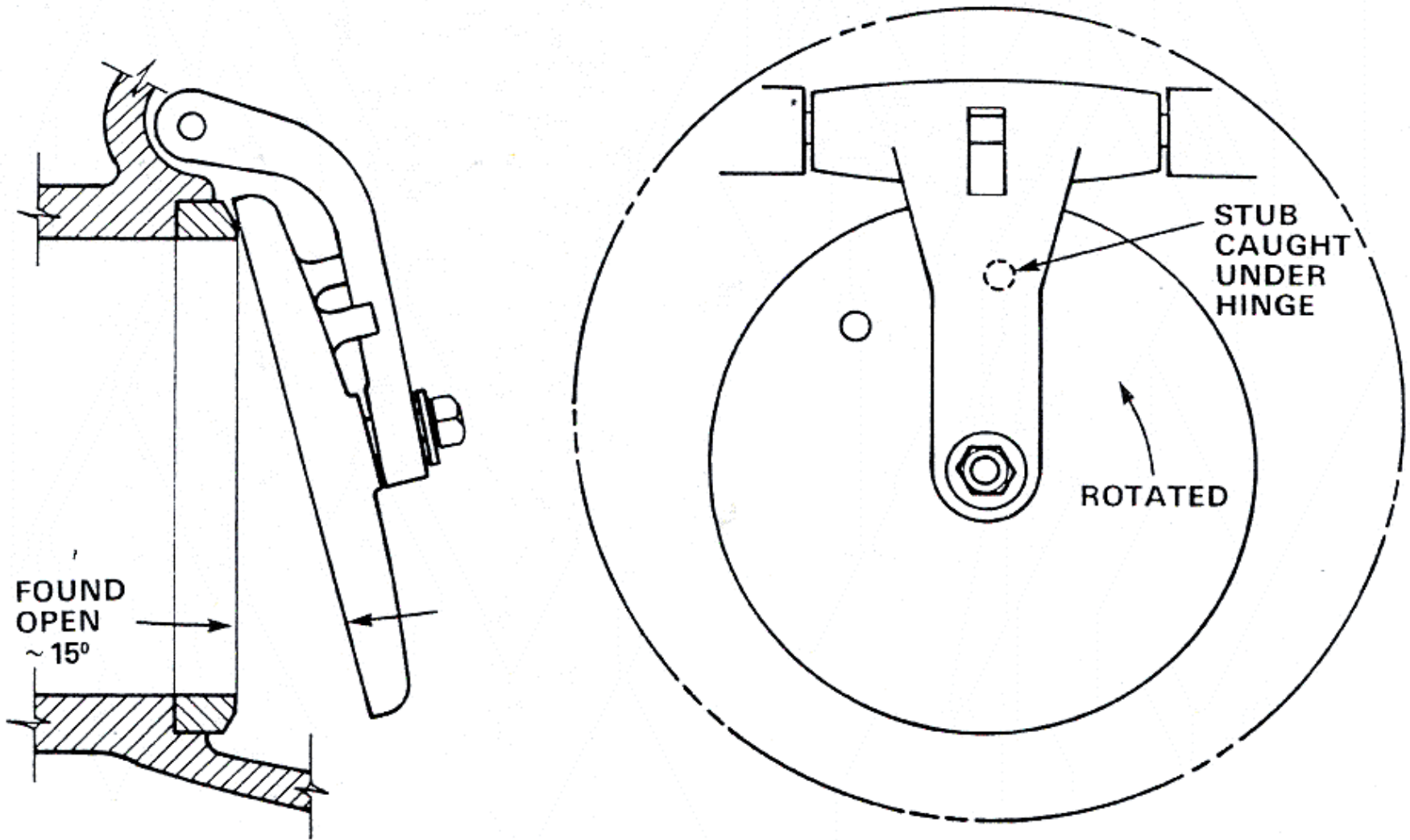


Fig. 7.3-13
MFP Discharge Check Valve As Found

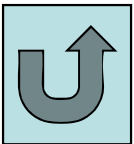


Fig. 7.3-12
Check Valve
Downstream
of FRV As
Found

