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Turbine Bypass to ACC: Desuperheating, Noise, and Vibration

Engineering GREAT Solutions

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Today's Presentation

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- Quick IMI CCI overview
- Turbine Bypass Application Basics
- Desuperheating
  - *Water Cooled Condenser vs. Air Cooled Condenser*
- Noise in Turbine Bypass Systems
  - *Physics of Noise*
  - *Impact of ACC on TBS*
  - *Impact of TBS on ACC*
- Summary

Goals of this Discussion

- Inform / Educate Users of the challenges associated with Bypassing to the ACC duct
- Be educated and informed from the Users on issues related to their bypass stations and ducts
- Partner with some Users to study the noise and vibration levels generated during startup and full bypass

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IMI CCI is …

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IMI CCI®

- The largest <u>dedicated</u> severe service valve company in the world ~$600M revenue per annum
- What is Severe Service?
  - *High Pressure*
  - *High Temperature*
- Local support
  - *Sales*
  - *Engineering*
  - *Commissioning and Start-up Services*
  - *Outage Support*

Common Severe Service Applications in Power

- Main BFP min flow recirculation
- Start-up & Main Feedwater Regulation
- Turbine Bypass
- Interstage Attemperation
- Startup and Emergency Vents
- Auxiliary Steam / Steam AUG

Turbine Bypass Application Basics

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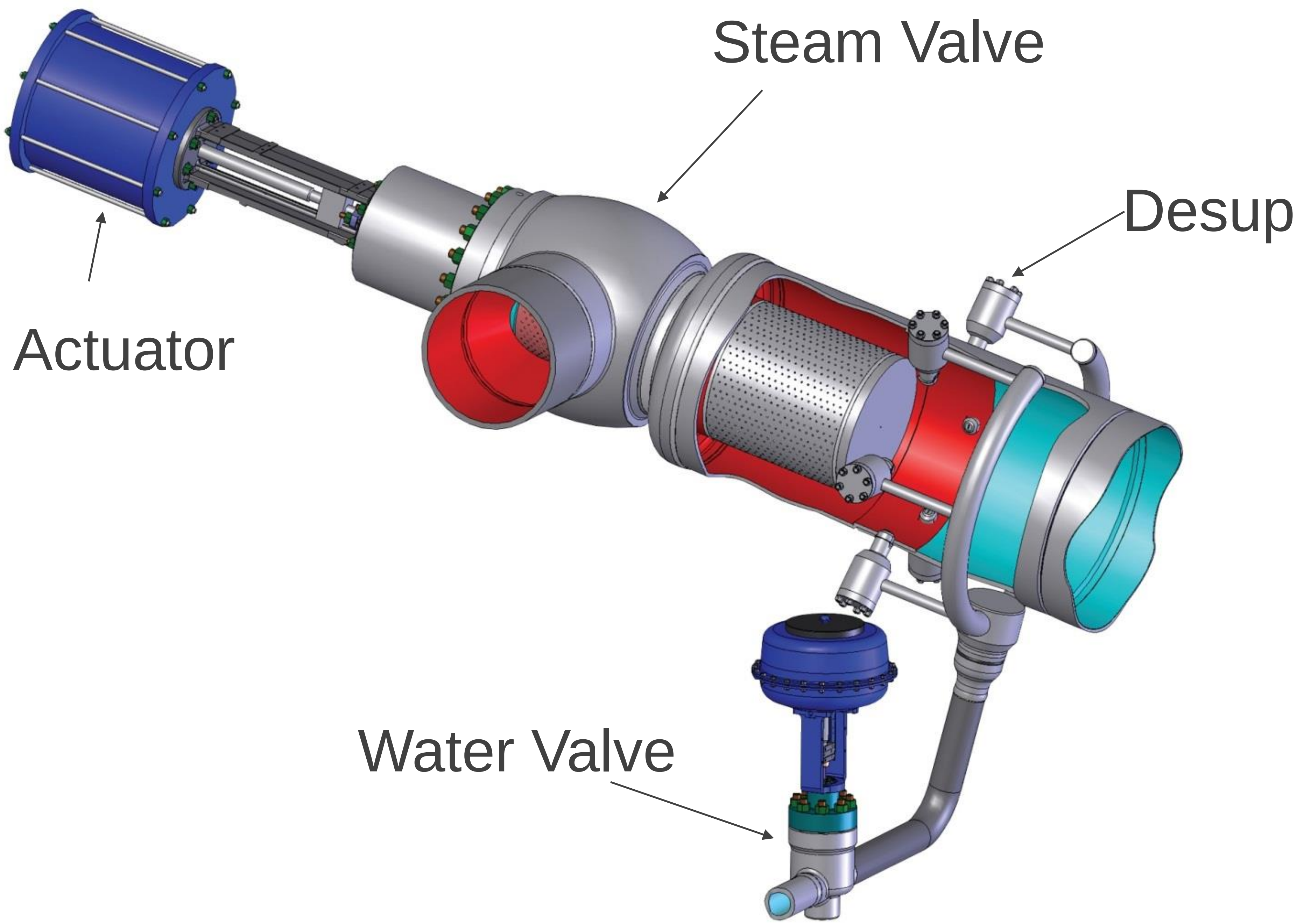
Application Basics

- <u>What is a Turbine Bypass System (TBS)?</u>

A steam conditioning system that reduces pressure and temperature while bypassing the Steam Turbine

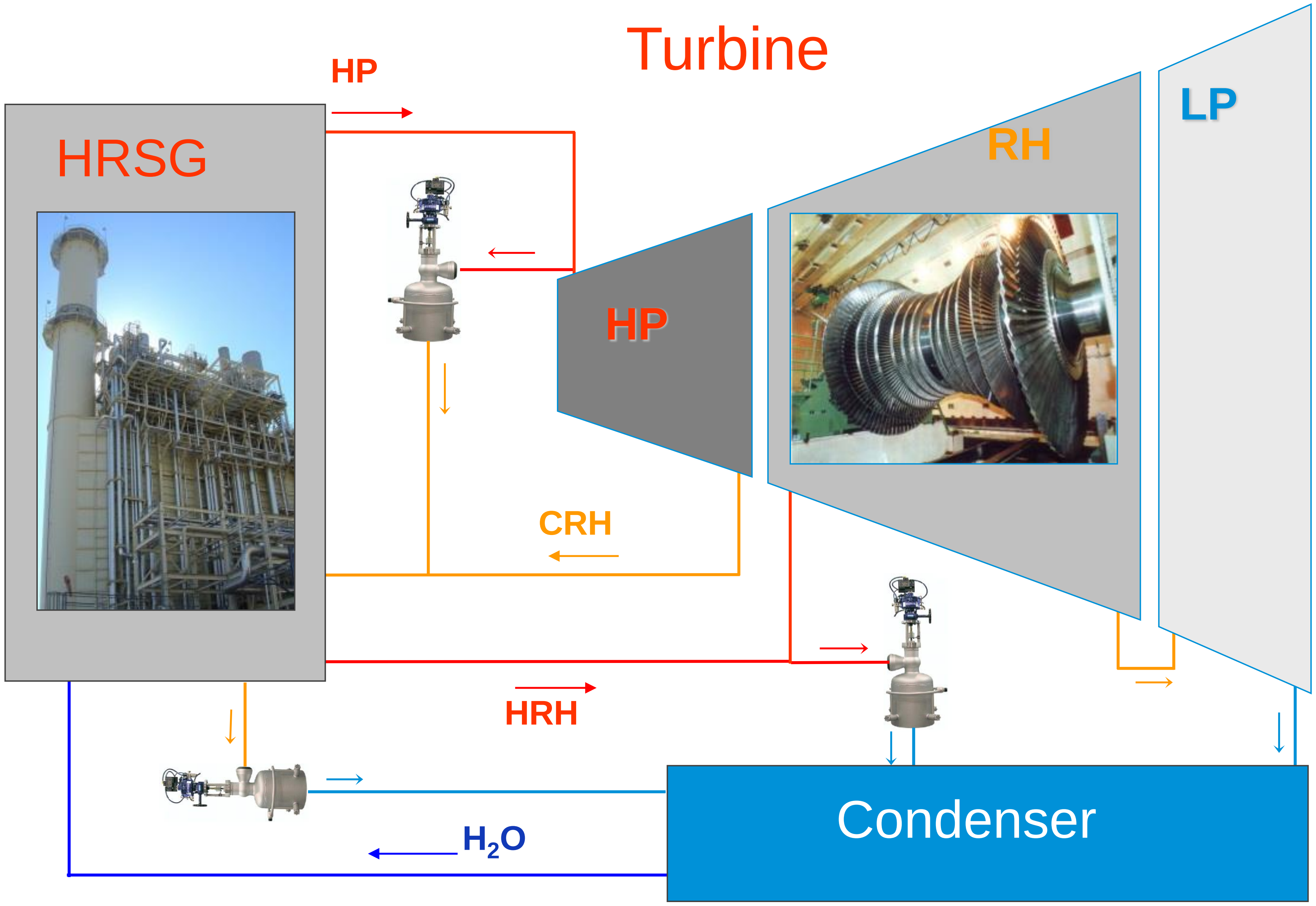


Large Bypass System

- **Millmerran 420MW Power Plant**
- **HRH-Bypass**

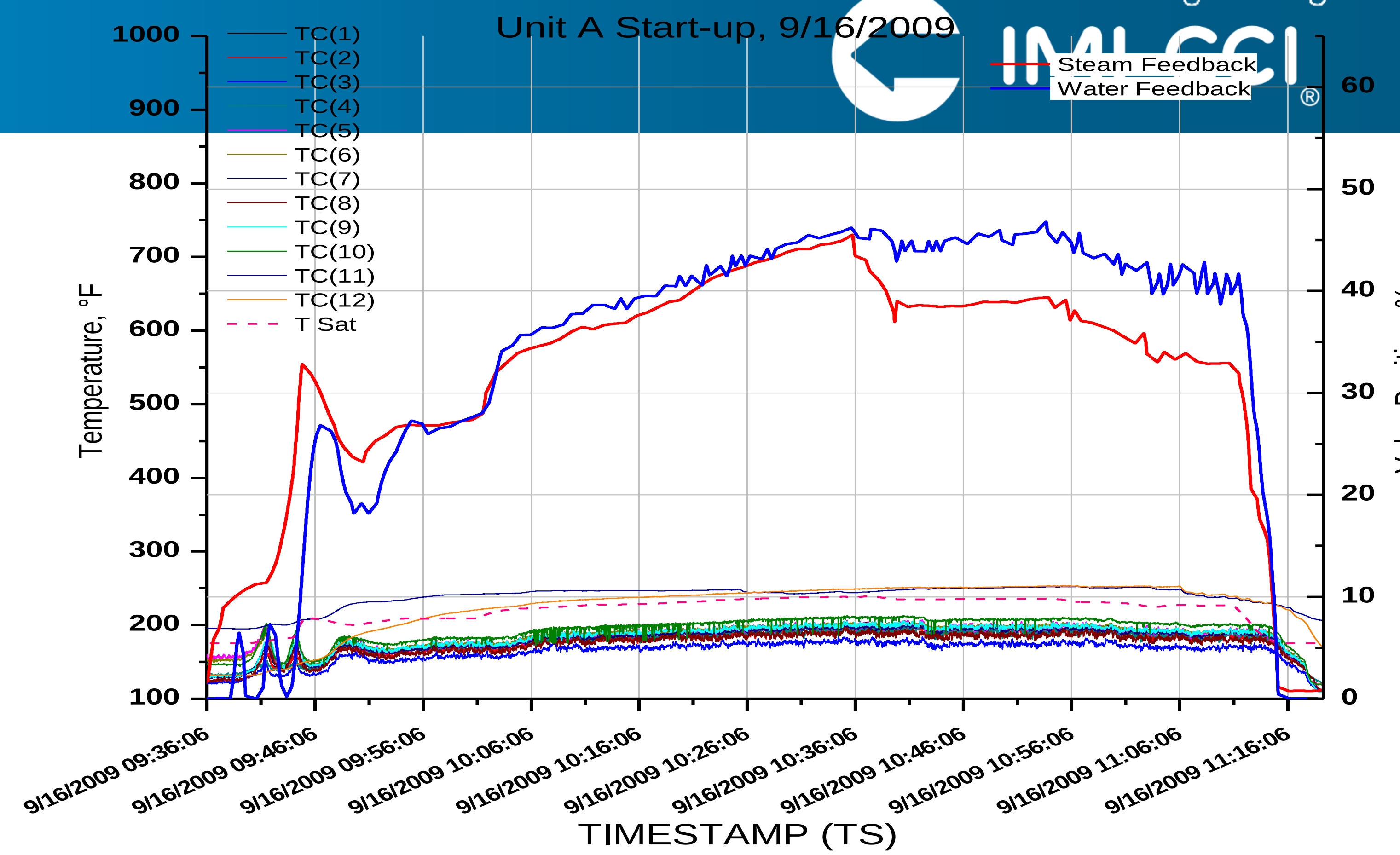
Application Basics

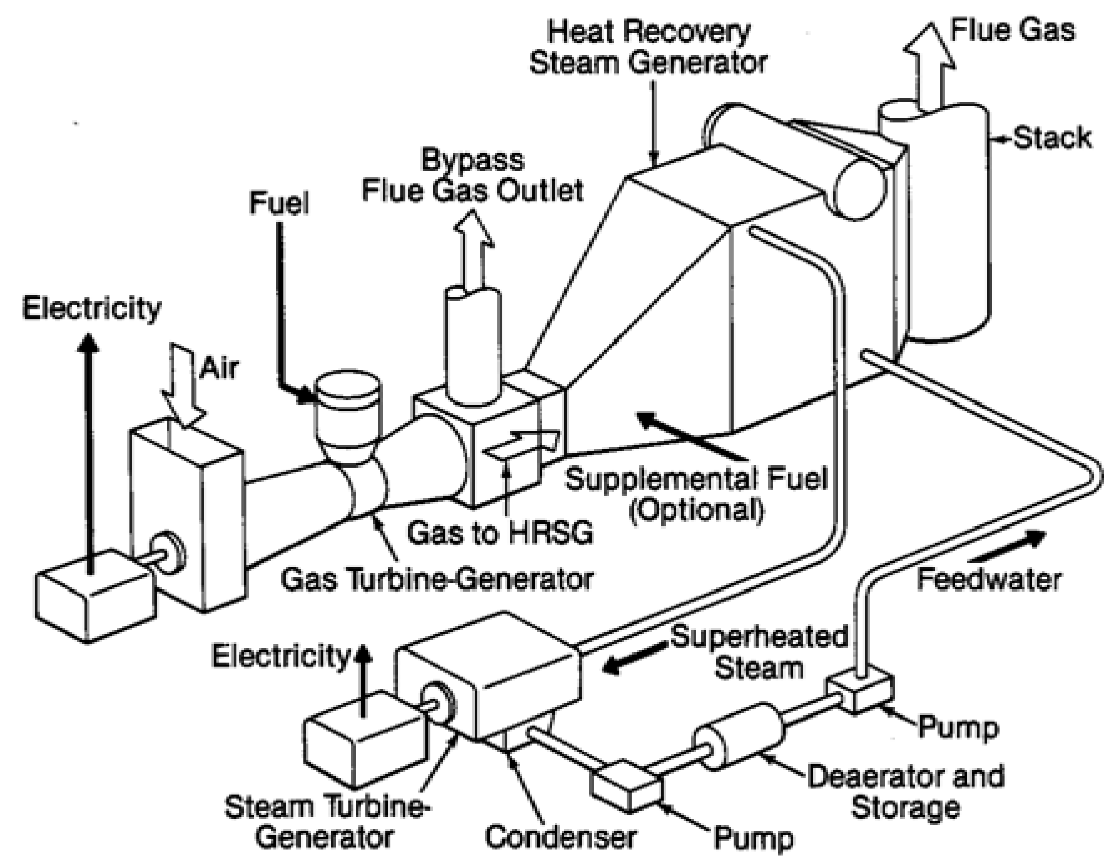
- **In CCPPs typically 3 systems**
  - **High Pressure (HP) to Cold Reheat (CRH)**
  - **Hot Reheat (HRH) to Condenser**
  - **Low Pressure (LP) to Condenser**



Application Basics

- When & Why are TBS used?
  - Startup and Shutdown
    - Control the heat up of the HRSG and ST
    - HRSG and Condenser fully operational before rolling the ST
  - Steam Turbine (ST) Trip
    - Conserve steam vs. dumping it to atmosphere
    - Decouple the Gas Turbine/HRSG from the ST/Generator
    - Protect the HRSG and Condenser





(a)

Turbine Bypass Valve Design

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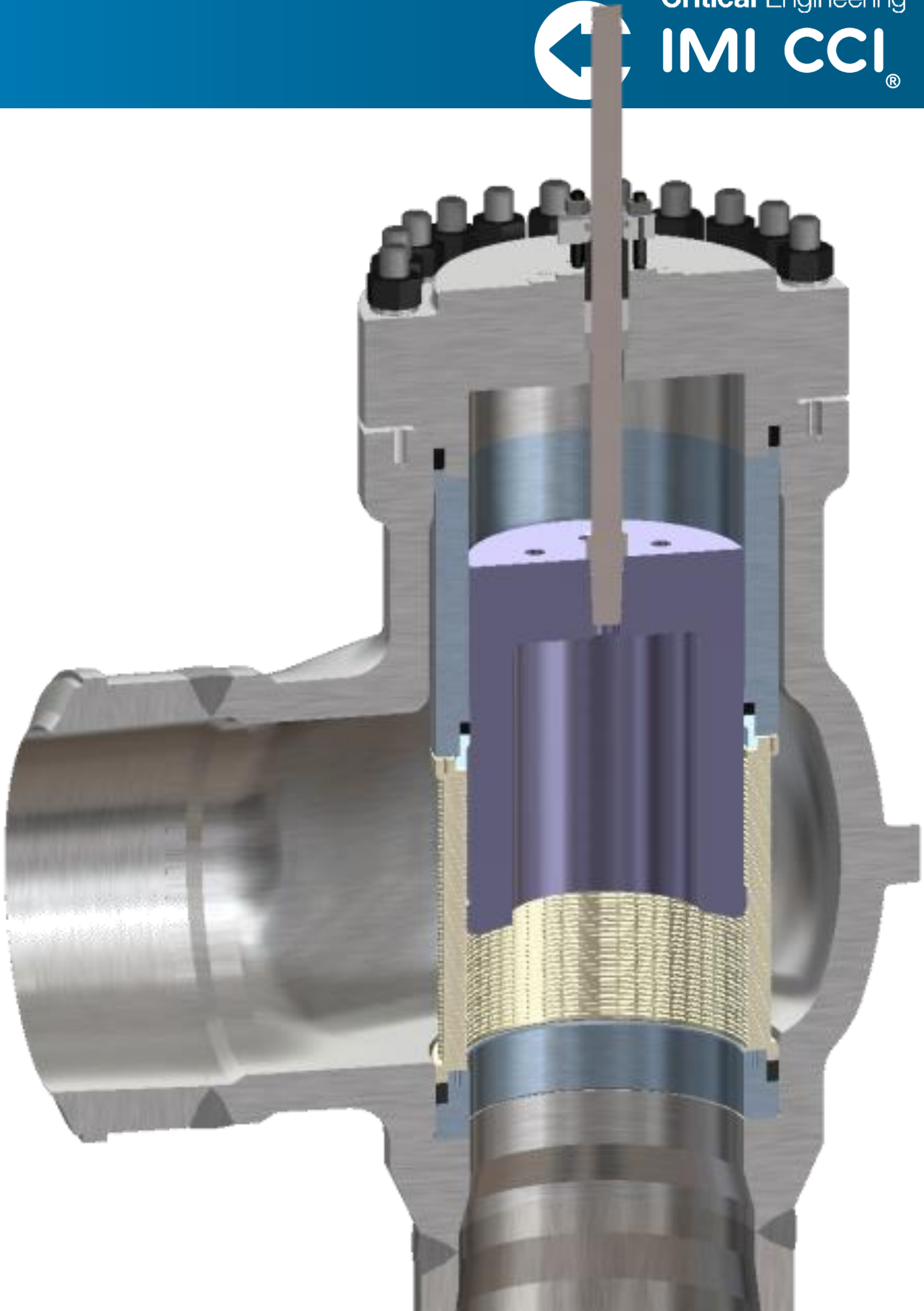
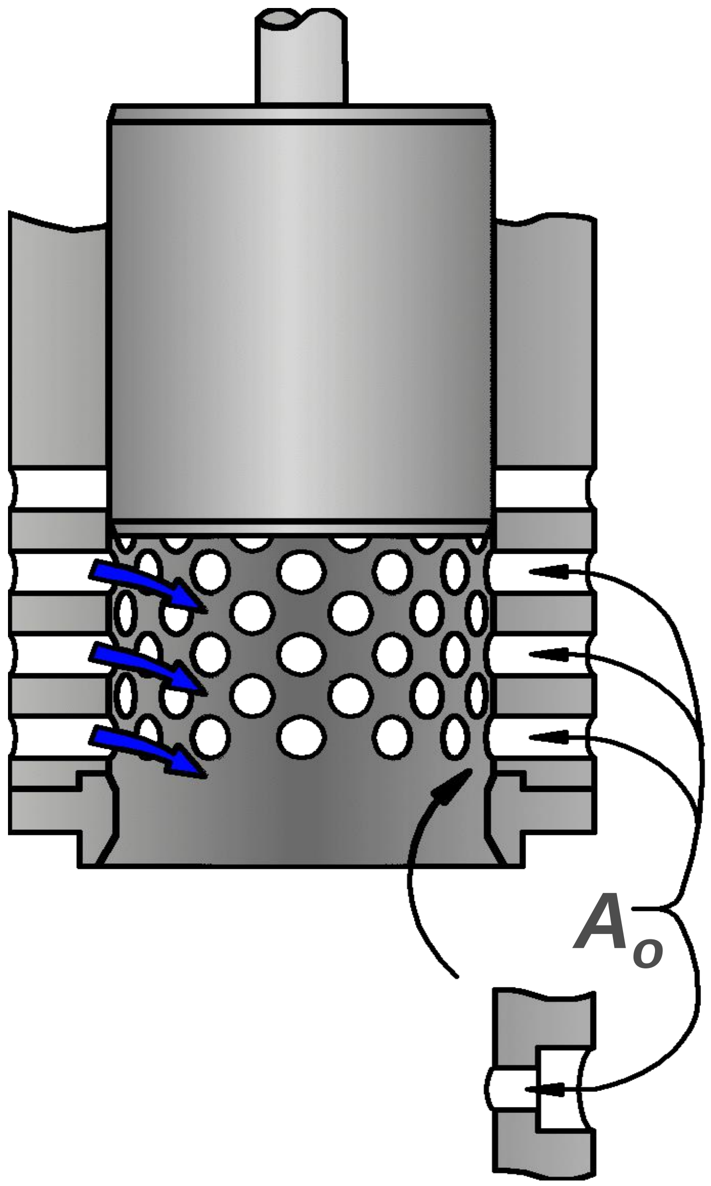
Valve Internal Design

- Sliding plug and stem valve
- High temperature design
  - *Material Strength*
  - *Galling*
- Fast acting in trip mode
  - *Thermal gradients*
  - *Differential Expansion*
- High Pressure Drop
  - *High velocity*
  - *High energy*

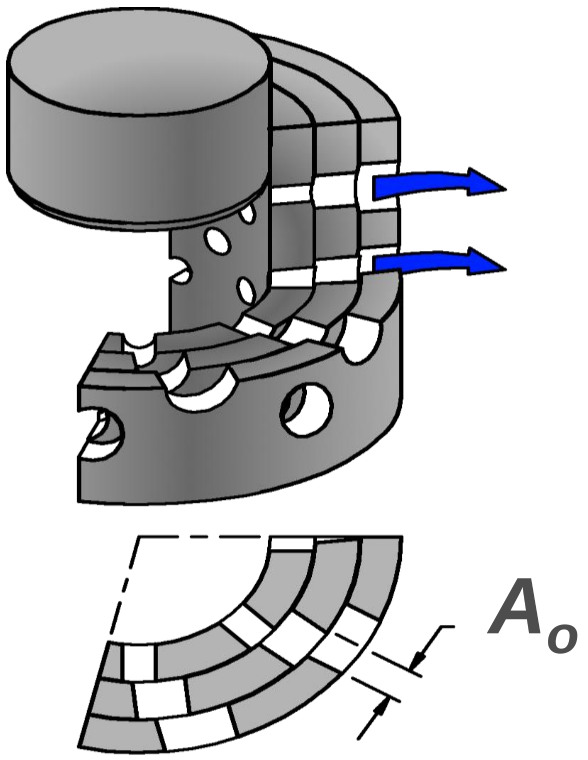


General Valve Design

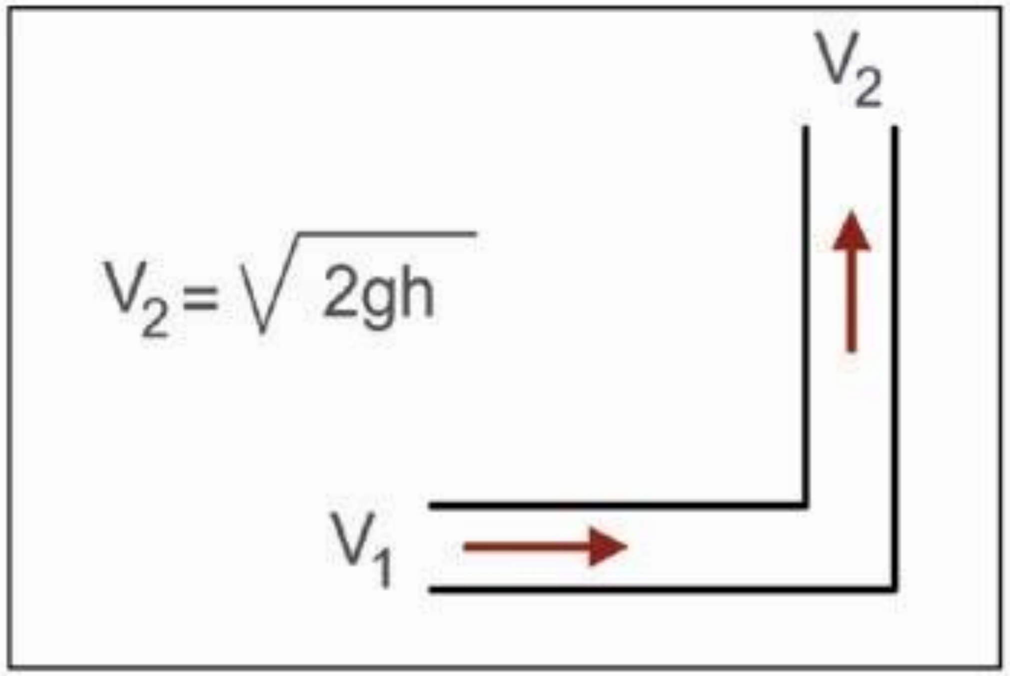
Single-Stage
Multi-Path



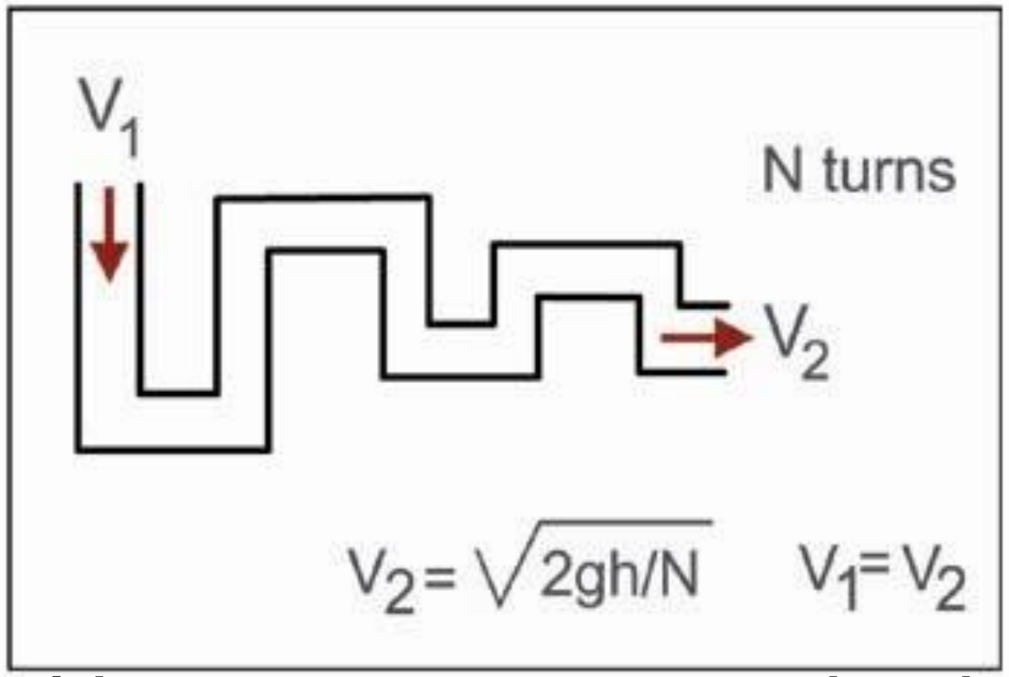
Multi-Stage
Multi-Path



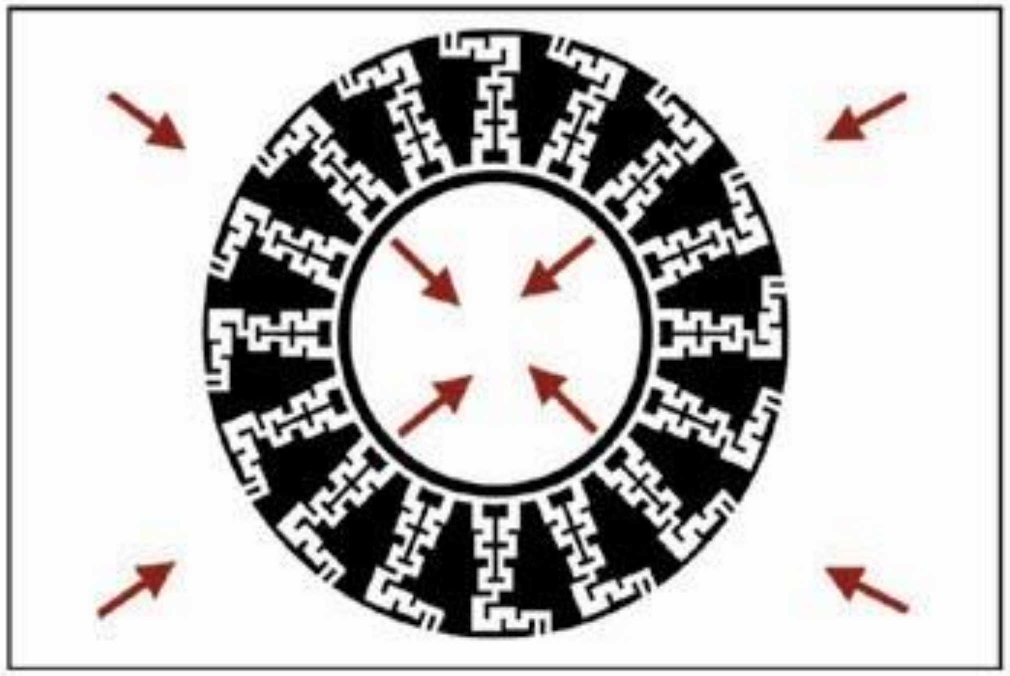
DRAG® velocity control principle



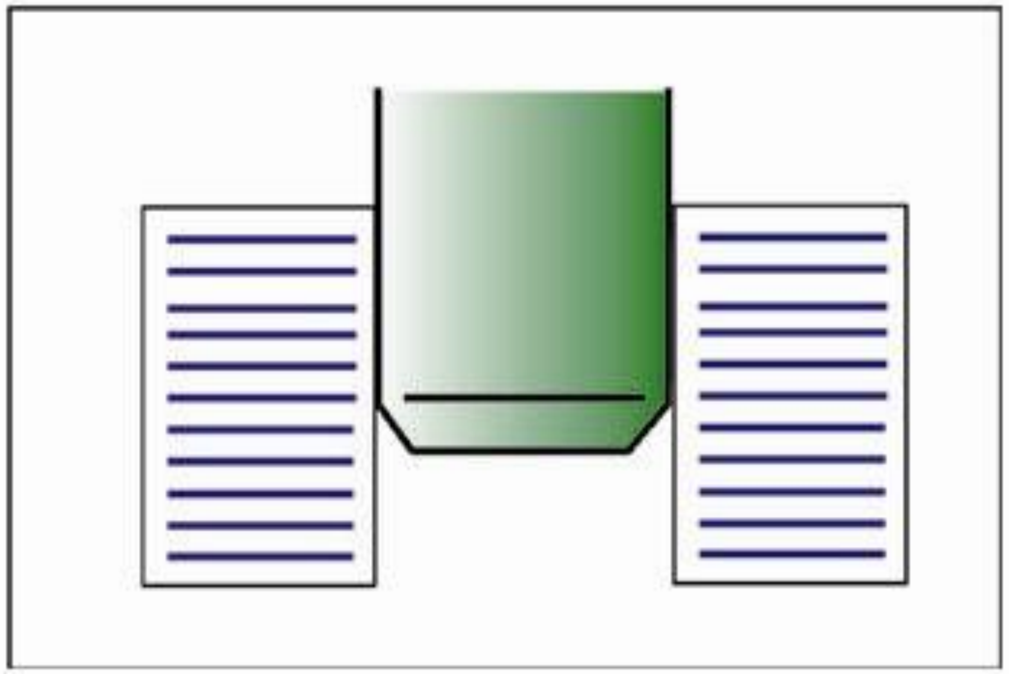
Single stage pressure reduction



Multi stage pressure reduction

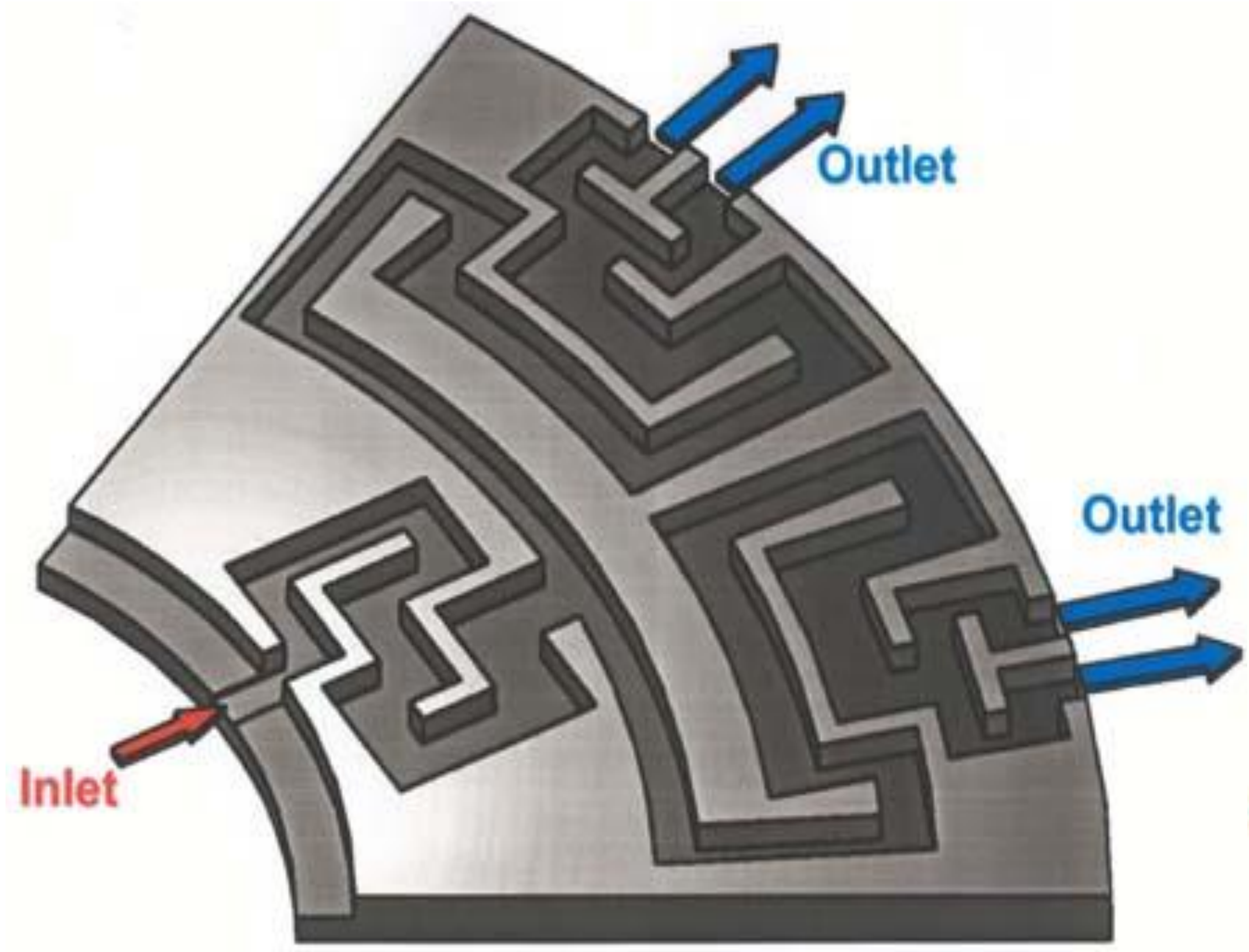


Multi path multi stage disk

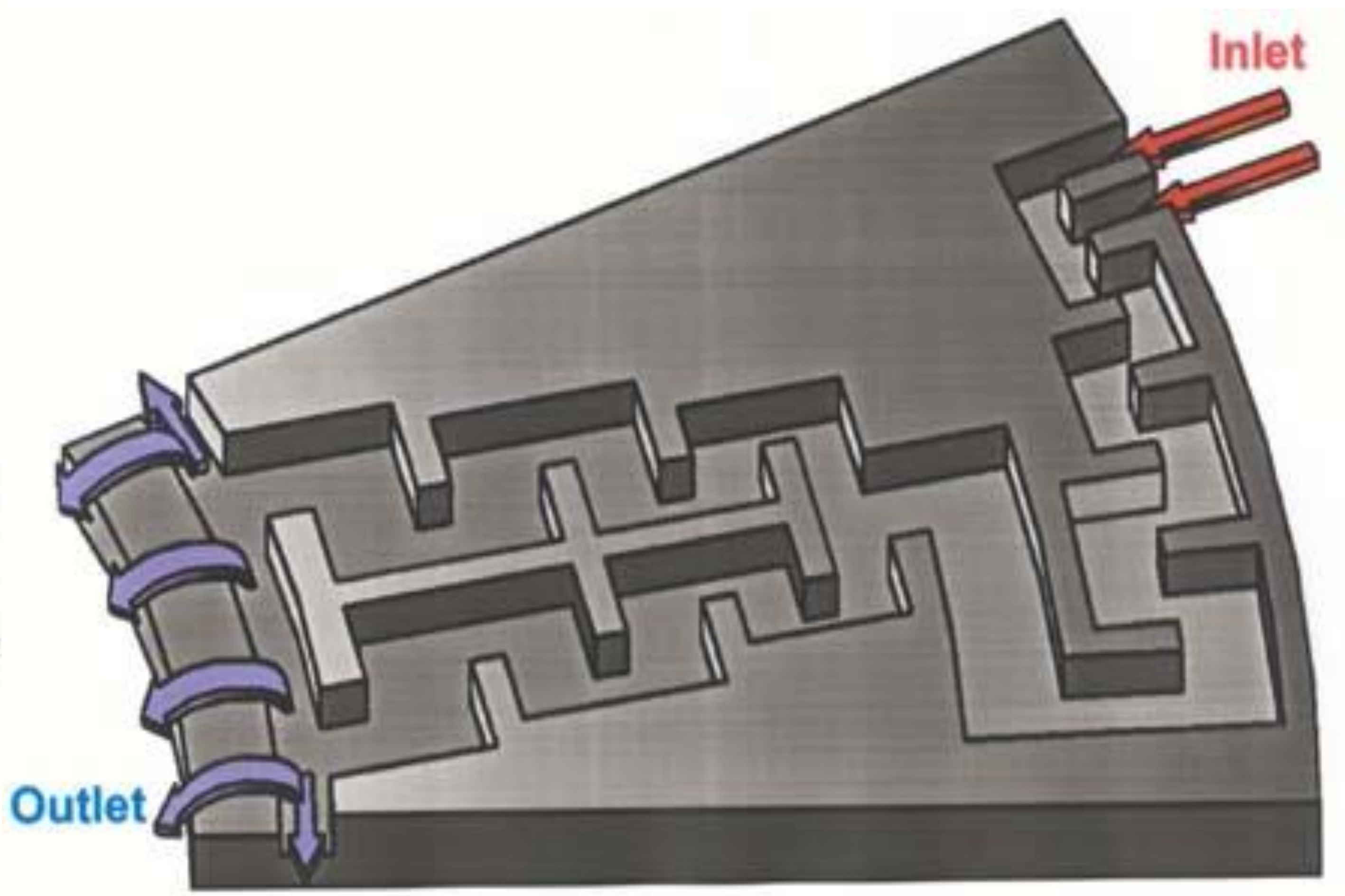


DRAG® disk stack

DRAG® velocity control flow path

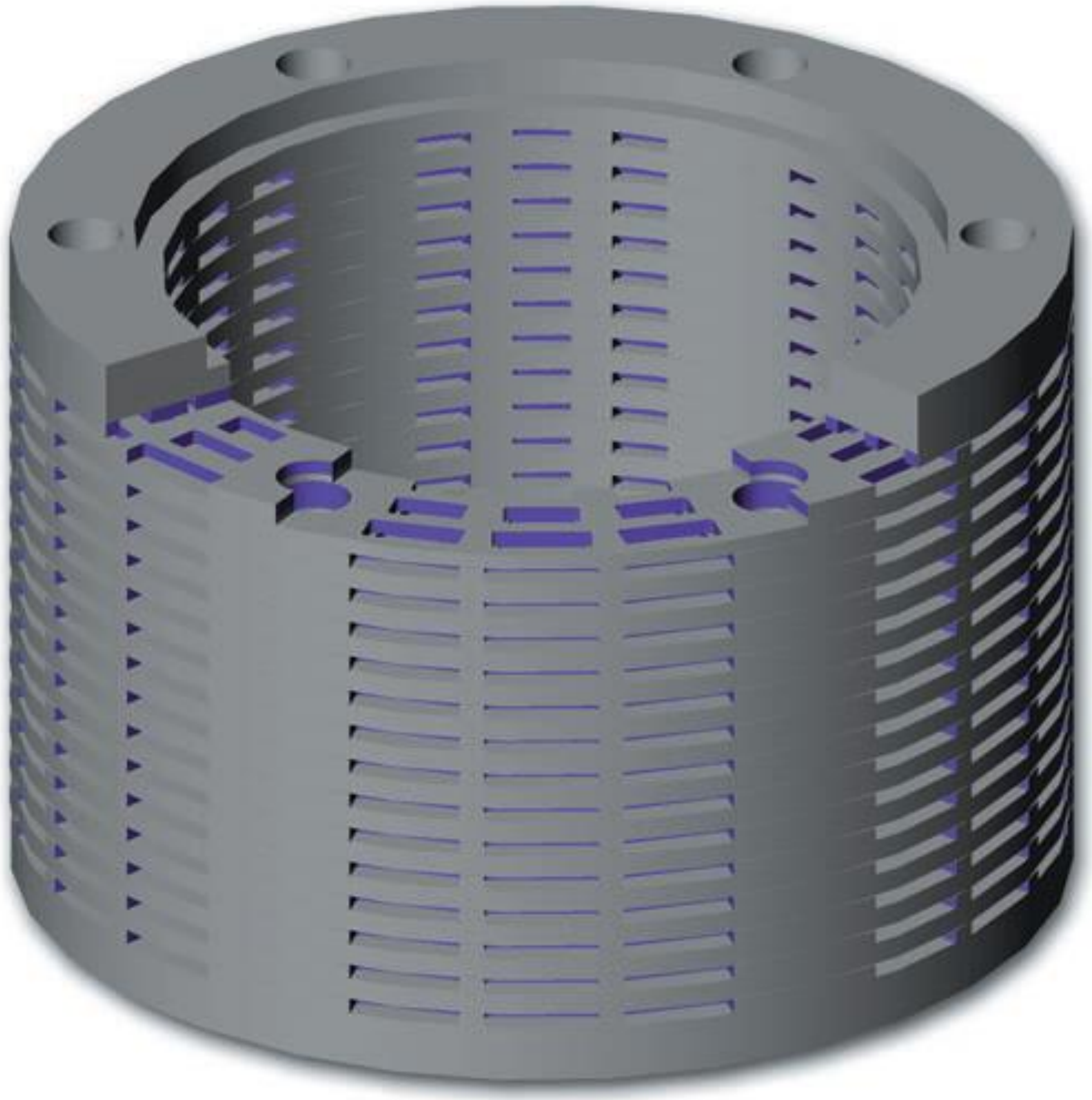


Under the plug flow

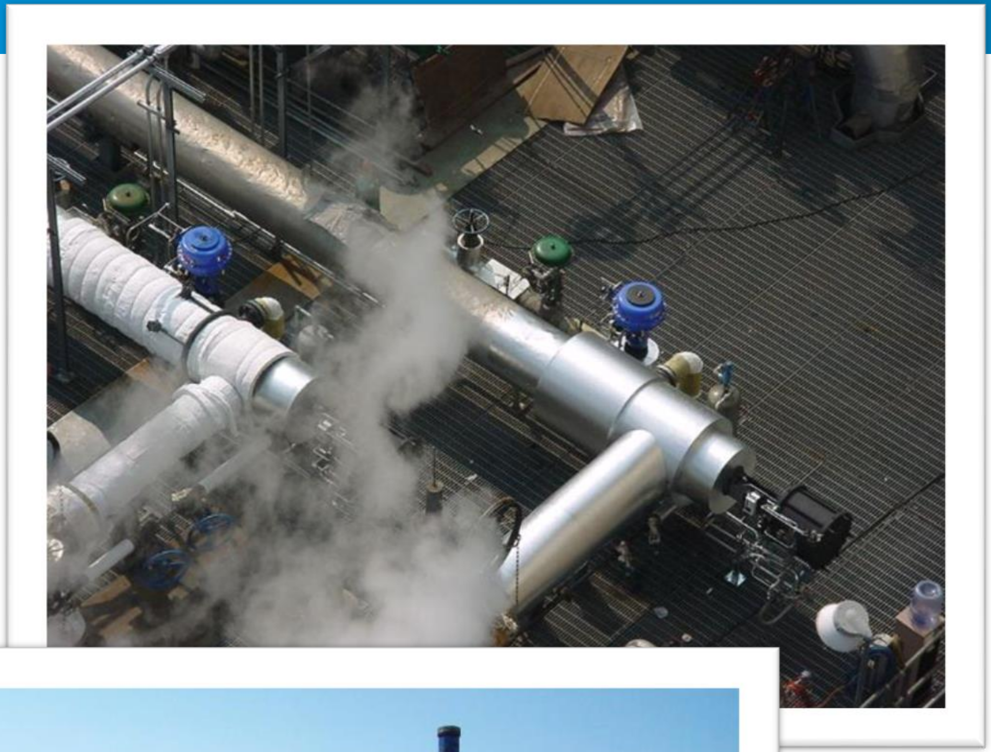


Over the plug flow

DRAG® Punched Diskstacks



Turbine Bypass Experience



Over 1000 Turbine Bypass Installations in North America

+85 Years of Steam Conditioning Experience World Wide

Desuperheating in Turbine Bypass Systems

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Desuperheaters in TBS

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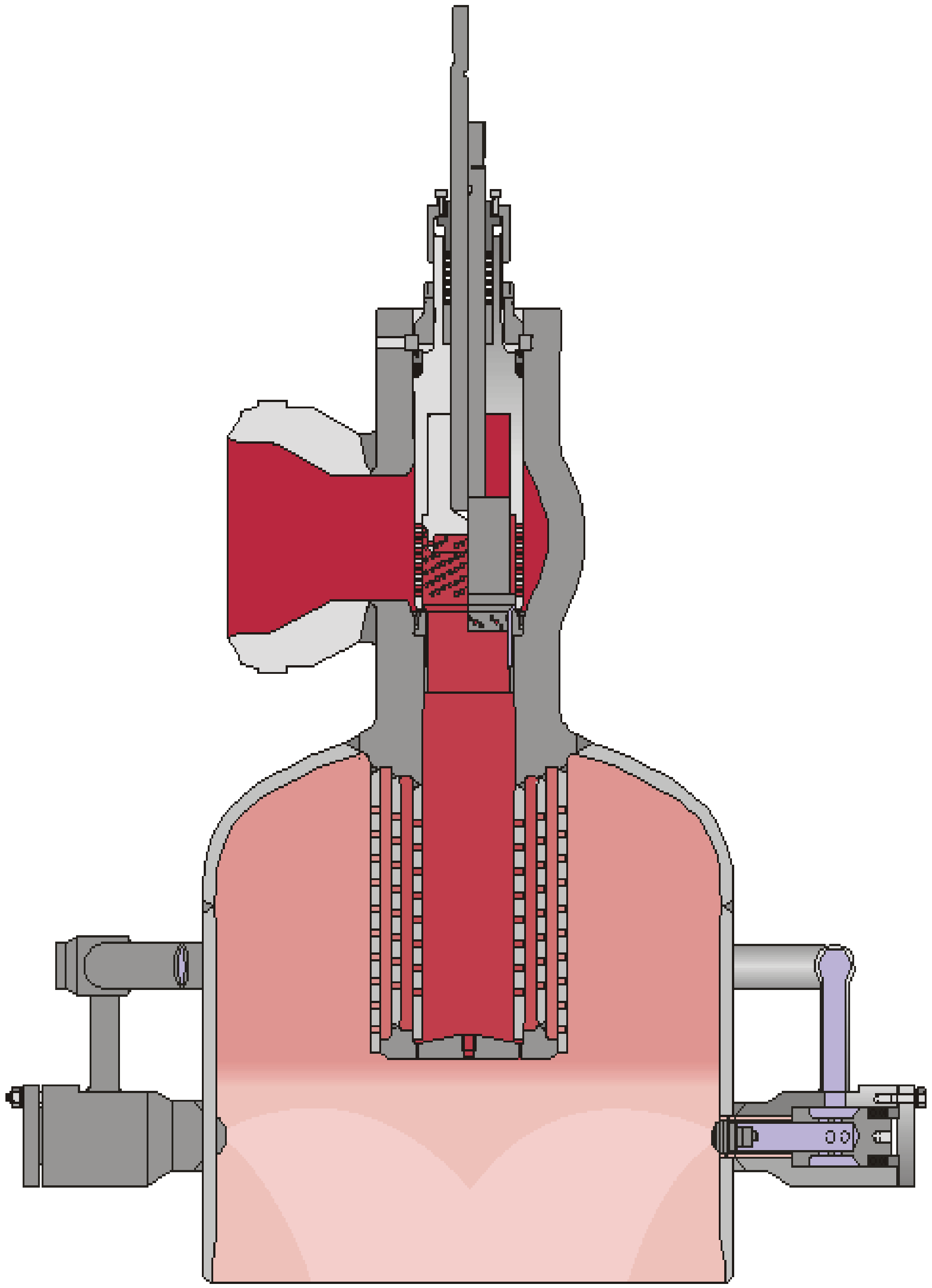
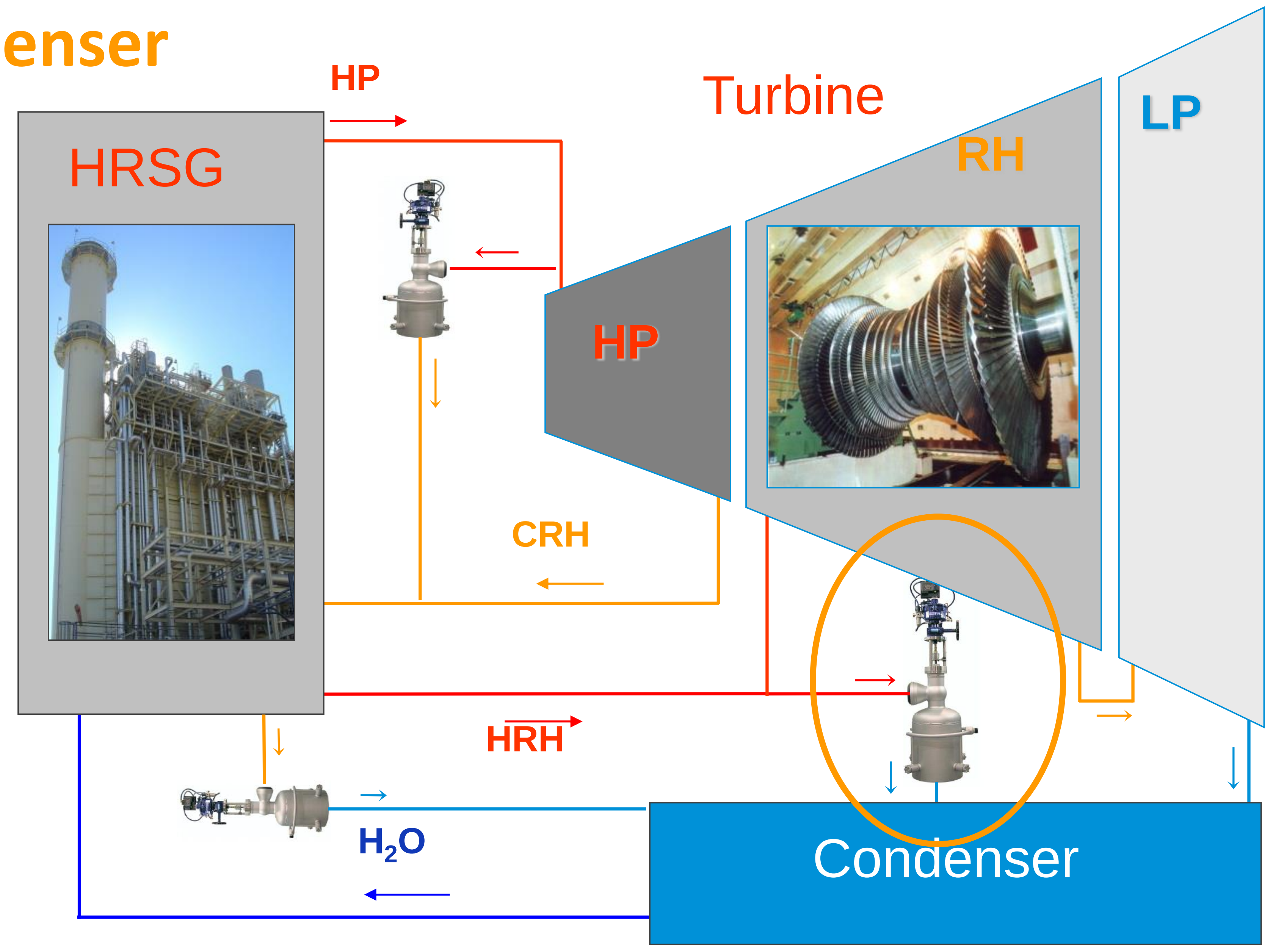


HRH to Condenser Desup – Critical

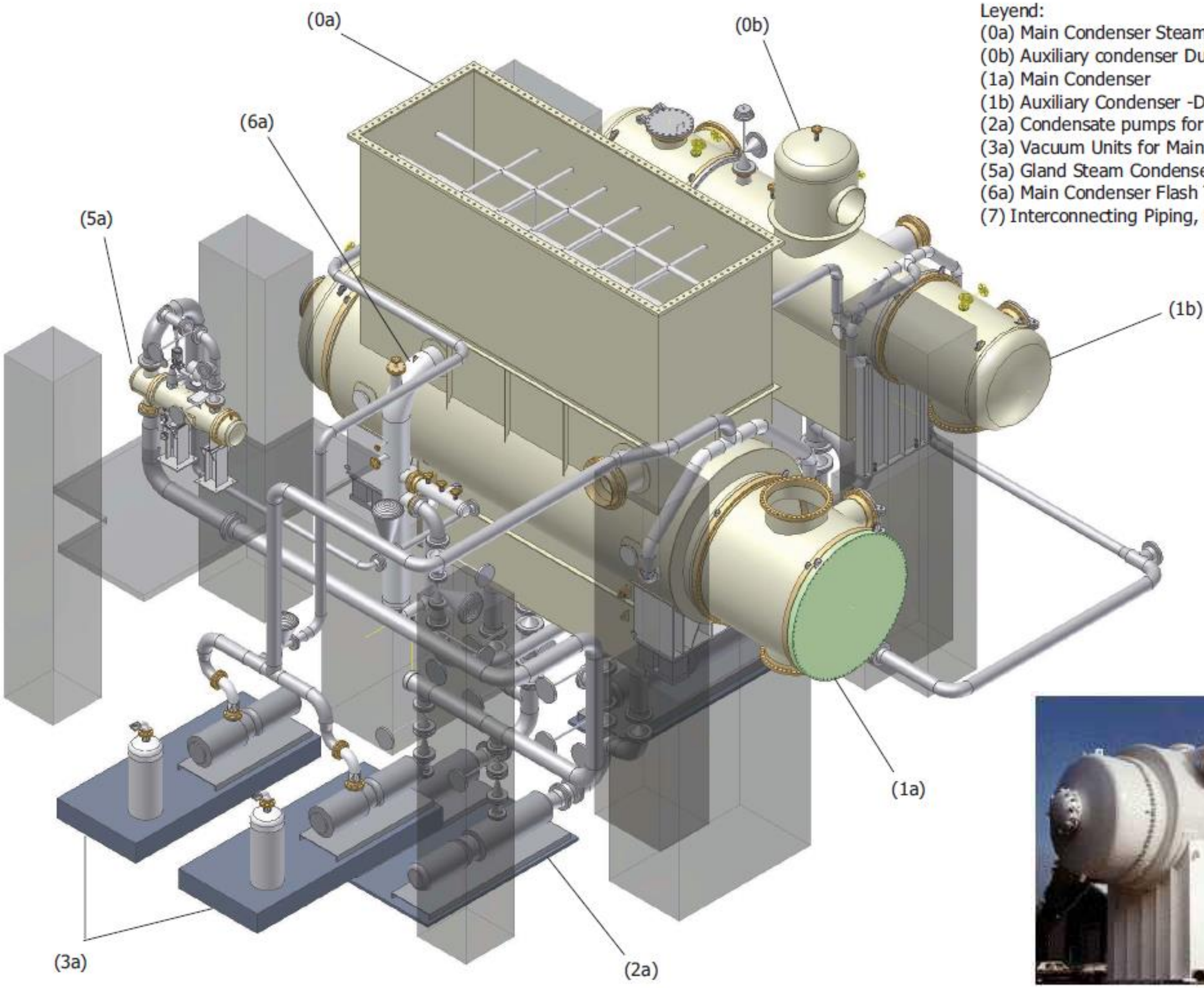
- **Hot Reheat (HRH) to Condenser**

- Highest temperature differentials, **>900F**
- Coldest spray water, uses condensate **~120F**
- Largest pipe, 24" – 42"
- Biggest change in density, dumping to vacuum
- Largest water-to-steam ratios (>30%)



Water Cooled – Moderate Design Temps

Leyend:
(0a) Main Condenser Steam Duct
(0b) Auxiliary condenser Dump connection
(1a) Main Condenser
(1b) Auxiliary Condenser -Dump Condenser-
(2a) Condensate pumps for Main Condenser
(3a) Vacuum Units for Main Condenser
(5a) Gland Steam Condenser
(6a) Main Condenser Flash Tank
(7) Interconnecting Piping, filters, fittings, valves

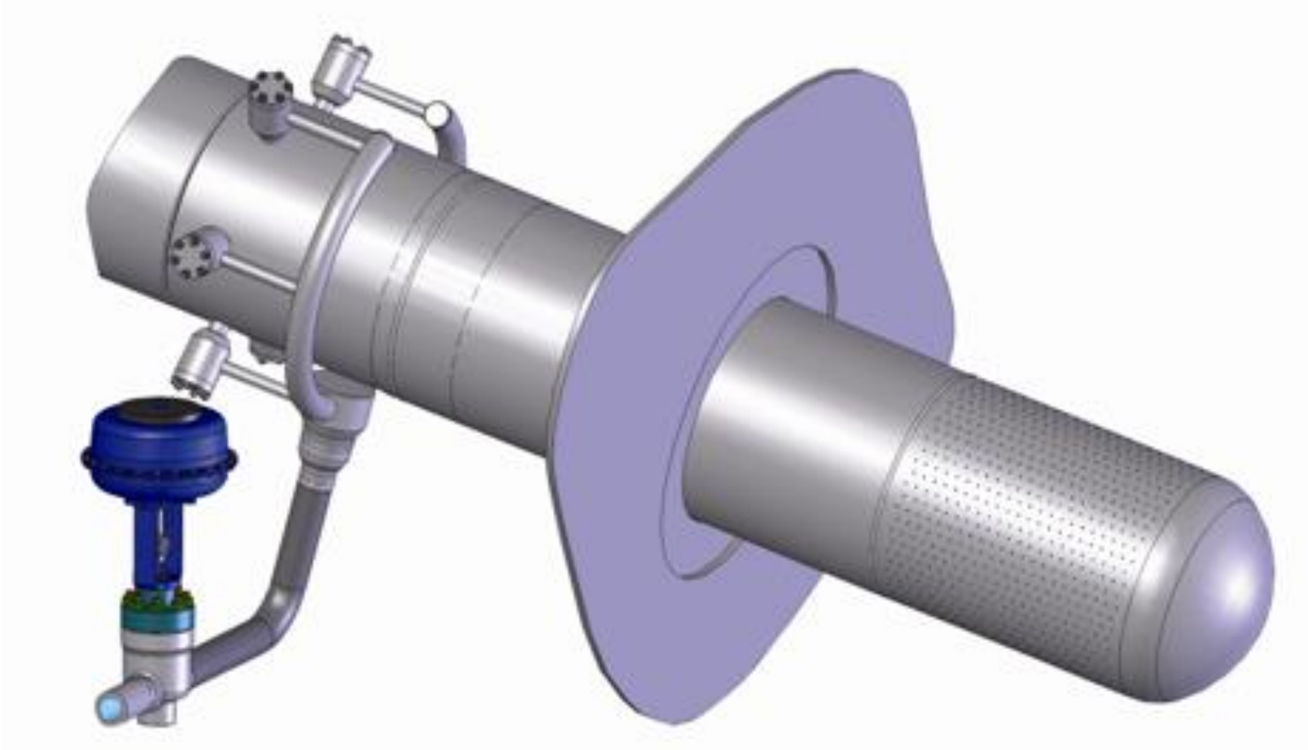


Air Cooled Condensers

ACC Steam Ducts – Low Design Temps

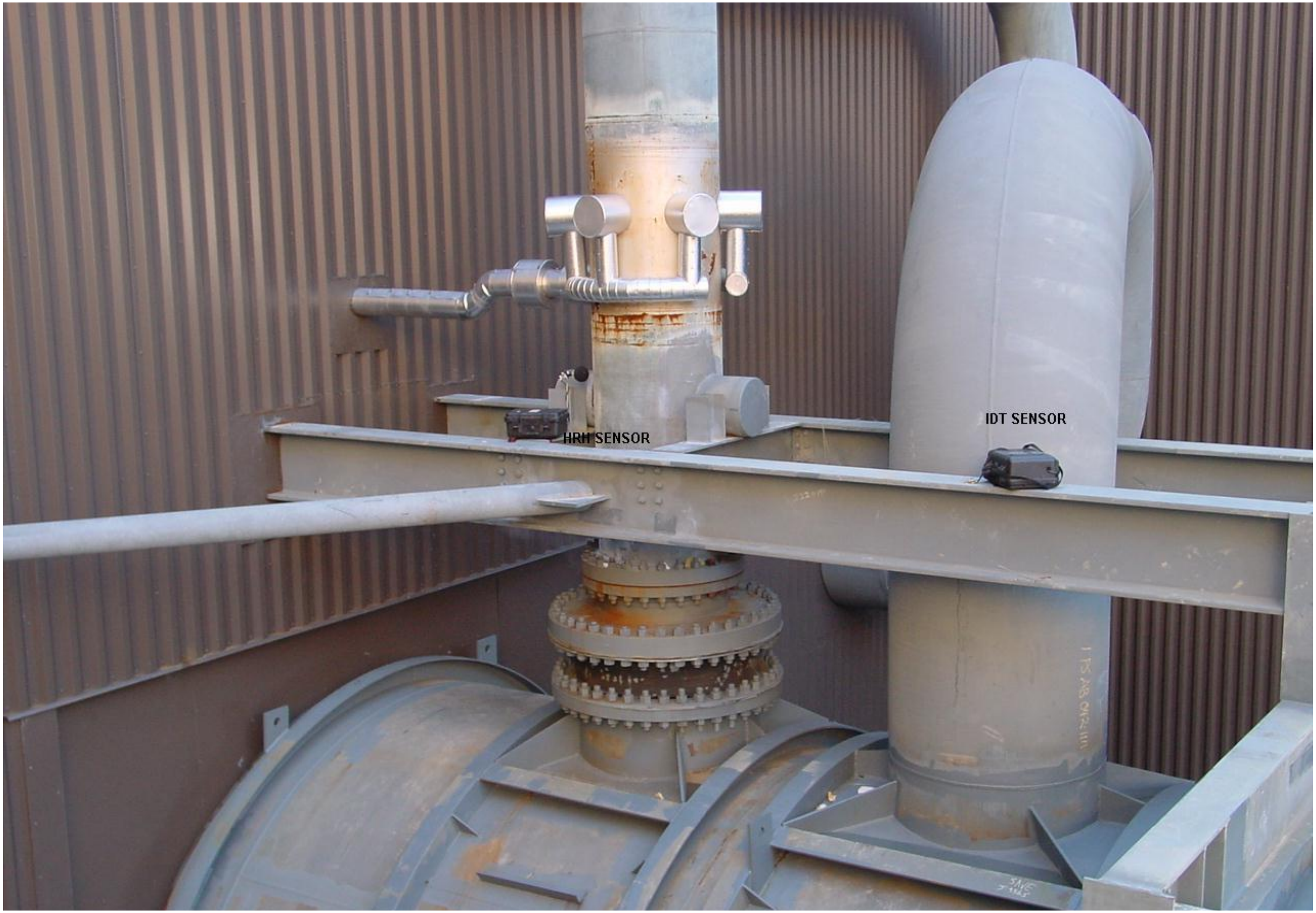
HRH Bypass Outlet Temperatures

- WCC plant designs
  - *Common water cooled condenser enthalpy ~ 1225 Btu/lbm*
  - *Equals ~395F at 100psi,* ***<u>~67F Superheat</u>***
- ACC designs require lower temperatures due to flexibility requirements of the seals in the ACC Steam Duct
  - *Common temperature limit of 250F in condenser, ~1160 Btu/lbm*
  - *Equals ~330F at 100psi –* ***<u>Saturated Steam ~97% Quality</u>***
  - *2-stage desuperheating is often required*



HRH Bypass – CLOSE COUPLED

HRH Bypass – 2nd Stage Spray



Installation Example

- Elbow into duct – not ideal
- Site was using Temp Feedback
  - *Setpoint < Tsat*
  - *Cracking Downstream Pipe due to excess water*

Water Damage to ACC
- separation at inlet elbow

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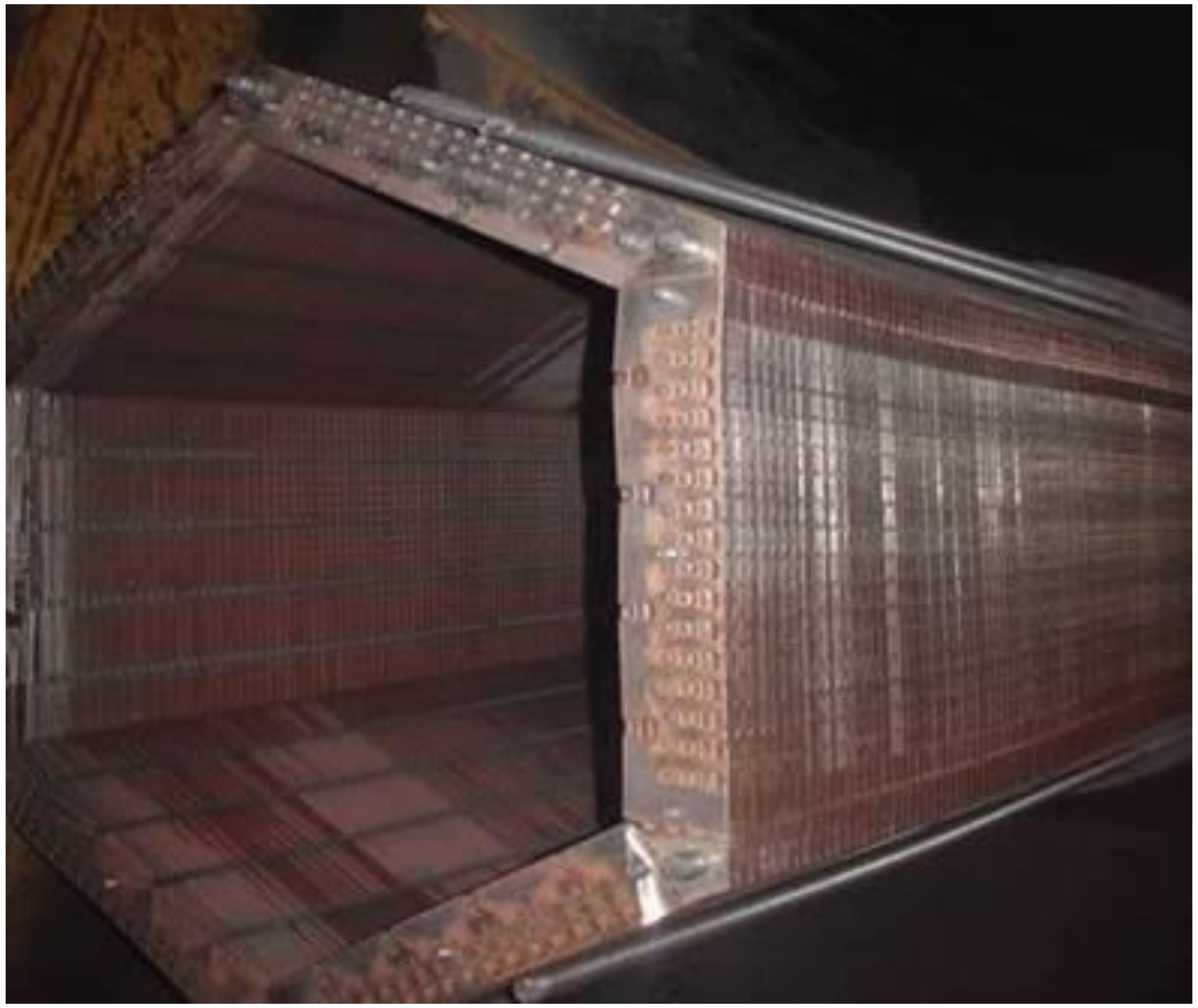
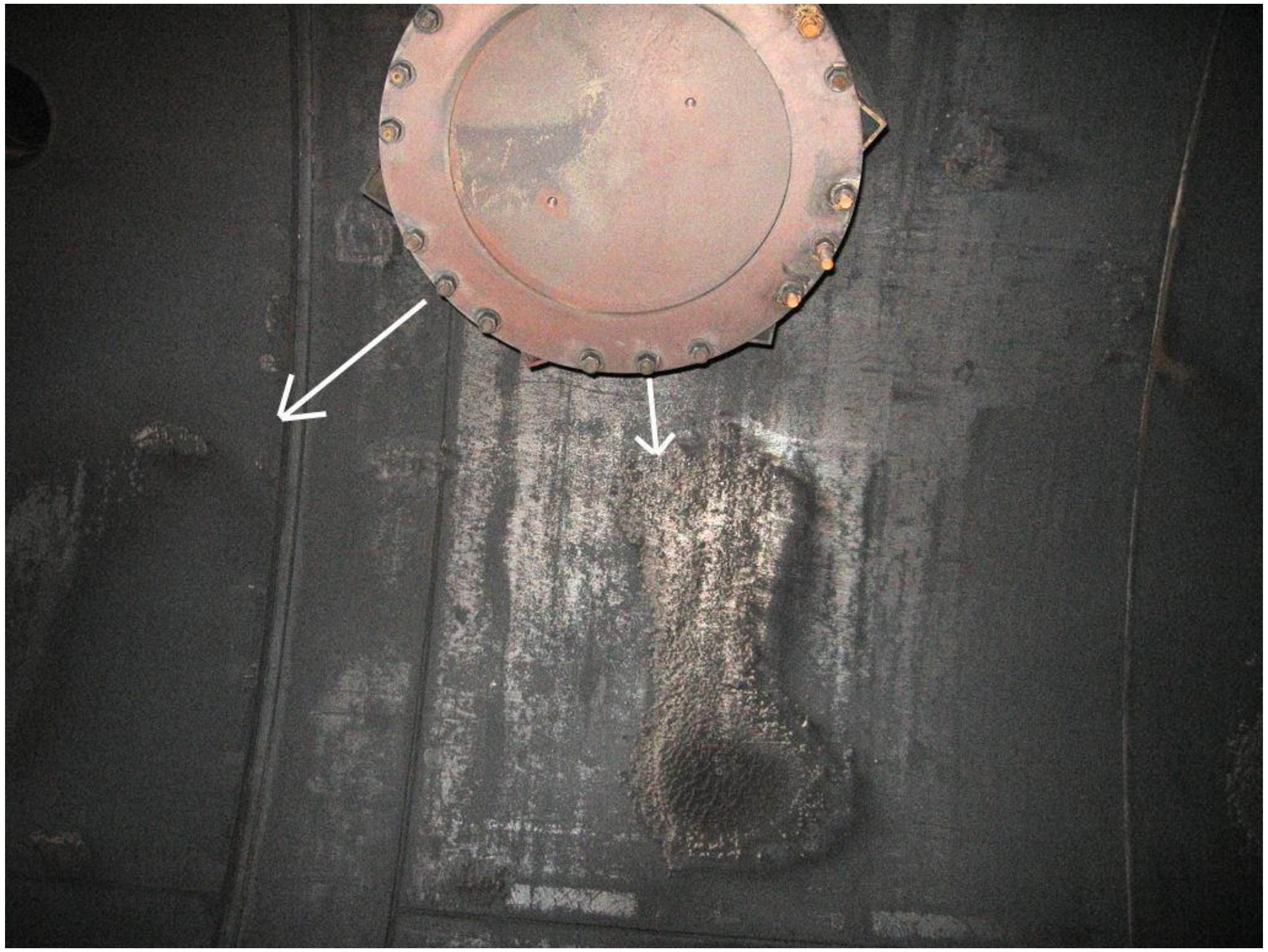


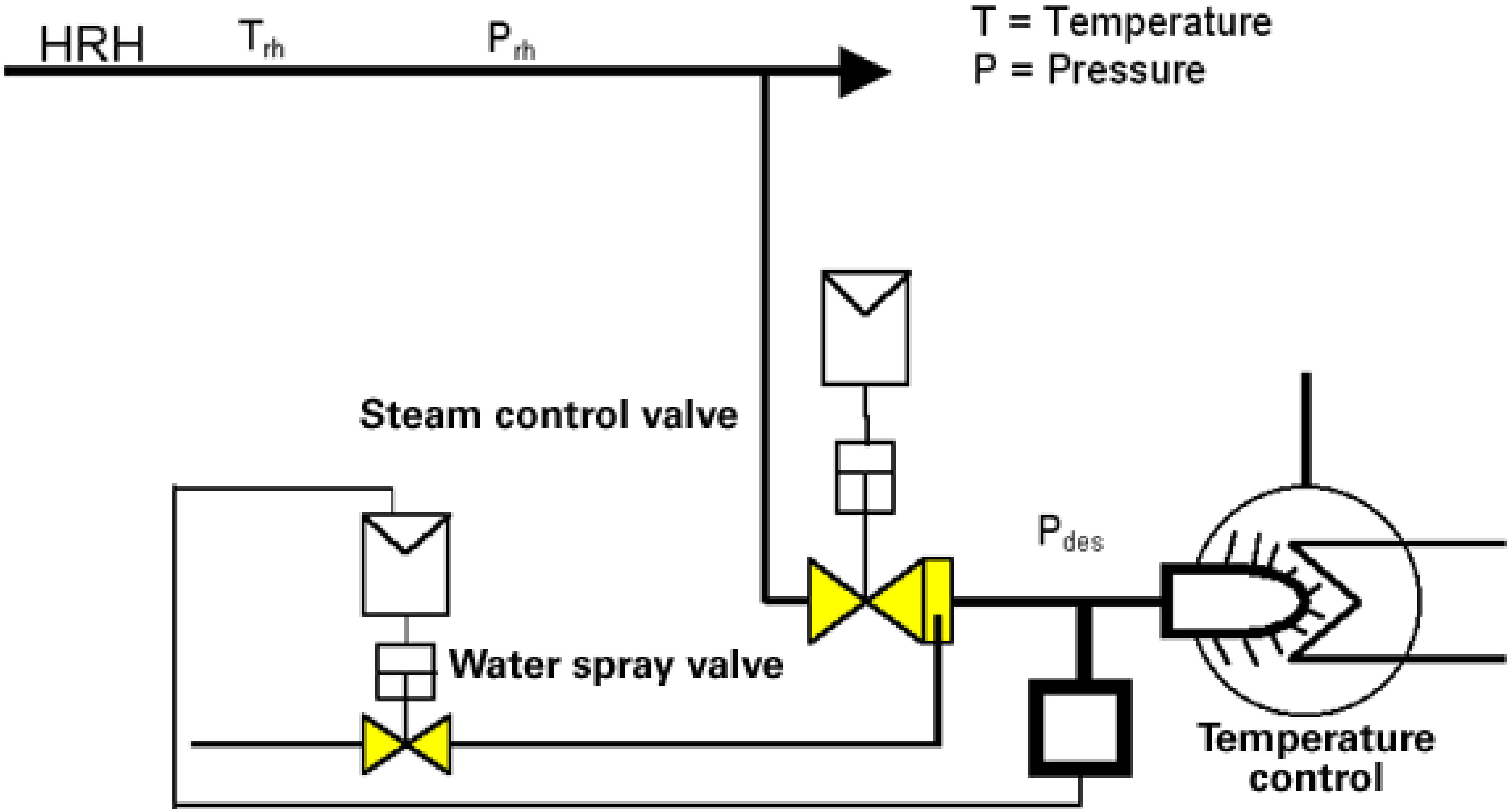
Destroys Dump Resistor: Elbow into duct and poor water control

Excess water erodes duct: Poor Control



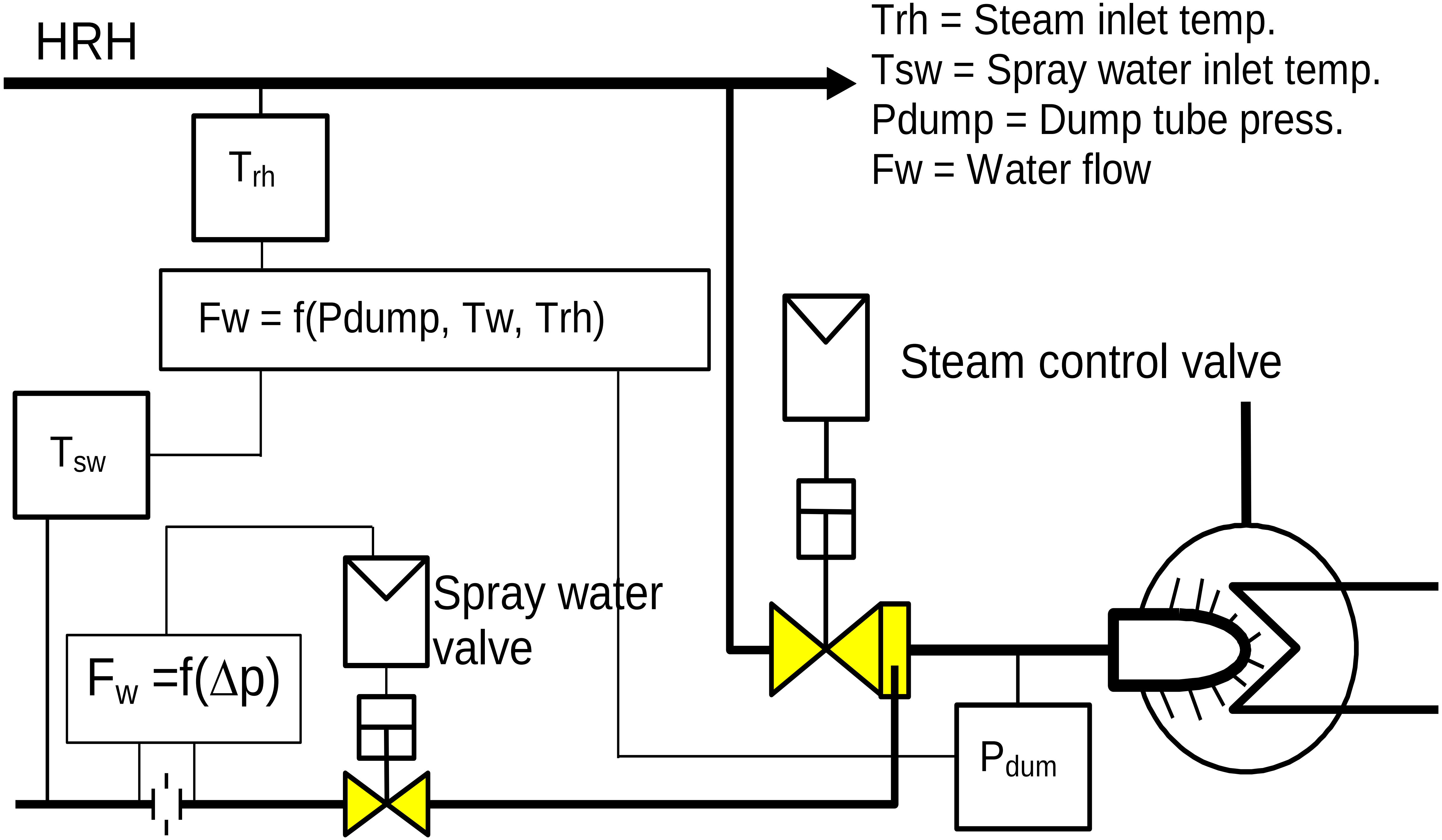
Excess Water – Cracks Pipes

Temperature Feedback – Not Possible



Enthalpy Control System – Back Press.

Trh = Steam inlet temp.
Tsw = Spray water inlet temp.
Pdump = Dump tube press.
Fw = Water flow



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Noise in Turbine Bypass Systems

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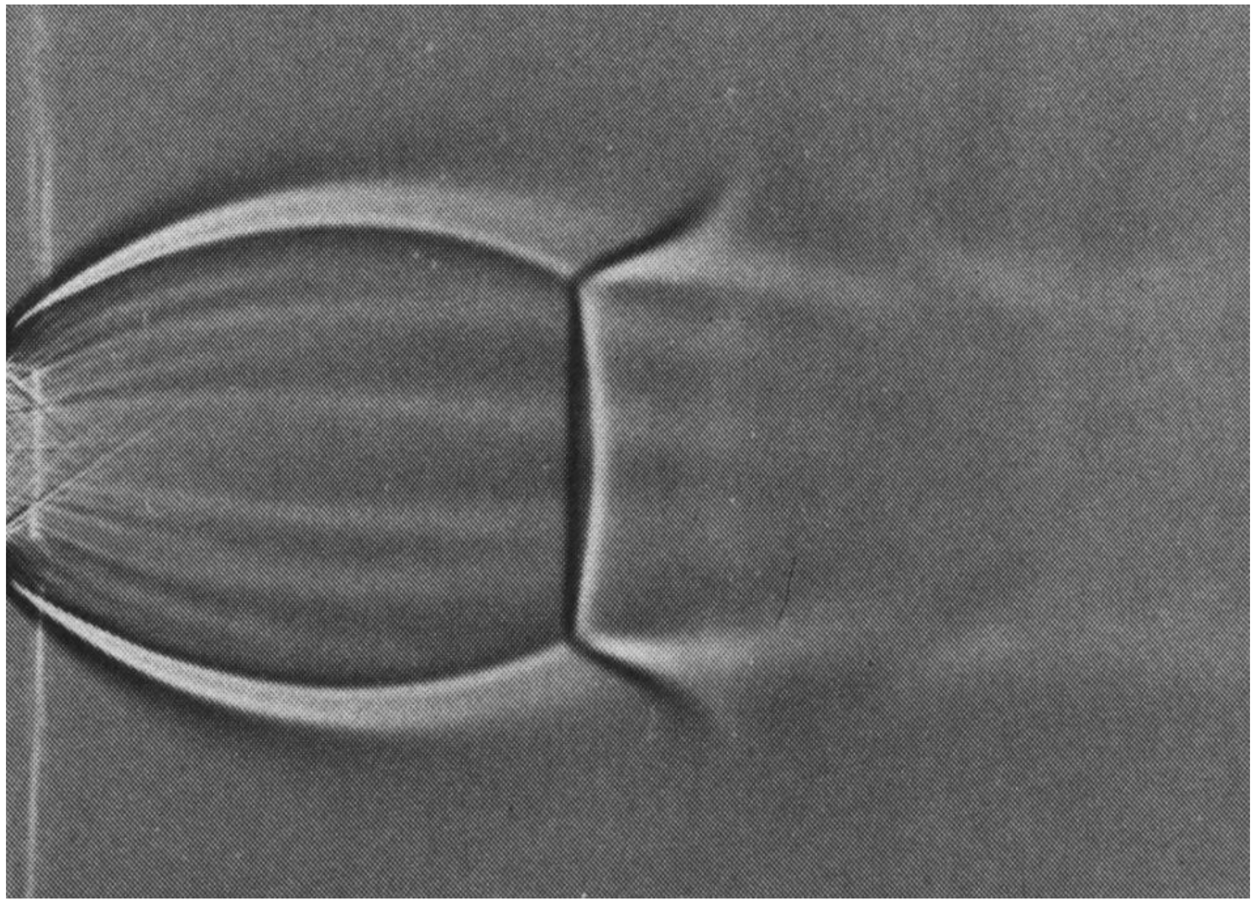
Turbine Bypass System Noise

- Methods of Prediction
  - *ISA*
  - *IEC - International Electrotechnical Commission*
  - *Modified measurements*
- The final prediction is a hybrid of many calculations
- Entire Physics of Compressible Flow Noise
  - *Generation*
  - *Acoustic field development*
  - *Transmission through pipe wall*
  - *Propagation to the measuring point*

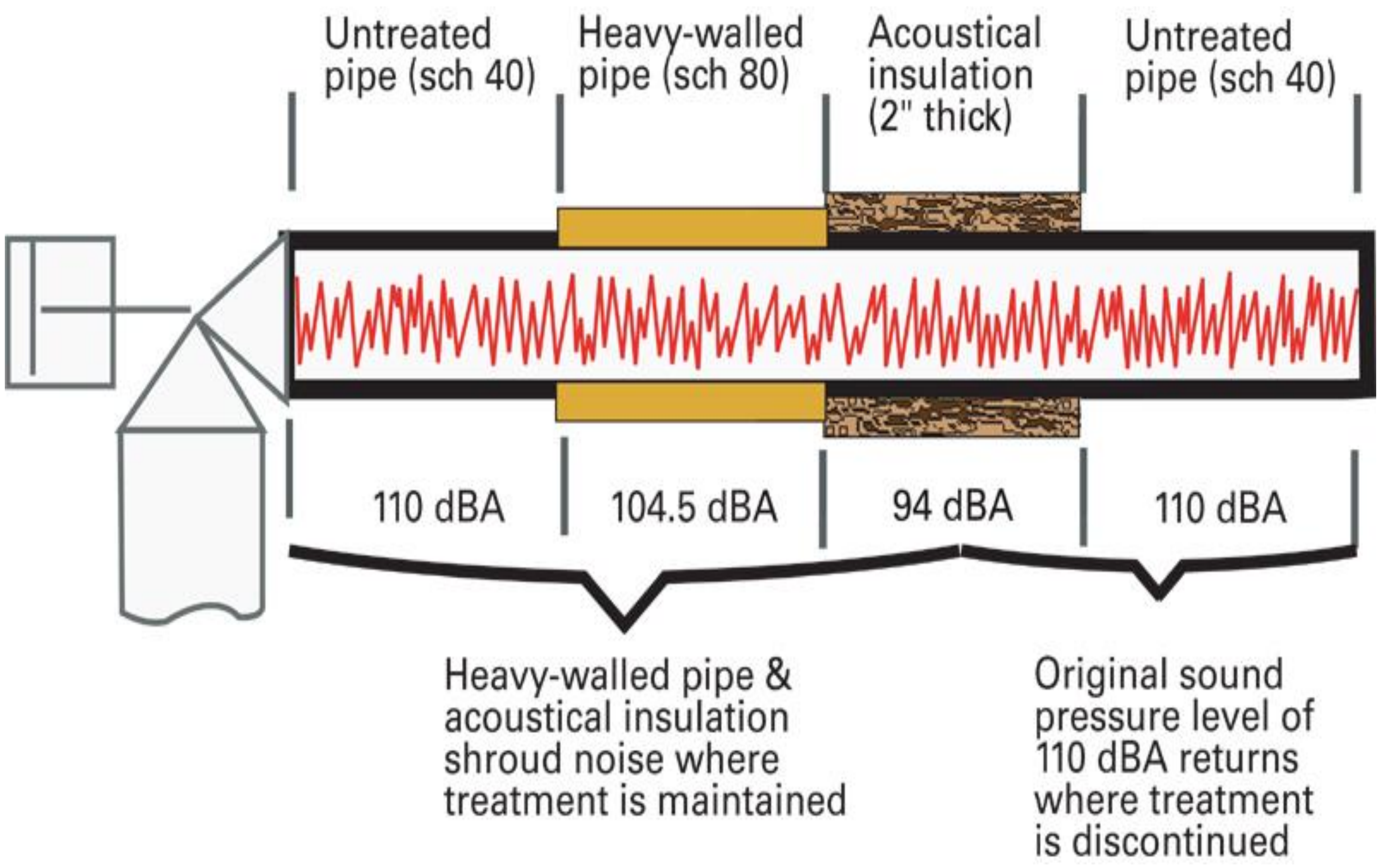
Compressible Flow Noise

- Generation/Acoustic Field Development
  - *Noise is created in compressible systems by pressure fluctuations due to jets that are dominated by:*
    - *Turbulence*
    - *Shock-cell interactions*



Compressible Flow Noise

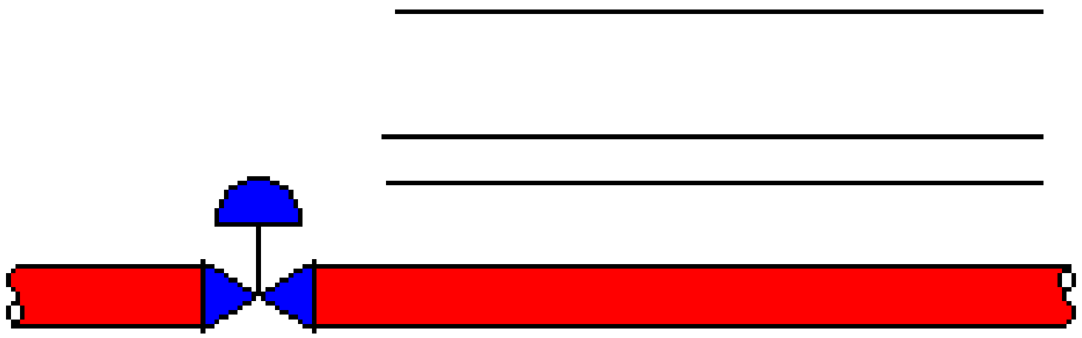
- Transmission through pipe wall
  - *Coupling of frequencies from generated noise with piping modes*



Compressible Flow Noise

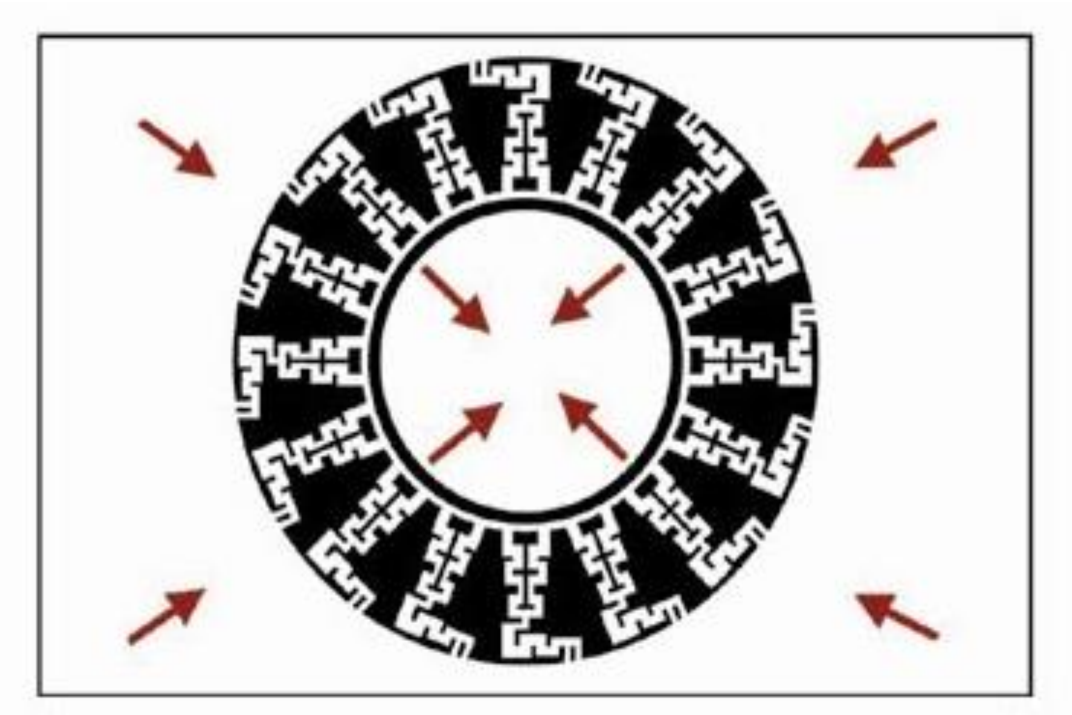
- Propagation to the measuring point
  - *Point source*
    - *Double distance results in 6 dB(A) less noise*

  - *Line source*
    - *Double distance results in 3 dB(A) less noise*

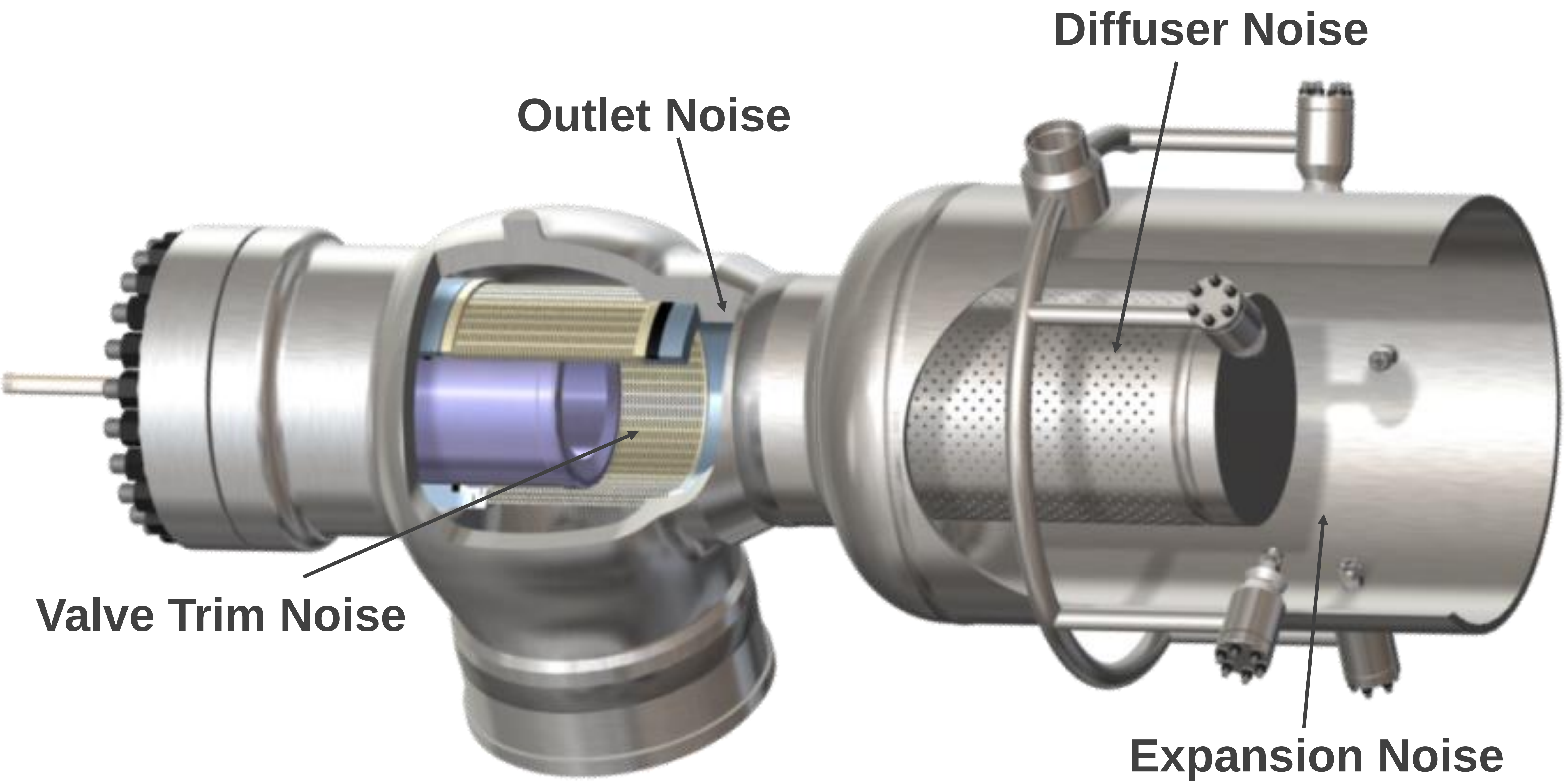


Noise Reduction

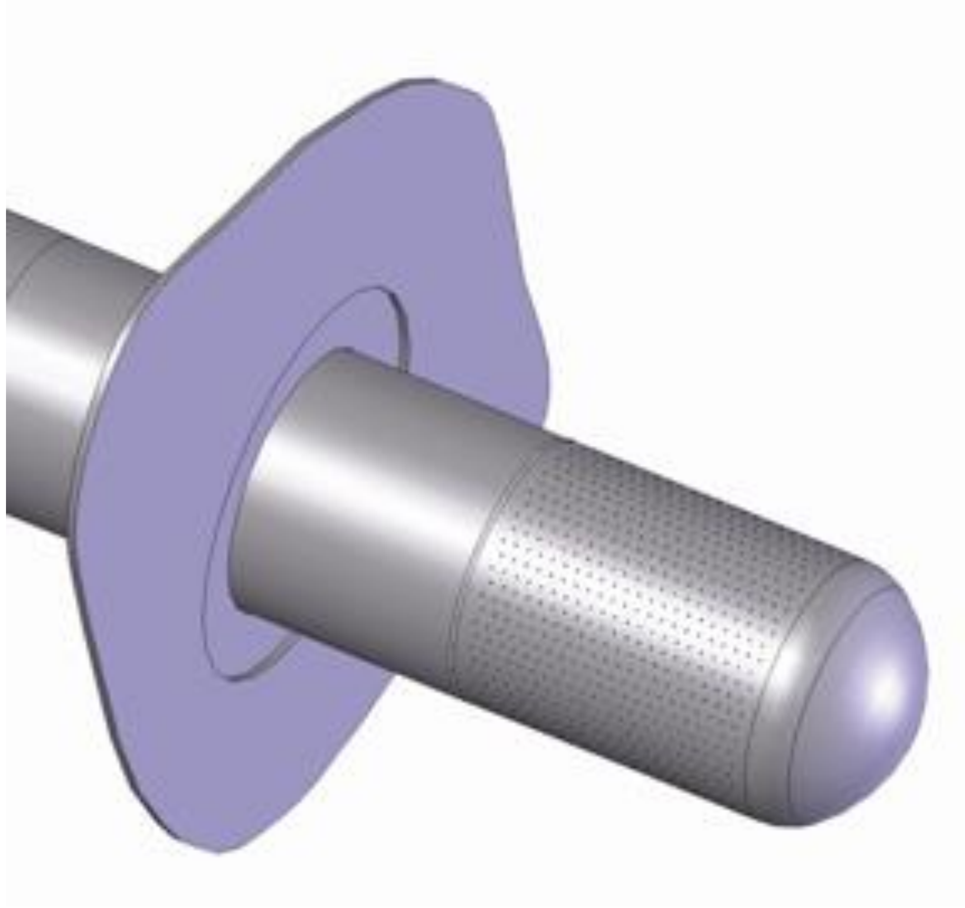
- Reduce noise by:
  - *Divide total pressure drop into multiple stages*
  - *Divide large diameter jet(s) into smaller diameter jets*
  - *Dampen the noise (absorption material)*
  - *Move further away from the noise (distance attenuation)*

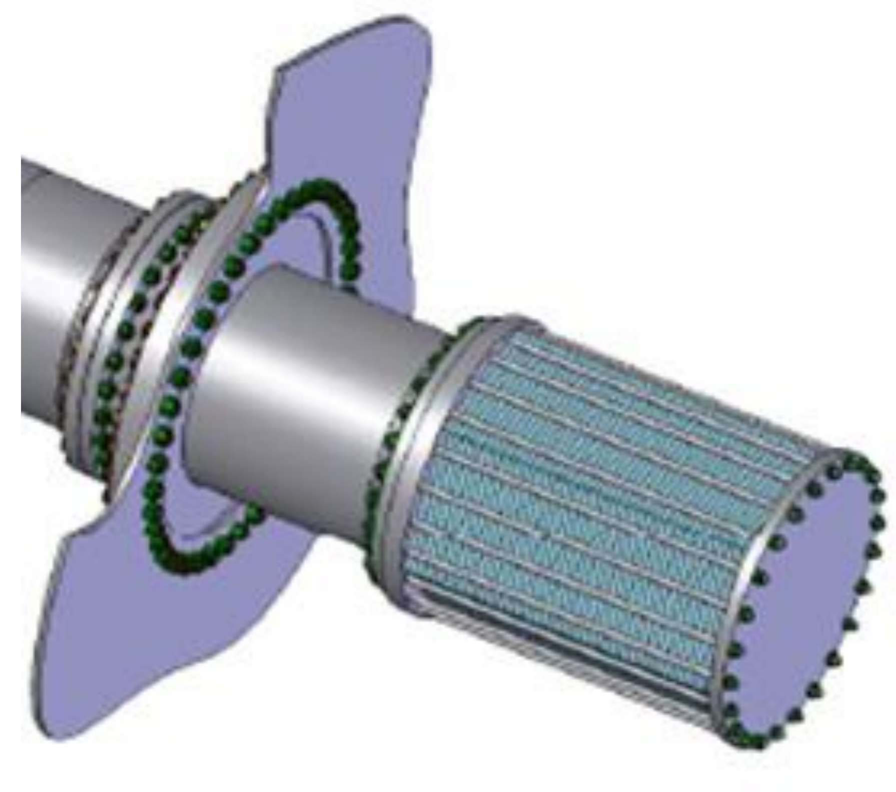


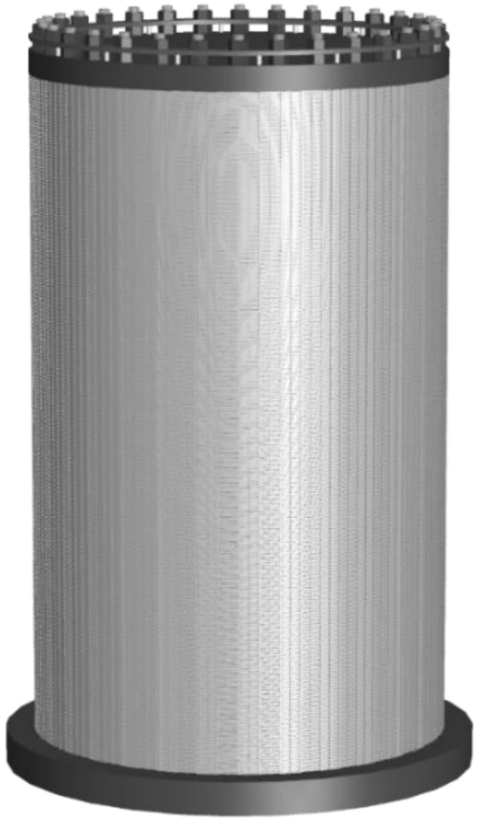
Noise Sources



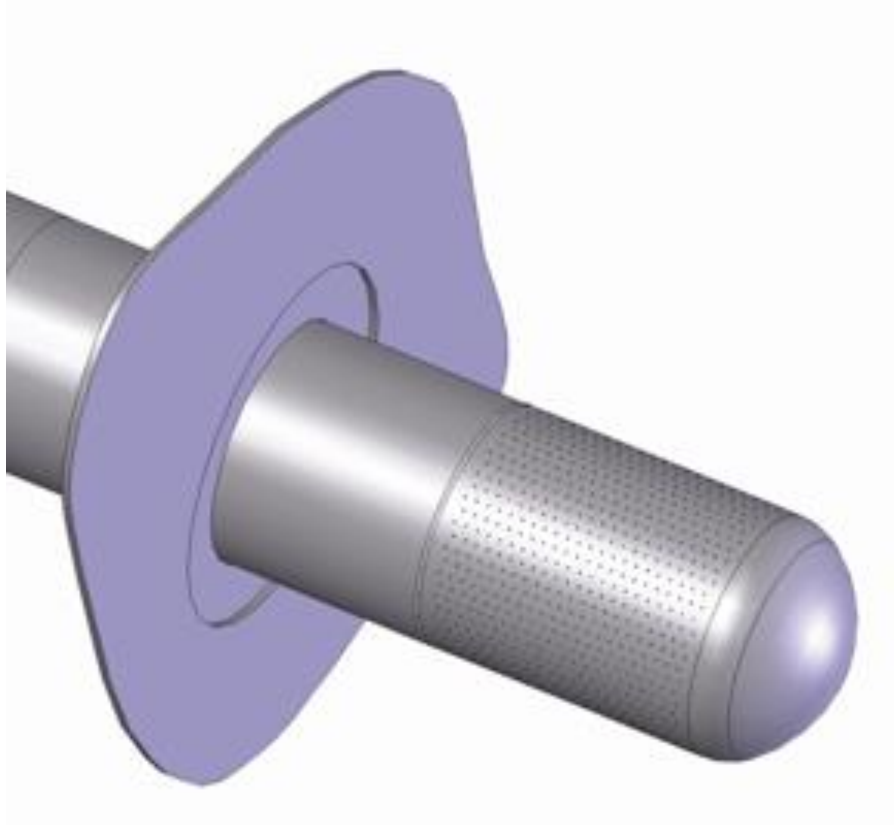
Discharge Device/Sparger/Dump Element

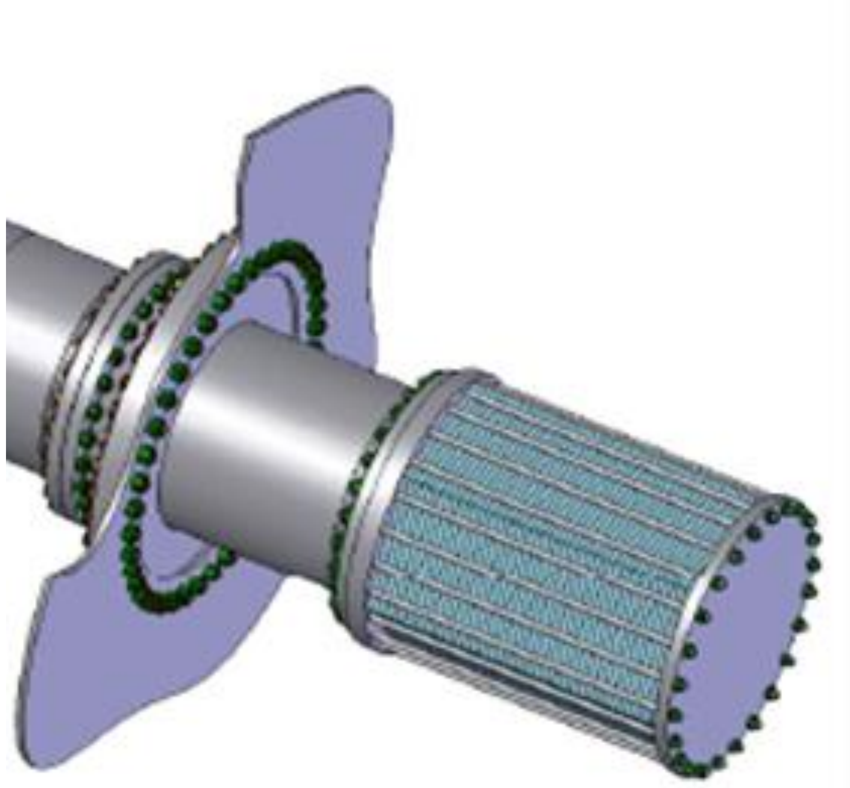


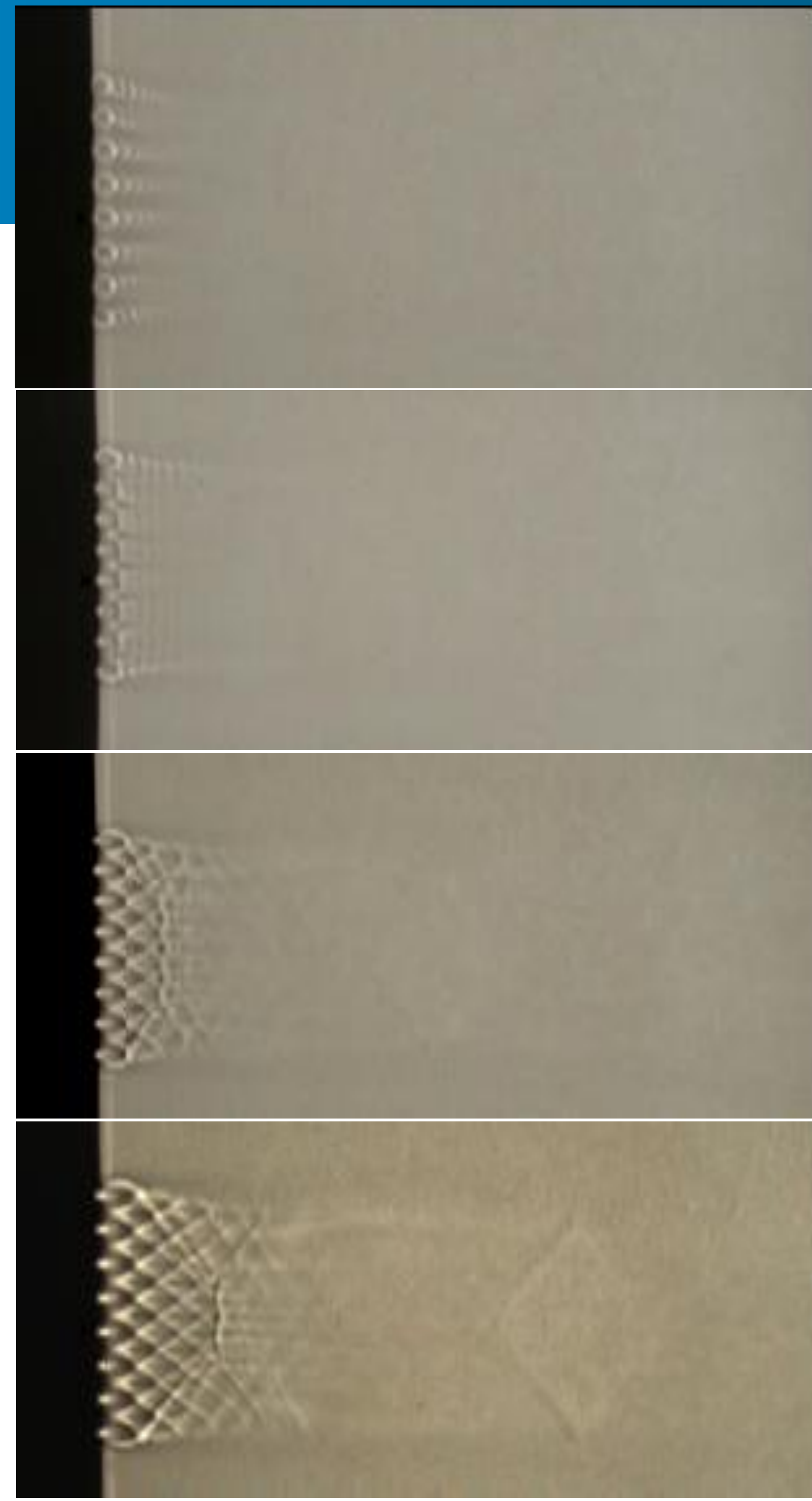




Coalescing Jets







Adding Noise Sources

$$SPL_t = 10\log\left(10^{\frac{SPL_1}{10}} + 10^{\frac{SPL_2}{10}} + 10^{\frac{SPL_3}{10}} + \ldots + 10^{\frac{SPL_n}{10}}\right)$$

dB difference between noise sources	dB to add to largest noise source
0 to 1	**+3**
2 to 3	**+2**
4 to 8	**+1**
9 or more	**+0**

All Noise Exits Here!

ACC Steam Ducts

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- Large diameter – thin walled ducts
  - *10-30 ft diameters*
  - *0.375 – 0.5 in wall thickness*
  - *Diameter to wall thickness ratio = Aluminum Can!*
- No acoustic or thermal insulation - Expensive

Impact of ACCs on TBS Noise

- Noise from multiple sources
  - *Primary discrete jet noise*
  - *Secondary merging of jets*
    - *Low condenser pressures increases potential*
- Entire bypass noise exiting from dump elements into duct
- Dump elements protruding into thin-walled ducts that easily transmit noise
  - *Especially secondary noise*
- Due to size, ducts behave like line sources for large distances
  - *Far-field noise reduction not as rapid*

Impact of TBS on ACC Design

Mounting Interface Design

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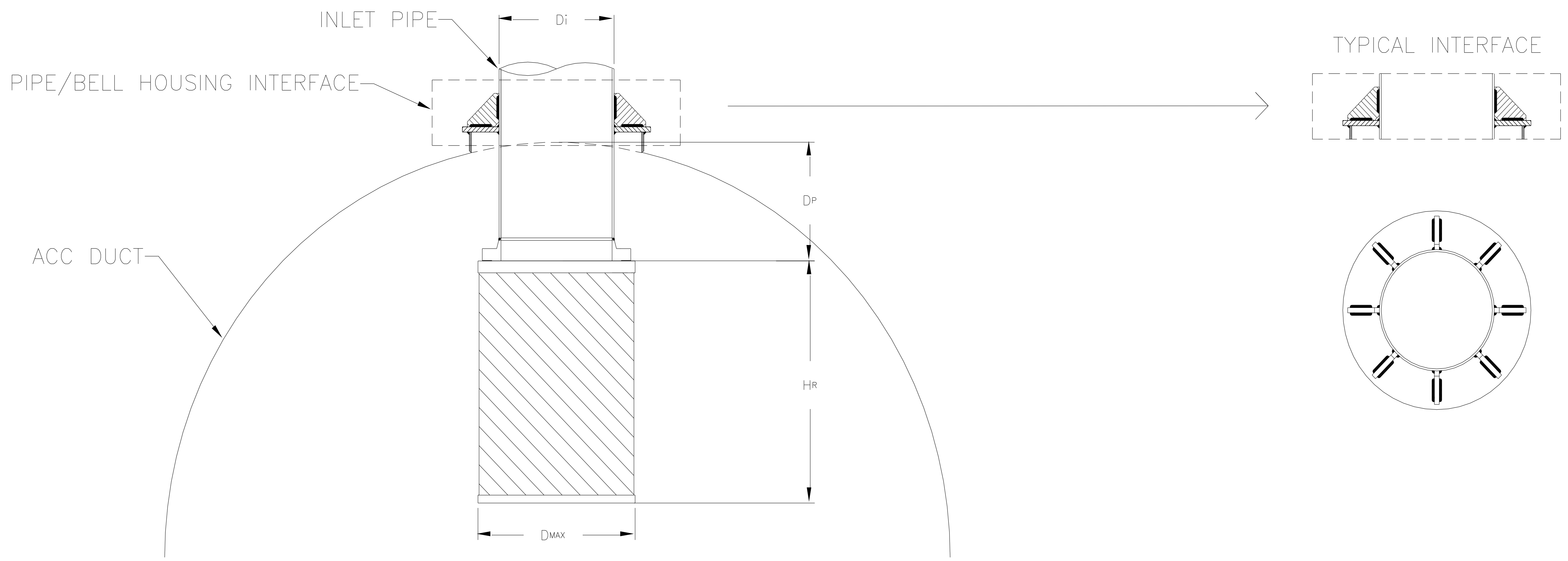
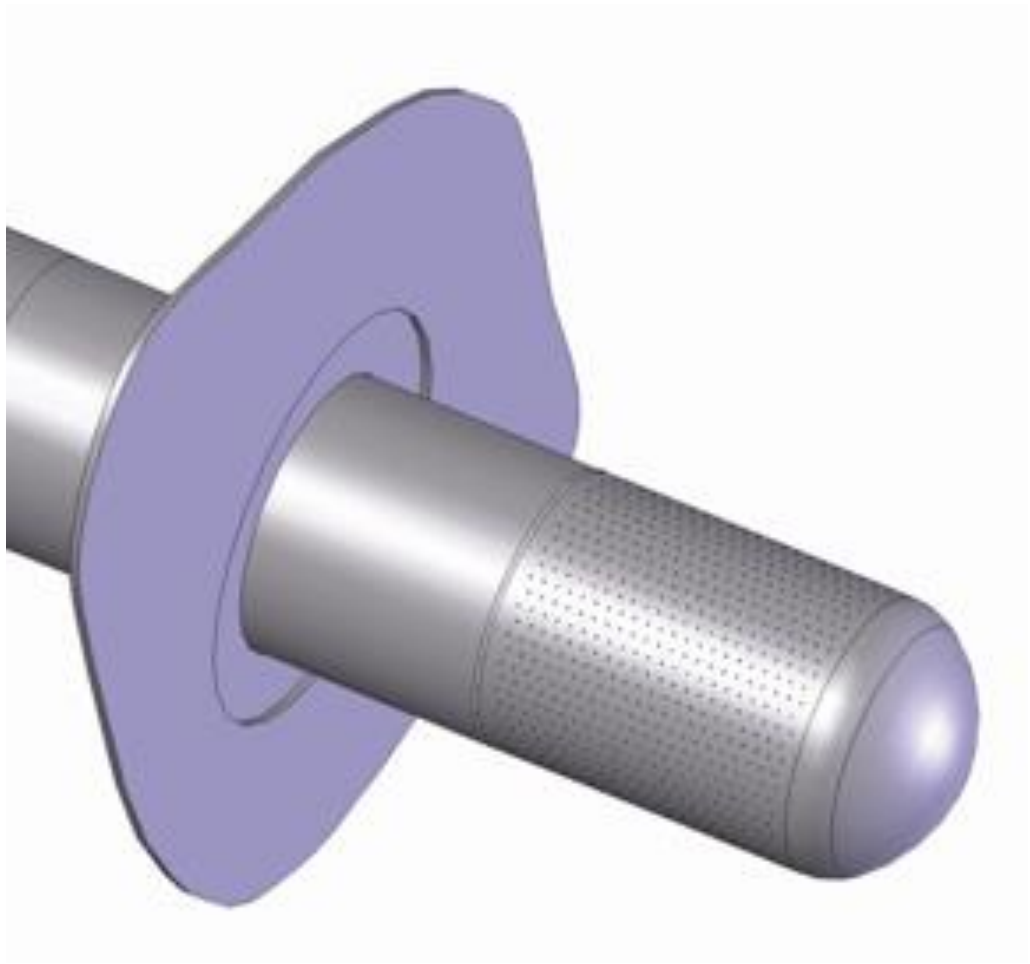
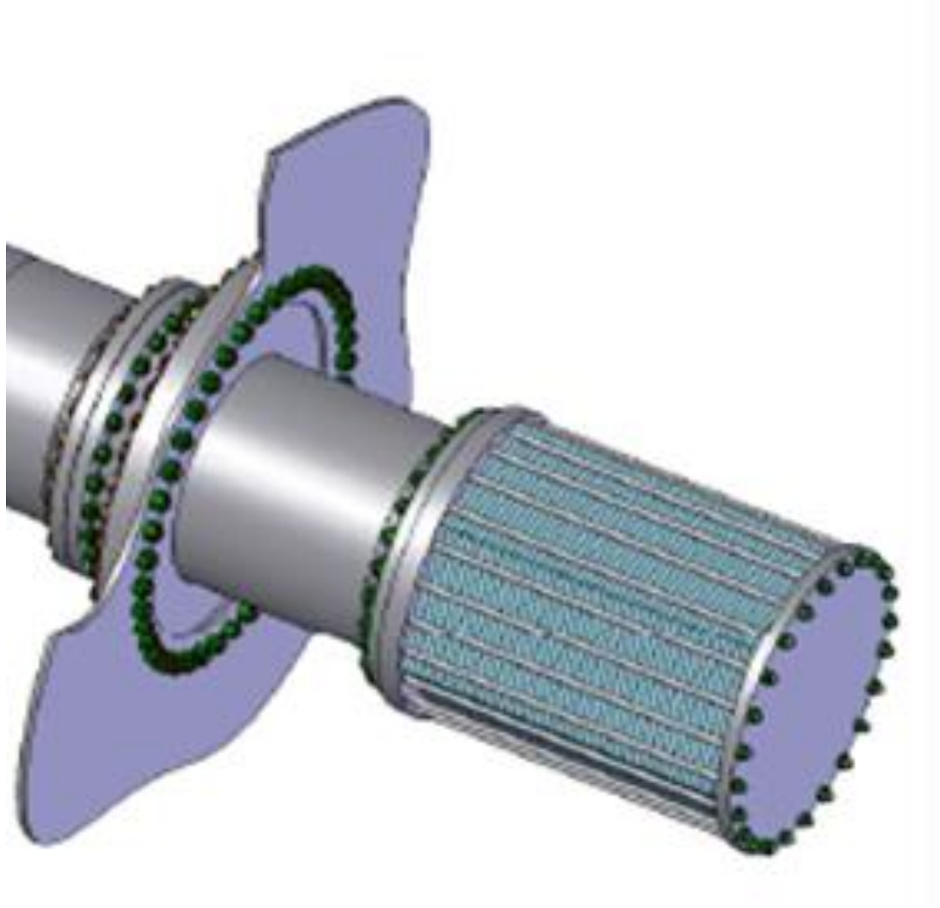


Condenser Dump Element Weight



Single stage dump tubes are essentially pipe

~150 lbs/ft for 36” SCH STD

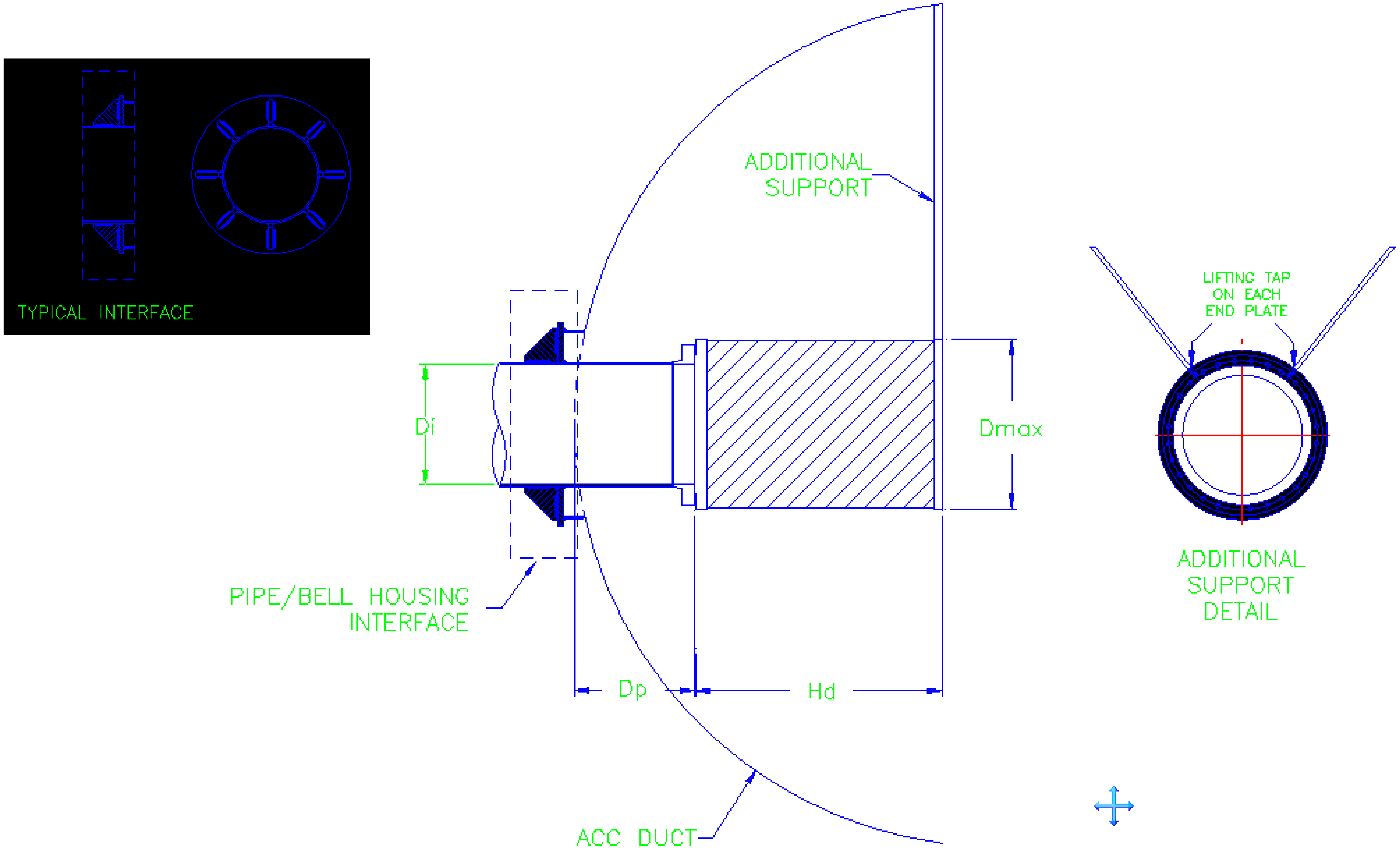


Multi-stage dump resistors are large fabricated components

~1000 lbs/ft for 42” Resistor

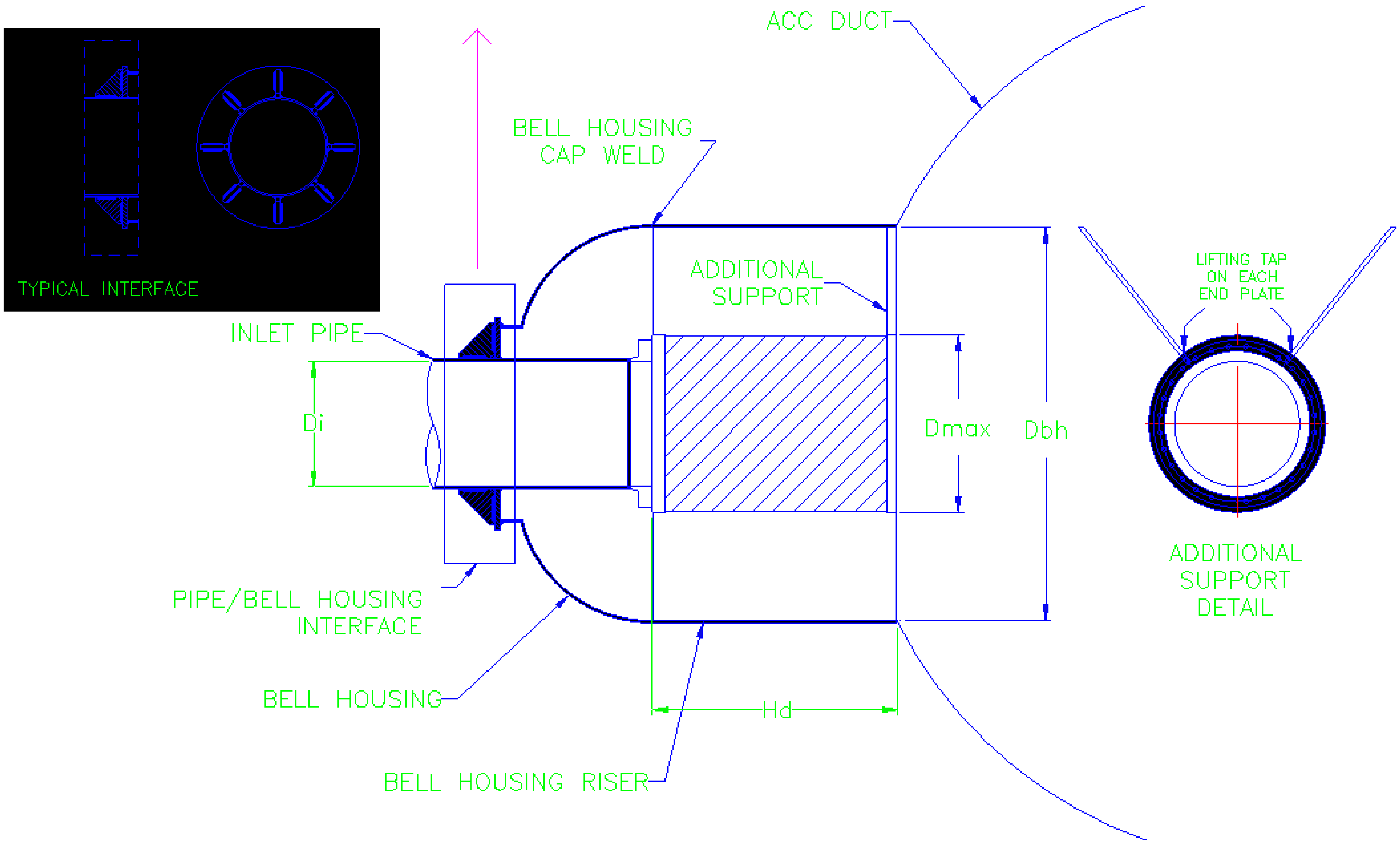
Condenser Dump Element Weight

- Supports typically required for multi-stage condenser dump device
- Affects loading at nozzle connection



Bell Housings/Domes

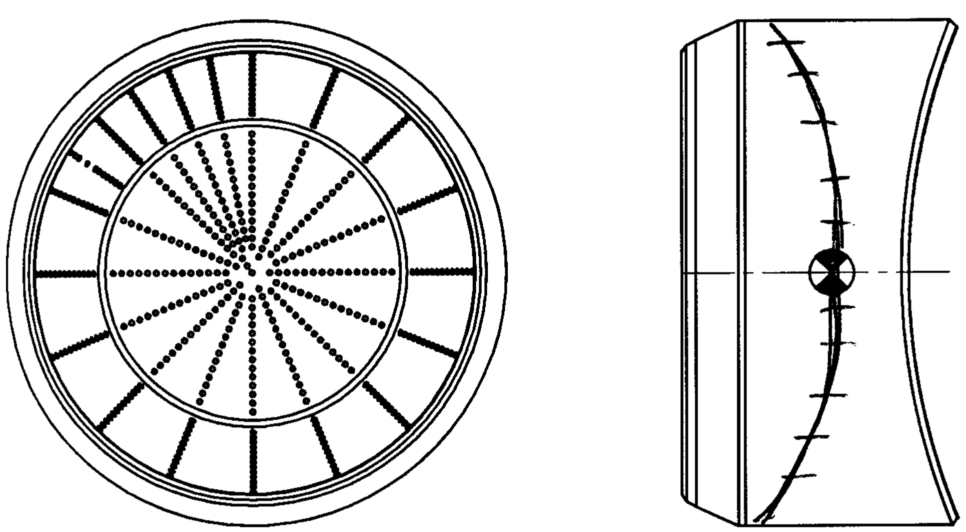
- Diameter driven by noise considerations
- Height driven by duct blockage limitations and length of condenser dump device



Historical Experience

Case Study 1 (2002)

- 779 MW, 2x2x1 CCPP
- HRH system using single-stage dump tube (0.47” holes)
  - *At 155 MW gas turbine load, measured noise 3 meters from duct was 115.0 dBA → **SEVERE VIBRATION OF DUCT***
  - *Cracking of duct and reinforcement rib welds (in 30 minutes of operation)*
- Dump tube re-designed with cylindrical discharge (0.24” holes)
  - *Noise decreased to 106.6 dBA, vibration eliminated*
  - *Local residences complaining of the noise. Estimates for acoustic installation were $2.0M. Does not include efficiency losses of insulating duct.*



Rib Weld Cracking

Duct Wall Cracking

Case Study 2 (2002)

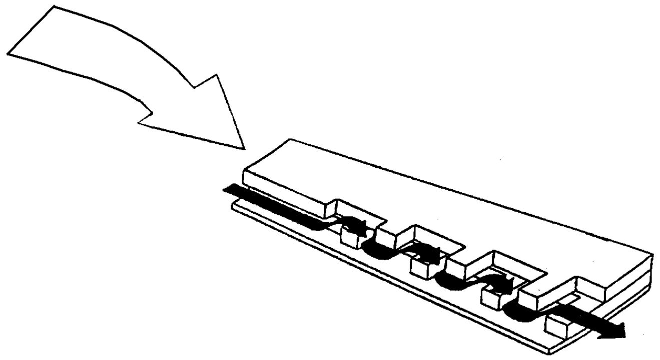
- 542 MW, 2x2x1 CCPP
- HRH system using single-stage dump tube (0.47” hole size)
- Due to previous knowledge, dump tube re-designed with cylindrical discharge (0.24” hole size)
  - *Measured noise 3 meters from duct was 110 dBA*
- Local residences complaining of the noise (nearest residence located 0.62 miles away)
  - *Start-ups and shutdowns occurring daily early morning/late at night*
  - *Requested noise reductions of 25-45 dBA.*

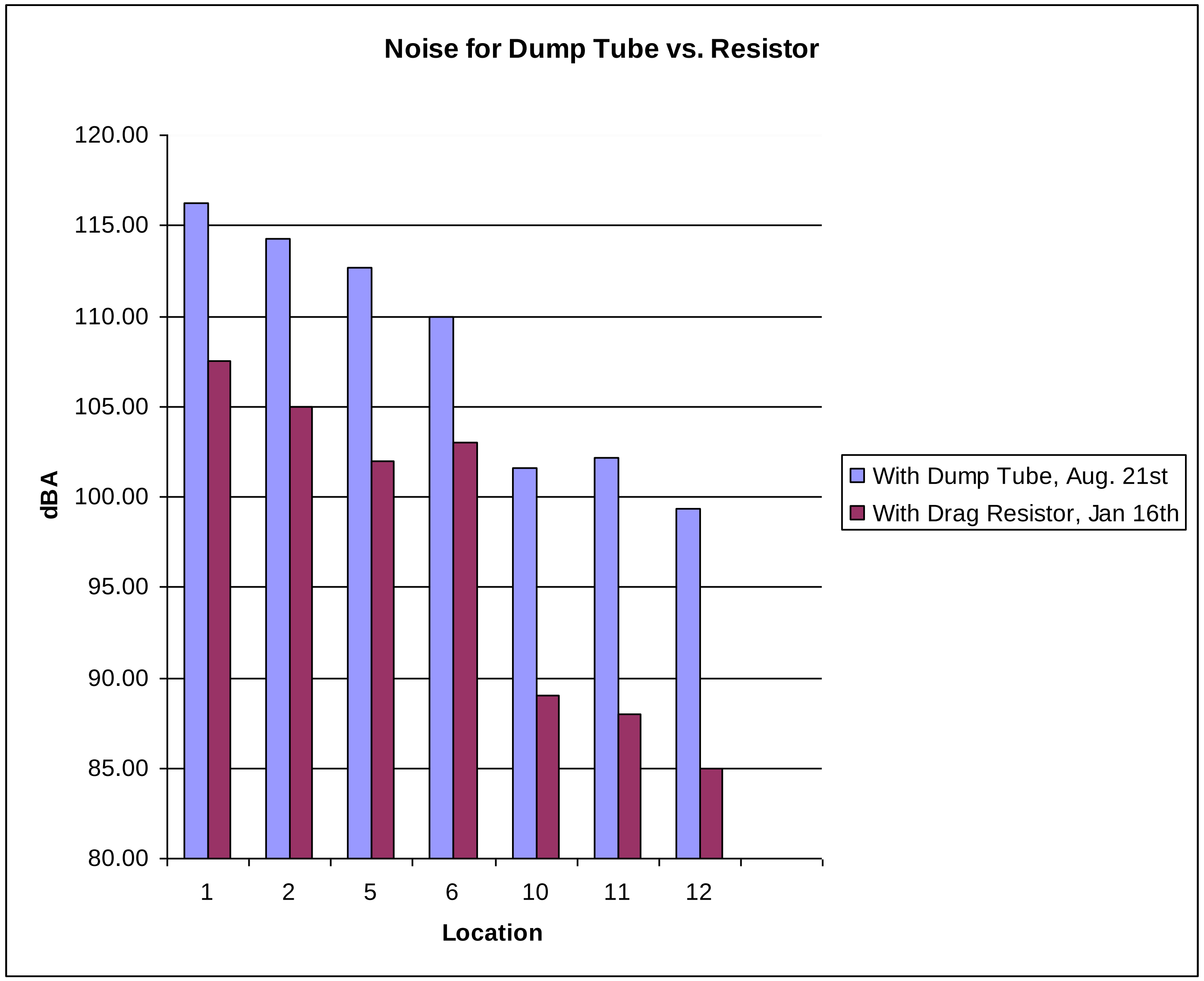
Original

Replacement 1

Case Study 2 (2002)

- Modified HRH bypass valve for reduced noise (reduced hole size in cage from 0.69" to 0.157")
- Replaced single stage dump tube with 16 stage DRAG® resistor
  - *9 dB noise reduction (near-field)*
  - *20+ dB noise reduction (far field)*





Acoustically-Induced Vibration

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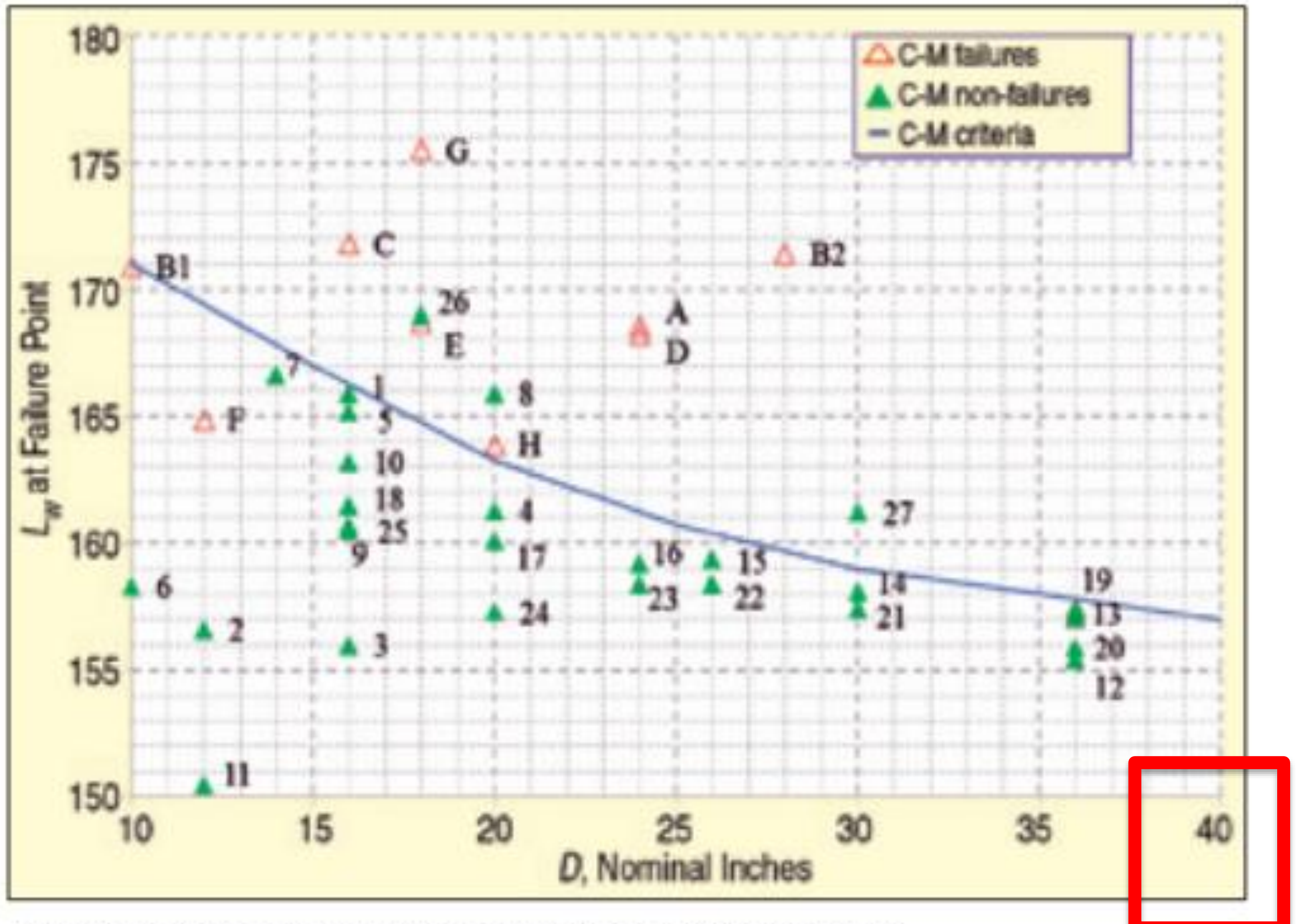

Figure 1. Carucci and Mueller data and criteria curve.

150 – 160 dB (Internal Sound Power) typical for single-stage valves and single-stage dump tubes (~100-110 dBA external Sound Pressure Level)

Assume duct size:

- 10 ft (3048 mm)
- 0.5” (12.7 mm) thk wall

D/t = 240

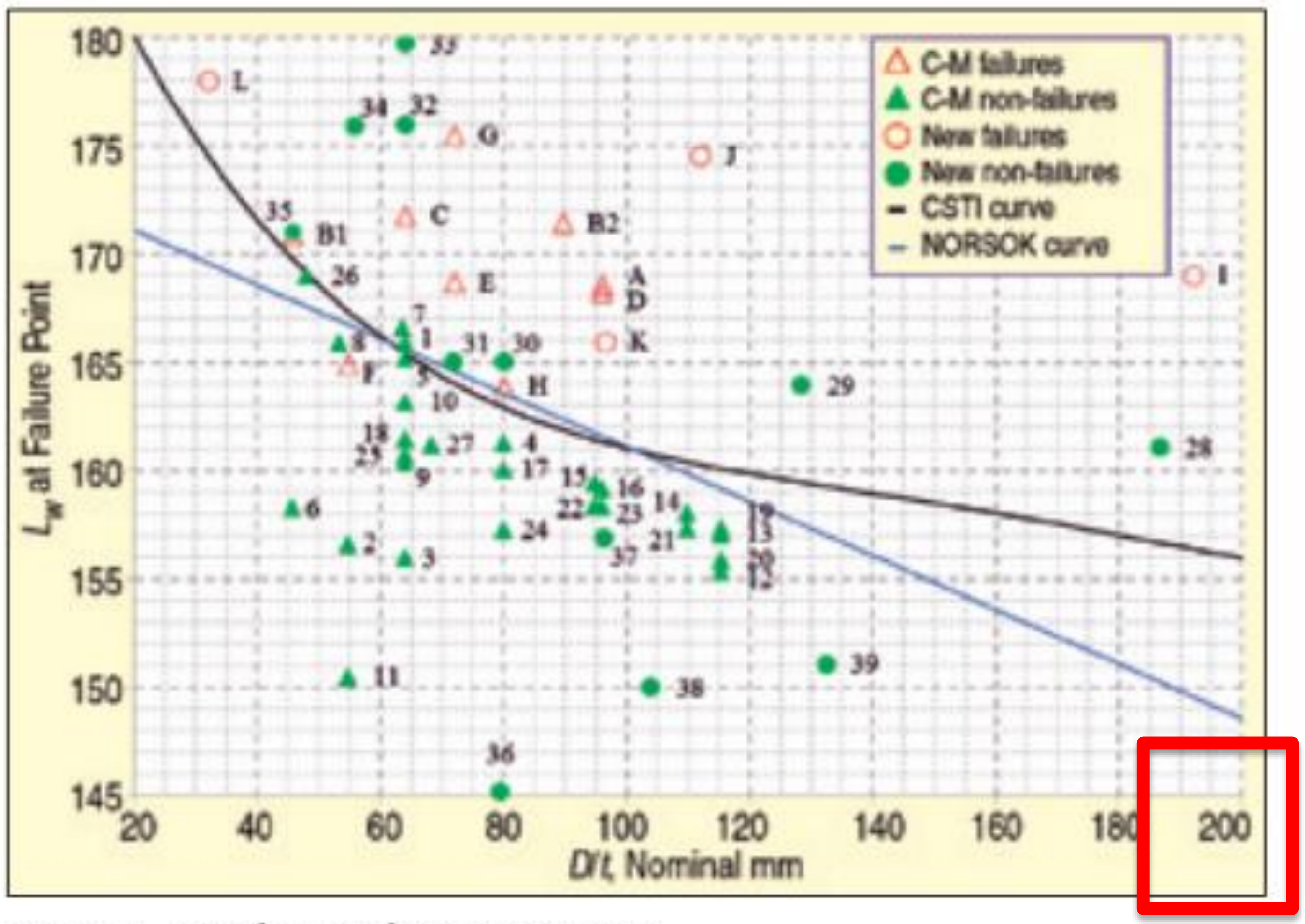

Figure 2. AIV data and criteria curves.

Reference: *Solving Acoustic-Induced Vibration In The Design Stage* Robert D. Bruce, Arno S. Bommer & Thomas E. LePage, CSTI Acoustics, Houston Texas

Questions / Comments