Enertech Post Fukushima Technologies for BWR Mark I & II Hardened Containment Vent

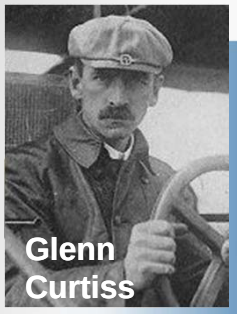
Enertech, a business unit of
Curtiss-Wright Flow Control Company

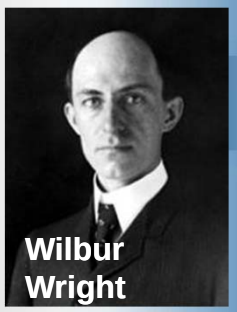
Enertech Hardened Vent Capabilities

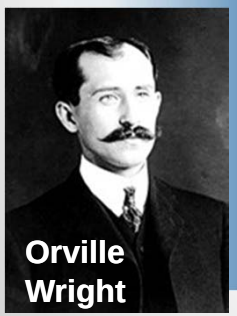
Presentation Outline

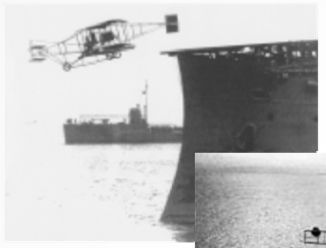
- Enertech/Curtiss-Wright Company Overview
- Summary of Fukushima Hardened Vent Failure
- Site Specific Approaches to NRC Order EA-12-050
- Enertech Hardened Vent Solutions
  - EA-12-050, Section 3 Operation Characteristics, 1.2.1 through 1.2.6
- Enertech Flex Capabilities

Curtiss-Wright: Our History…Our Heritage


Glenn Curtiss


Wilbur Wright


Orville Wright



First Carrier Launch / Landing

Glenn Curtiss

1903

First Powered Flight

Wright Brothers

1910-11

1929

Curtiss-Wright formed; merger Wright Aeronautical Corp. and the Curtiss Aeroplane and Motor Company

CW LISTED NYSE

1939-1945

Curtiss-Wright major manufacturer of aircraft and components

1952

Expands into flow control business supporting US Naval Nuclear Program; USS Nautilus

1957

Provided equipment to Shippingport Atomic Power Station - US first commercial nuclear power plant

Curtiss-Wright Business Segments

Over 85 years of innovative solutions and high performance

2012: $2B

CURTISS WRIGHT Flow Control Company

$1B
50%
Power Generation,
Oil & Gas,
Naval Defense,
Aerospace.

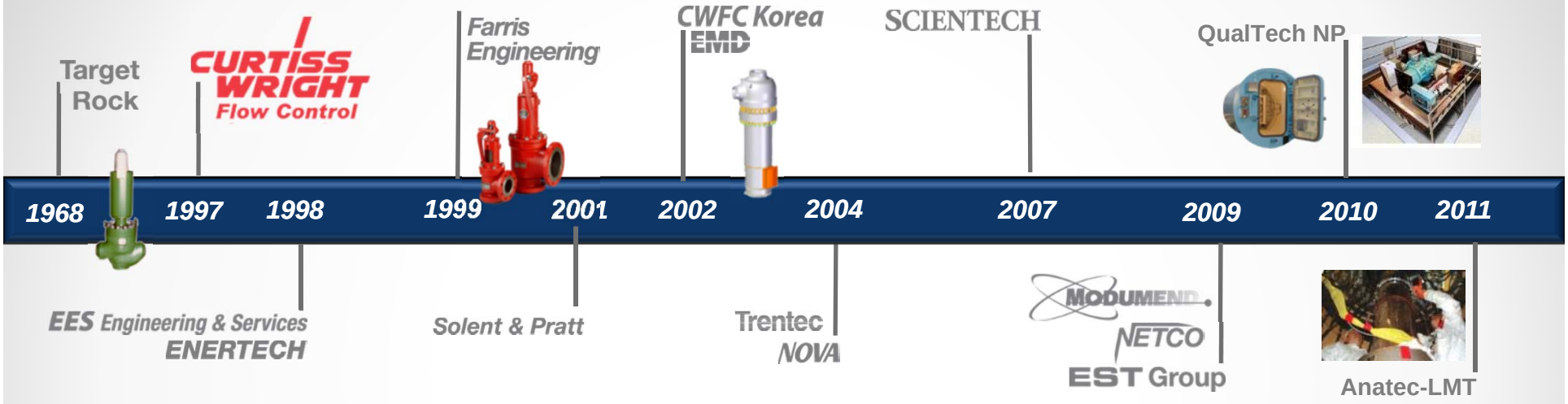
CURTISS WRIGHT Controls

$0.7B
35%
Defense,
Aerospace,
Government.

CURTISS WRIGHT Surface Technologies

$0.3B
15%
Aerospace,
Defense,
Power Generation,
Oil & Gas

Nuclear Focused Growth

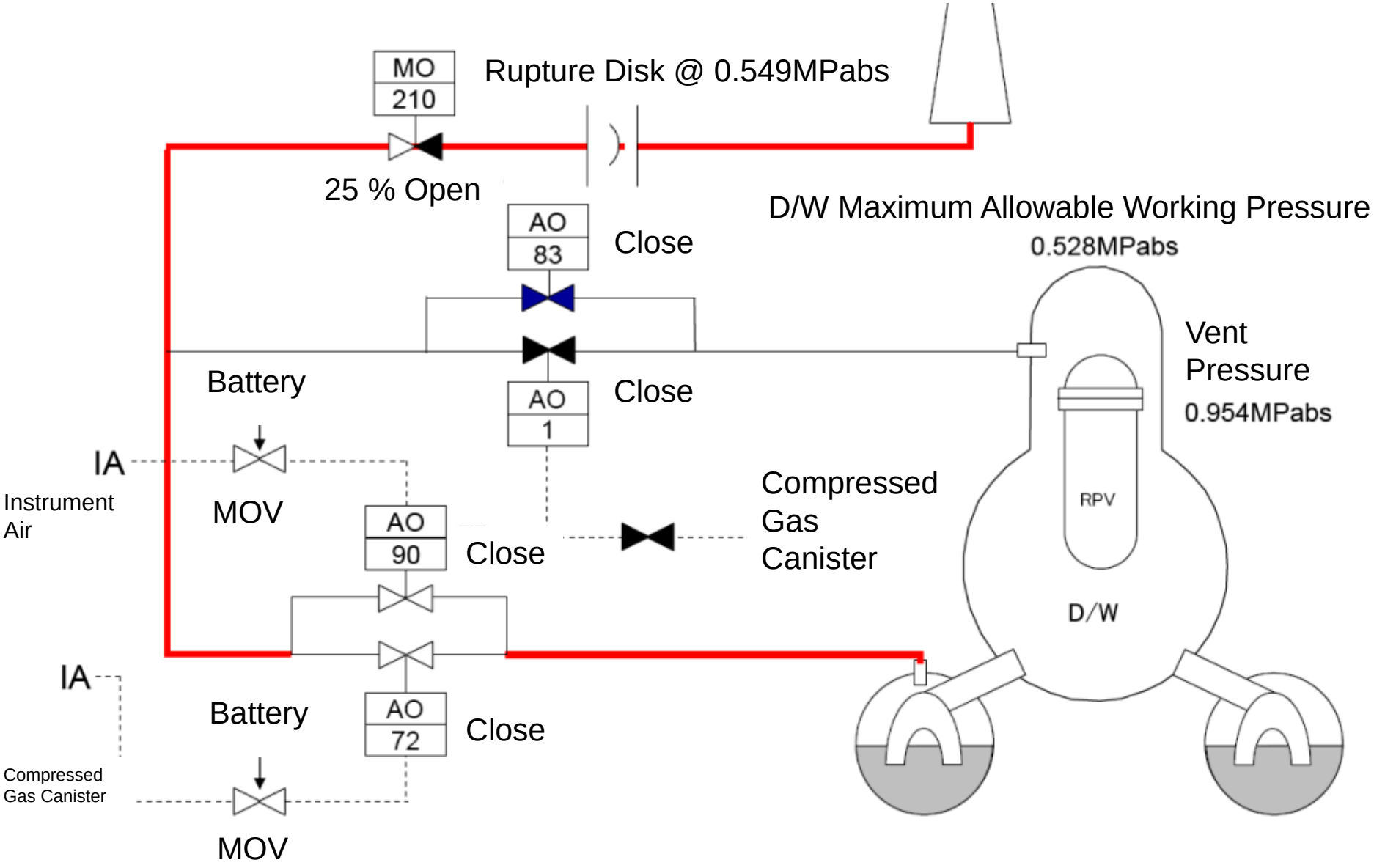


2012

- **10 Nuclear Focused Business Units**
  Anatec-LMT, EMD, EST Group, Enertech, Farris, NETCO, Nova, QualTech NP, Scientech, TargetRock
- **ASME Certificates** N NPT NV NA NS **NUPIC and NIAC Auditied**
- **Core Competencies – Operating and New Construction**
  EQ/CGD, Engineered Solutions, Component Supplier (valves, pumps, instrumentation, fasteners), Fabricated Engineered Products (SG nozzle dams, airlocks, hatches), Obsolescence Solutions, Engineering Programs, Nuclear Power Plant and Outage Support Services

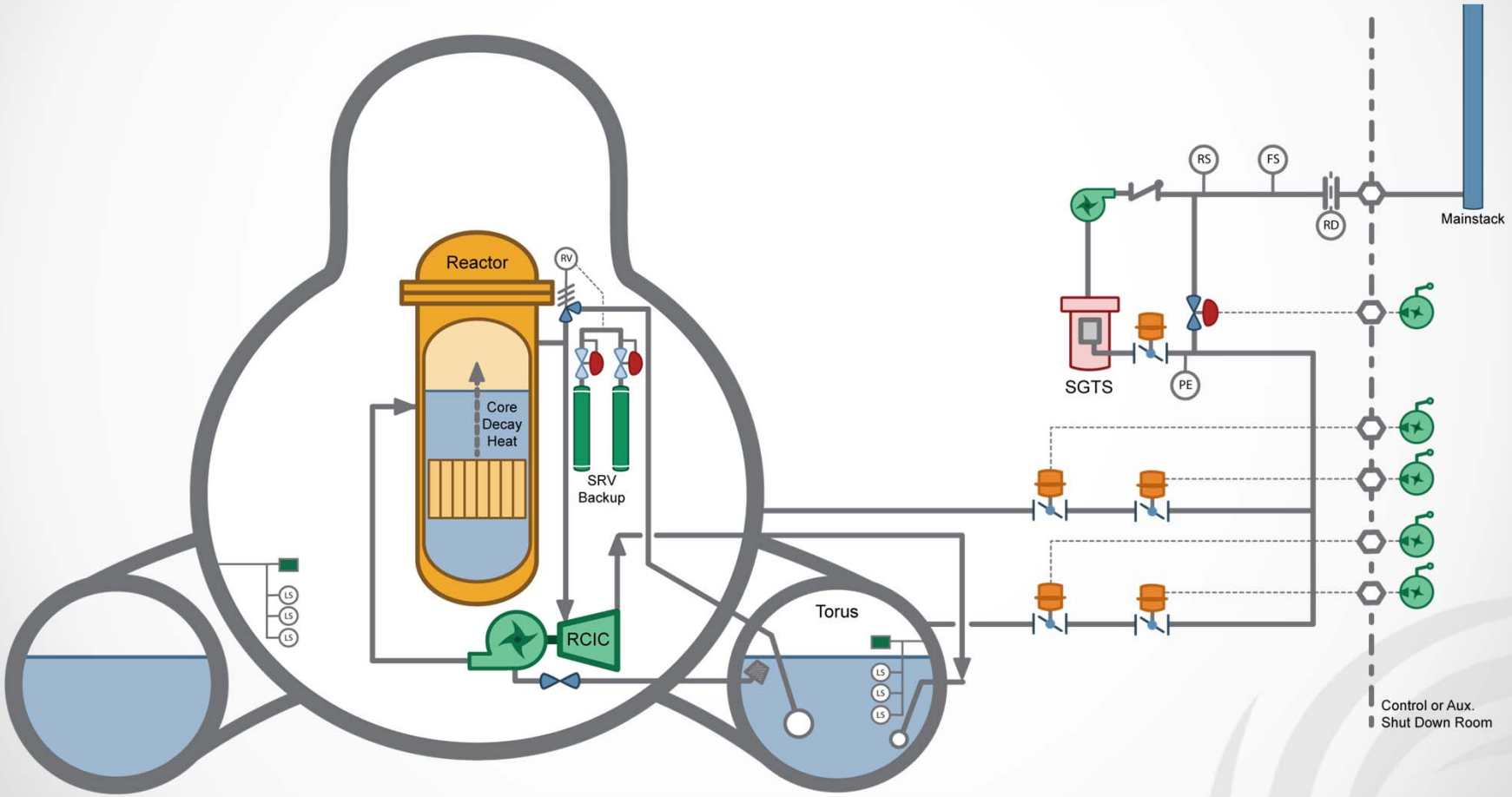
Fukushima Hardened Vent Failure

Measure to Reduce Pressure of Primary Containment Vessel



Enertech Hardened Vent Capabilities

Hardened Containment Vent System for Prolonged Station Blackout



Requirement 1.2.1- Capacity to Vent

1.2.1 – The HCVS shall have the capacity to vent the steam/energy equivalent of 1 percent of licensed/rated thermal power (unless a lower value is justified by analyses), and be able to maintain containment pressure below the primary containment design pressure.

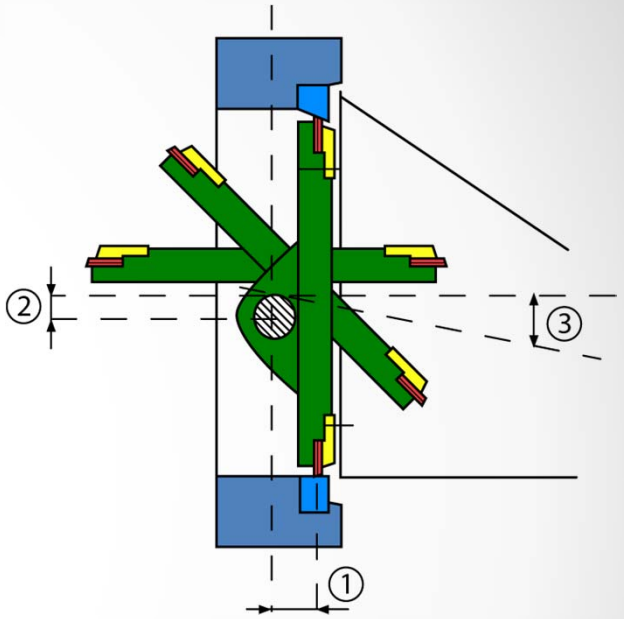
The Enertech Solution:

- Metal Seated, Triple Offset Butterfly with Operator
  - Class VI Shut-Off
  - Tested in Accordance with Appendix J Requirements
- Optional Sharktooth™ Trim for Pressure Let Down
  - Improved Throttling and Control Capabilities
  - Smaller Envelope Dimension
  - Combined with Outboard Containment Isolation Valve
- Reduced Port Control Ball Valve for Pressure Let Down
  - Metal Seated, Control Ball Design

Requirement 1.2.1- Capacity to Vent

Triple Offset Butterfly Valve – Theory of Operation

- Triple Offset Geometry – Non Rubbing Rotation of the Segment Resulting in Less Wear, Longer Life, and Tighter Shut-Off
  - Offset #1 - The Shaft Centerline is Offset Away from the Centerline of the Sealing Surface
  - Offset #2 - The Shaft Centerline is Offset from the Pipe/Valve Centerline to Provide the Camming Action
  - Offset #3 - The Inclined Angle on the Conical Disc Allows for Simultaneous Engagement of the Seal to the Seat Ring



- Zero Leakage is Achieved When the Torque Generated by the Actuating Mechanism is Allowed to Flex the Metal Seal within its Elastic Limit

- The Laminated Seal Uses the Seat Ring as the Stopping Point, Eliminating Mechanical Stops

Requirement 1.2.1- Capacity to Vent

Triple Offset Butterfly Valve - Benefits

- Resilient Metal Seat
  - Torque of Actuating Mechanism Compresses the Seal Ensuring that the Seat and Seal Are Perfectly Matched
- Zero Leakage
  - Provided with Class VI Shutoff and Will Meet the Requirements of Appendix J
- Stainless Steel Seat and Graphite Seal
  - Not Susceptible to Seat Damages Commonly Found in Soft Seats
- Seat and Seal Ellipsoidal Geometry
  - Allows the Seal to Touch the Seat with a Uniform Contact Angle
- Throttling and Isolation Capabilities

Requirement 1.2.1- Capacity to Vent

Extensive Appendix J Application Experience

- Containment Isolation Butterfly Valves
  - BIF Rubber Lined Valves
  - Jamesbury Double Offset Valves
  - PermaSeat SP Triple Offset Valves
  - Over 2000 BFVs Installed in the Worldwide Nuclear Power Industry

- Containment Isolation Check Valves
  - NozzleCheck Axial Flow Check Valves

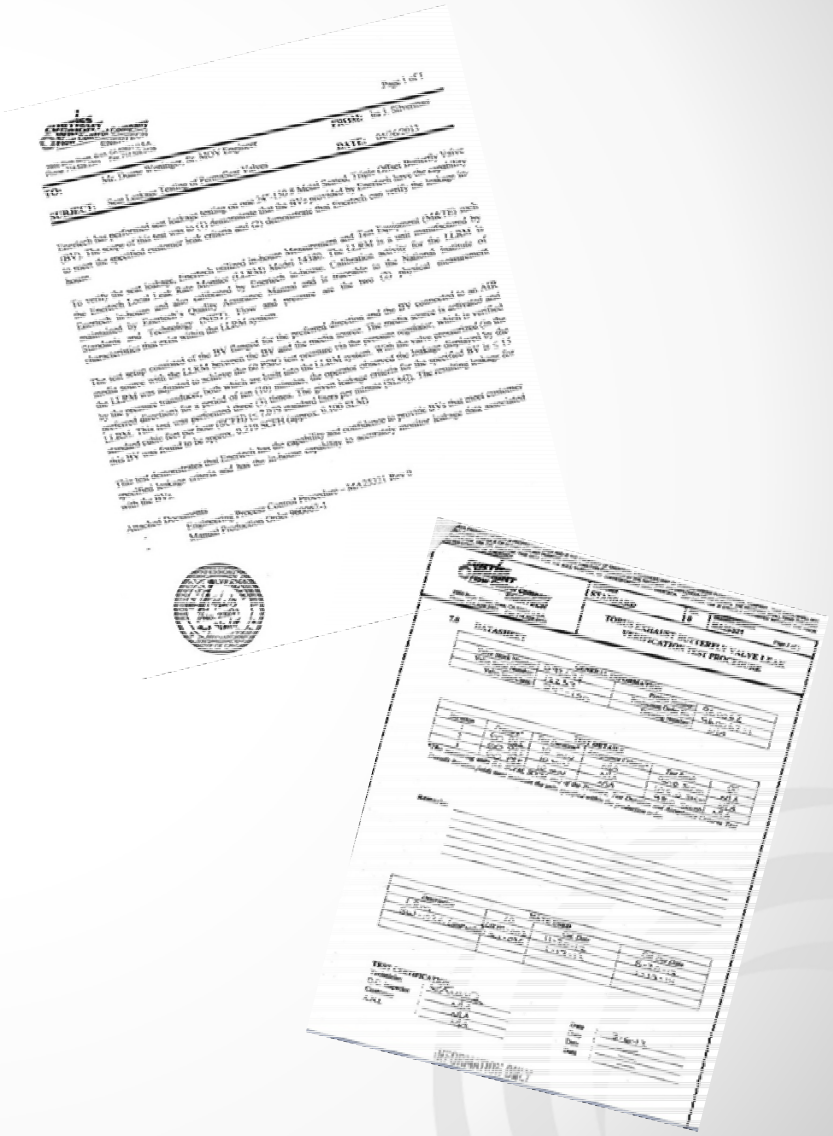
- Volumetric Leak Rate Monitors

- Qualtech Electrical Penetrations

Requirement 1.2.1- Capacity to Vent

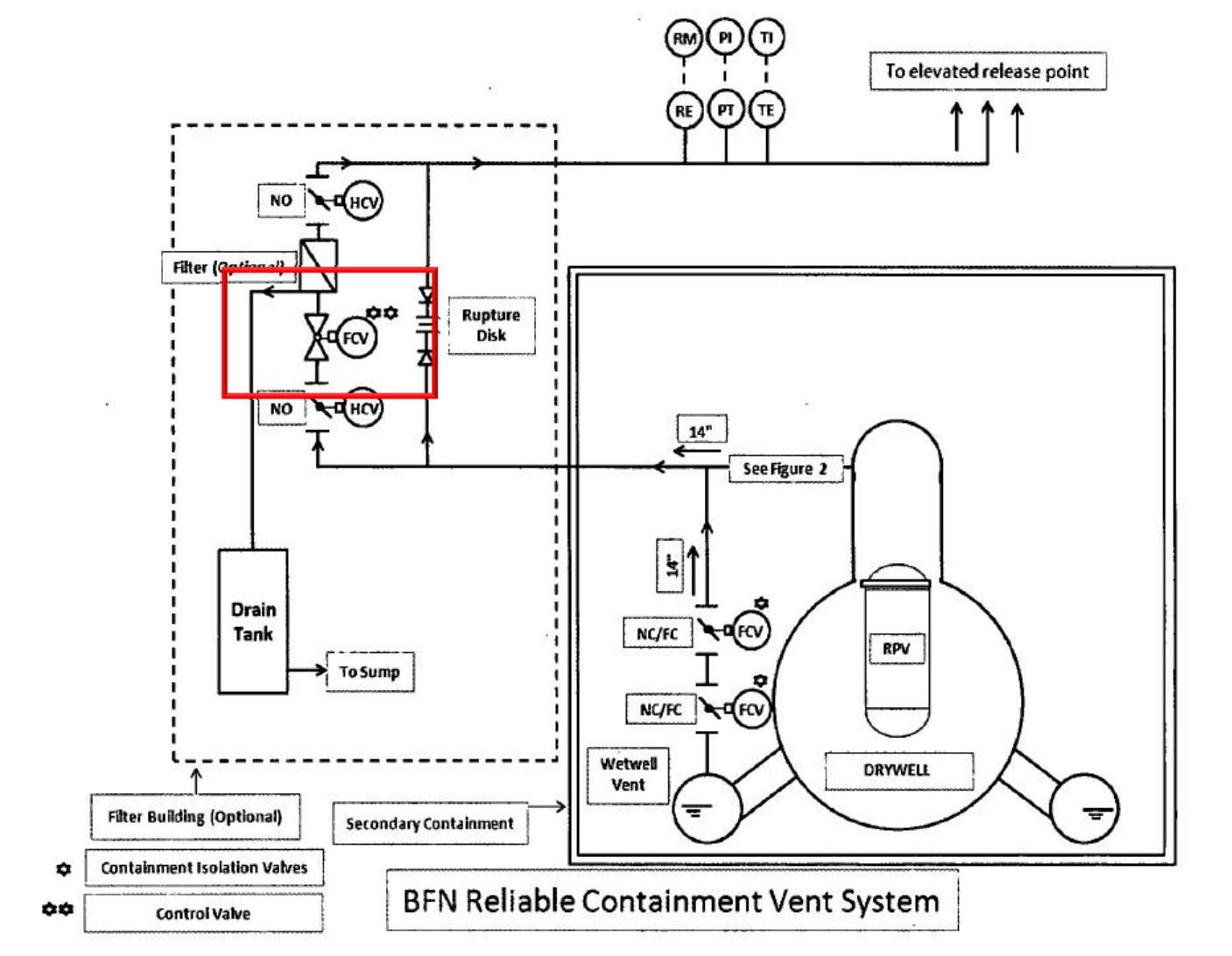
Leak Rate Testing of Enertech Metal Seated Valves

- Extensive Testing of Enertech Metal Seated Butterfly Valves have been Conducted Using Industry Standard Volumetrics Leak Rate Monitor
- Enertech's Metal Seated Valve Sealing Capability Consistently Exceeds the Requirements of any Appendix J Program
- Zero Maintenance and 60 Year Service Life



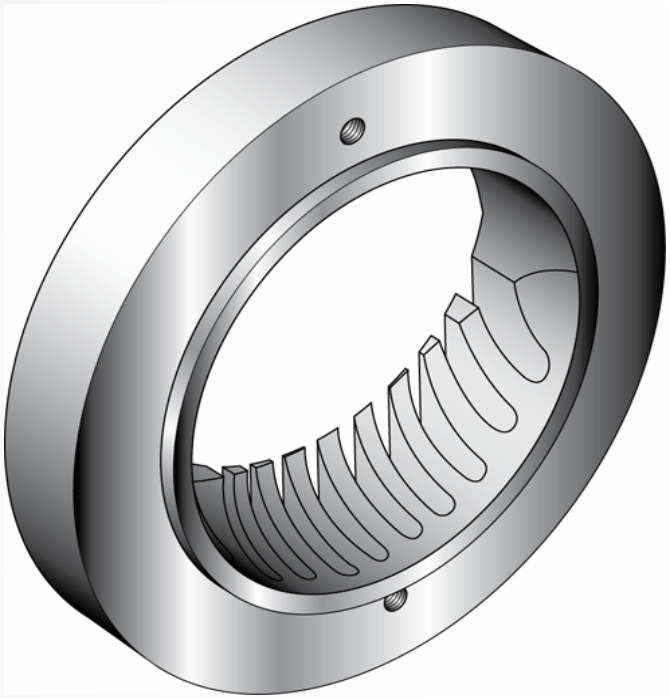
Requirement 1.2.1- Capacity to Vent

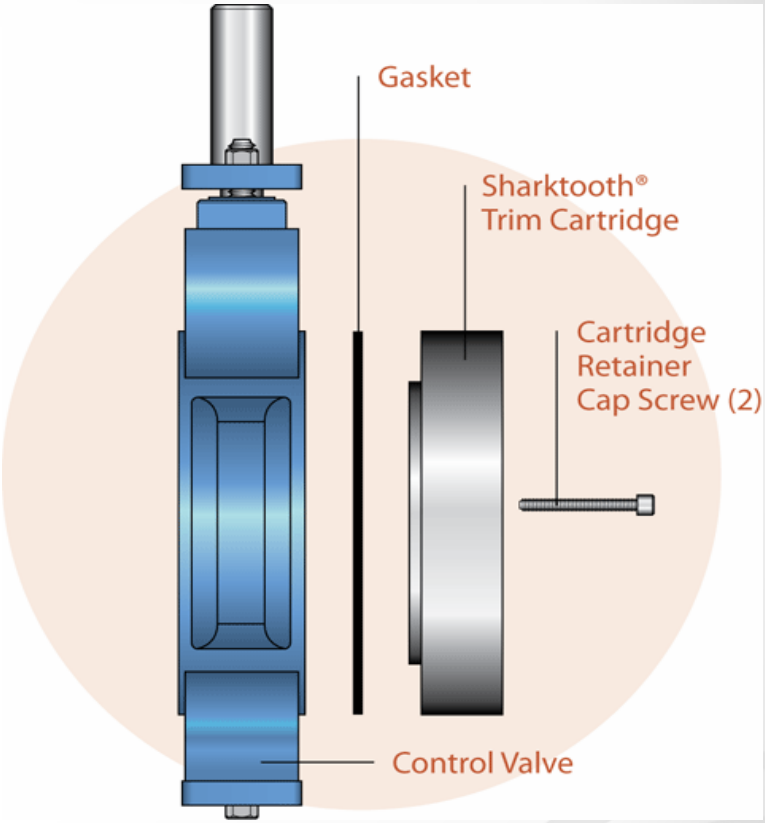
Pressure Control Valve Option



Requirement 1.2.1- Capacity to Vent

Enertech Metal Seated Triple Offset Butterfly Valve and Sharktooth™ Throttling Trim Cartridge



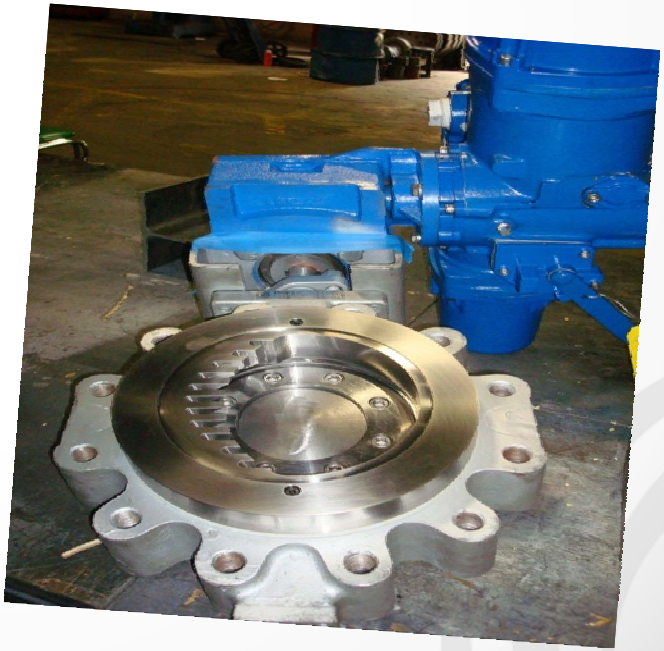


- Sharktooth “Throttling Trim Cartridge” Turns Enertech’s Triple Offset Butterfly Valve into a Throttling Control Valve
- The Outboard Containment Isolation Valve Can Serve both has an Isolation and Pressure Control Valve

Requirement 1.2.1- Capacity to Vent

Sharktooth Theory of Operation

- As the Enertech Triple Offset Butterfly Valve vane turns within the Throttling Trim Cartridge, the flow is first controlled via the characterized clearance between the disc edge and the solid, tapered portion of the cartridge; then through the multiple, optimized slots; and, finally, through the additional open area of the valve to provide:
  - Rangeability Exceeding 100:1
  - Equal Percentage Characteristic
  - Noise Attenuation
  - Reduced Cavitation

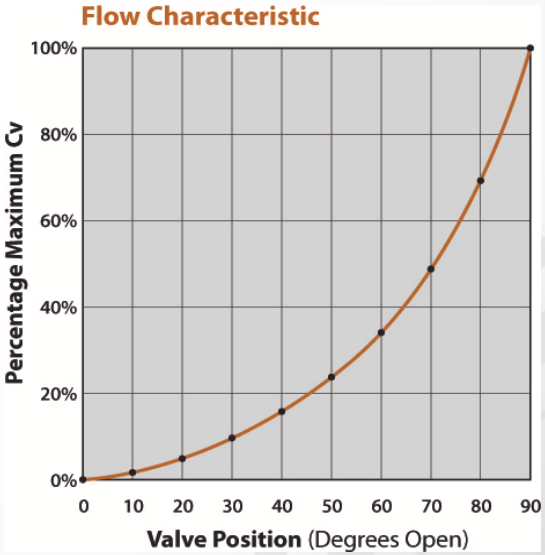


Requirement 1.2.1- Capacity to Vent

Sharktooth Control Capabilities

- Energy Absorbing Flow
  – Individual water jets impinge upon each other at approximately one pipe diameter downstream from the Sharktooth Control Element, thereby converting kinetic energy in the fluid prior to contacting the pipe wall

- Excellent Flow Range
  – Sharktooth Control Valves have an effective control range that extends from 1 percent at 5 degrees of travel to 100 percent at 90 degrees of travel.



Requirement 1.2.1- Capacity to Vent

Dual Function Butterfly Valve - Benefits

- Combines Zero Leakage Isolation with Control Throttling Capabilities into a Single Valve
- Significantly Smaller Envelope Dimensions Eliminate Major Seismic Issues
- Can be Equipped with a Pneumatic or Digital Positioner
- Tested and Verified at Utah State Laboratory
- Additional Applications
  - Heater Drain
  - Pump Bypass Control
  - Cooling Tower Bypass
  - Back Pressure Control

Requirement 1.2.1- Capacity to Vent

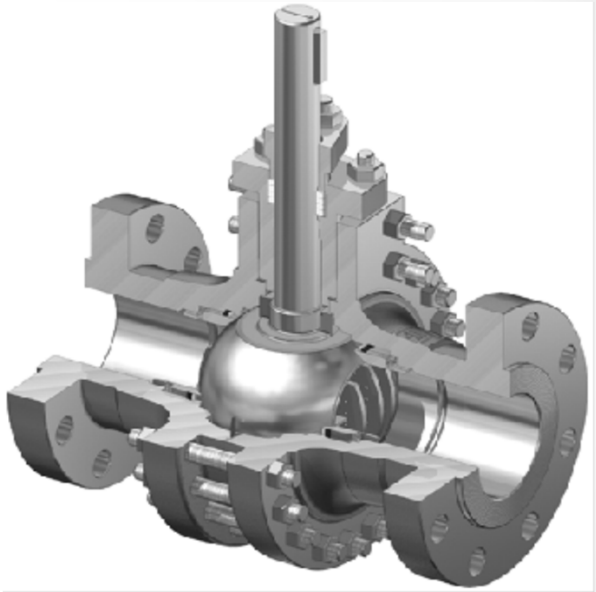
Metal Seated Ball Valve for Pressure Let Down

- Designed for Throttling and Isolation Service (Class V Leakage)

- Stem/Ball Design
  - One Piece assembly provides excellent response even under high differential pressure

- Trunnion Mounted
  - Good controllability and low operating torques

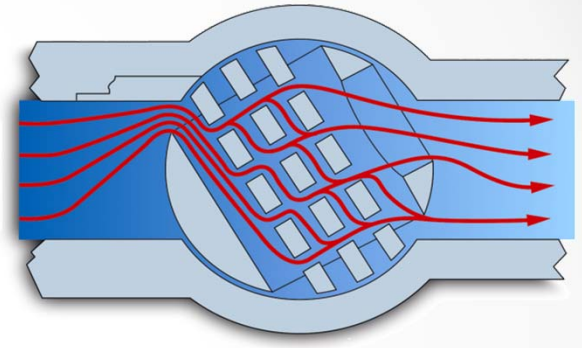
- Metal Seat
  - Spring loaded seats for continuous contact with ball



Requirement 1.2.1- Capacity to Vent

Metal Seated Ball Valve for Pressure Let Down

- Control Service
  - Excellent control characteristics
  - Equal percentage inherent characteristics
  - Full ball and two throttling stages reduces cavitation and noise
  - Self flushing low noise anti-cavitation trim
  - High noise reduction
  - High rangeability
- Sizes up to 36”

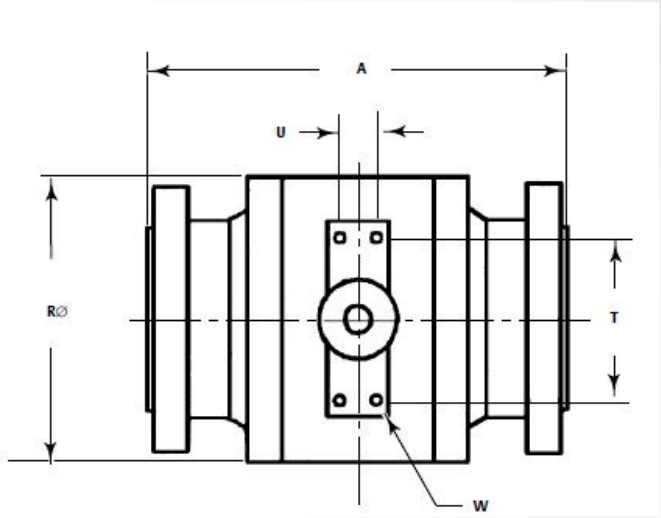


Requirement 1.2.1- Capacity to Vent

Triple Offset w/ Sharktooth Compared to Ball Valve Option

	Ball Valve		BFV w/ Trim	
	Length (in)	Weight (lb)	Length (in)	Weight (lb)
10”	30.02	850	4.99	210
12”	25.19	925	5.88	300
16”	30.00	1587	7.50	475

**weight does not include actuator or accessories*



Requirement 1.2.2 – HCVS Shall be Accessible to Plant Operators

1.2.2 – The HCVS shall be accessible to plant operators and be capable of remote operation and control, or manual operation, during sustained operations.

Enertech Solution:

- Bettis G-Series Pneumatic Actuator with Remotely Operated Hydraulic Override
  - Extensive Bettis Nuclear Installed Base
  - Unlimited Operation of Containment Isolation Valves During SBO
- Enertech Gas Spring Operator
  - Operation for Up to 72 Hrs
  - Prolonged Station Blackout and Multiple Step Changes
- Additional Accessories for Remote Operation
  - Nitrogen Storage Tanks
  - Remote Mounting 3-Way Solenoid Valves

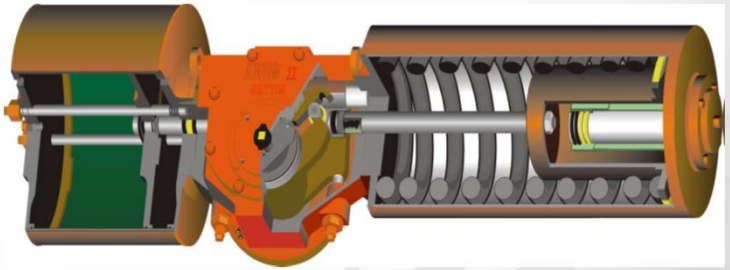
Requirement 1.2.2 – HCVS Shall be Accessible to Plant Operators

Bettis Pneumatic Operator

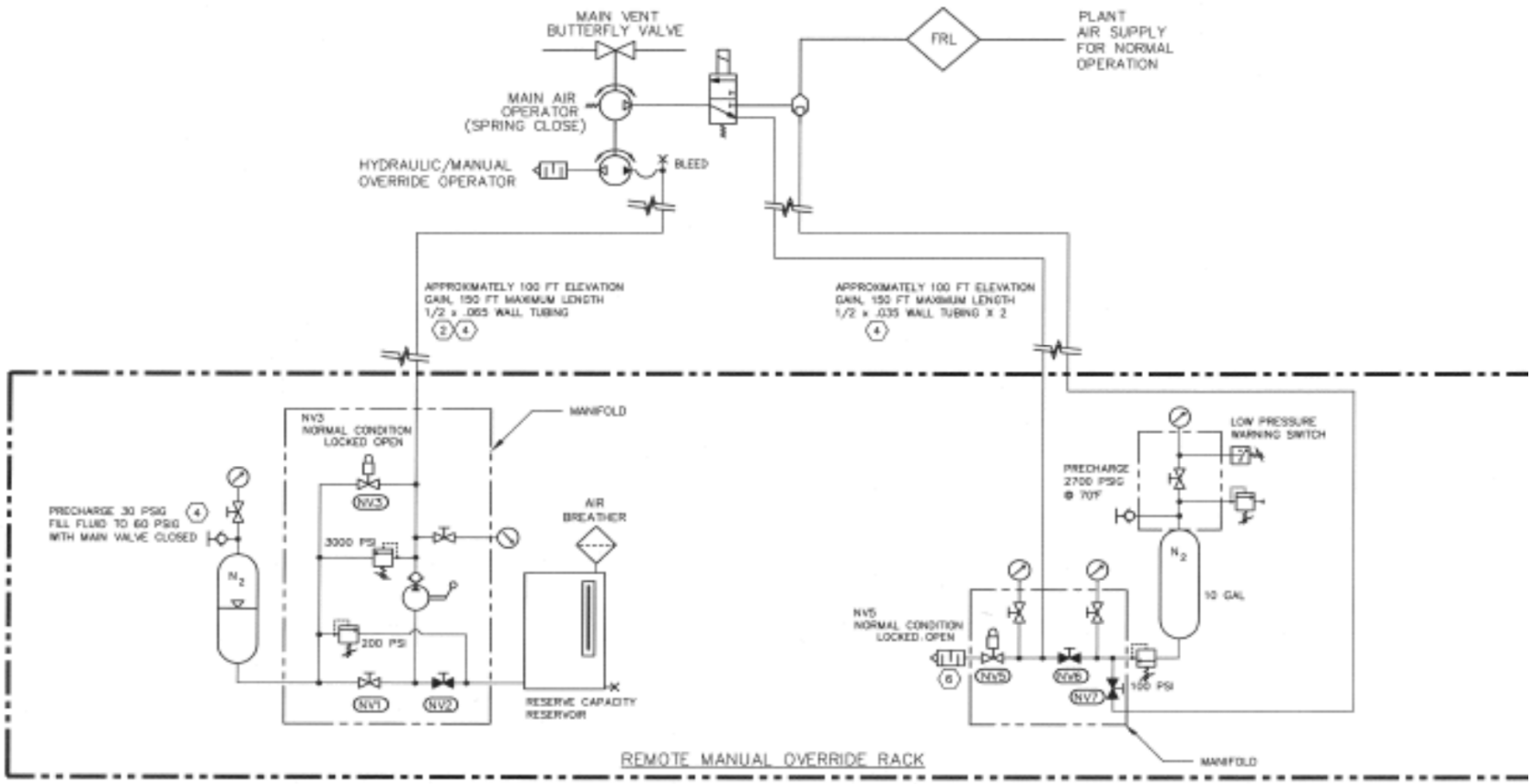
- Extensive Product Selection
  - Available in Spring Return and Double Acting
  - Operating Ranges up to 250,000 ft-lbs

- Reduced Wear
  - The Power-Swivl™ piston rod and guide block connection compensates for side load deflection and reduces wear

- Bi-Directional Travel Stops
  - Integral bi-directional travel stops, assist the G-Series in prolonging valve integrity



- Qualified NG Series
  - Qualified for LOCA, Seismic, and various aging processes to meet current nuclear qualification criteria



SINGLE ACTING MANUAL HYDRAULIC VALVE OPERATOR OVERRIDE.

OPERATION	MAIN VALVE POSITION	NV3	OPERATE PUMP
NORMAL (AIR OP)	ANY	O	NO
SPRING CLOSE	CLOSED/CLOSING	O	NO
OVERRIDE OPEN	OPEN/OPENING	C	YES (TO OPEN)

SINGLE ACTING MANUAL PNEUMATIC VALVE OPERATOR OVERRIDE.

OPERATION	MAIN VALVE POSITION	NV5	NV6	NV7	* NOTES
NORMAL OPERATION	ANY	O	C	C	ONLY OPEN NV6 AFTER NV5 IS FULLY CLOSED
SPRING CLOSE	CLOSED/CLOSING	O	C	C	
OVERRIDE OPEN	OPEN/OPENING	C	O*	C	

AUXILLIARY GAS PRES

OPERATION	MAIN VALVE P
NORMAL OPERATION	ANY
NORMAL OPERATION USING AUXILLIARY GAS SUPPLY AND 3-WAY SOLENOID CONTROL VALVE	ANY

O — OPEN

C — CLOSED

NOTES:

1. SCHEMATIC SHOWN IN NORMAL CONDITION, ALLOWING UNENCUMBERED OPERATION VIA THE MAIN PNEUMATIC OPERATOR.
2. ALL HYDRAULIC LINES TO RUN "UPHILL" TO THE BLEED PORTS AT THE ACTUATOR TO ALLOW EASY BLEEDING OF CIRCUIT.
3. HYDRAULIC FLUID: SYNQUENCH FRH (PREFERRED) OR FYRQUEL EHC. PETROLEUM BASED OIL MAY BE USED IN AN EMERGENCY.
4. VALUES SHOWN FOR 100 FT ELEVATION CHANGE AND 150 FT HYDRAULIC LINE LENGTH. VALUES WILL CHANGE FOR DIFFERENT DISTANCES AND/OR ELEVATIONS.
5. NEEDLE VALVES NV3 & NV5 CAN BE LOCKED IN POSITION.
6. 1/2" NPT EMERGENCY EXTERNAL 100 PSI COMPRESSED AIR OR LIQUID OVERRIDE INLET.

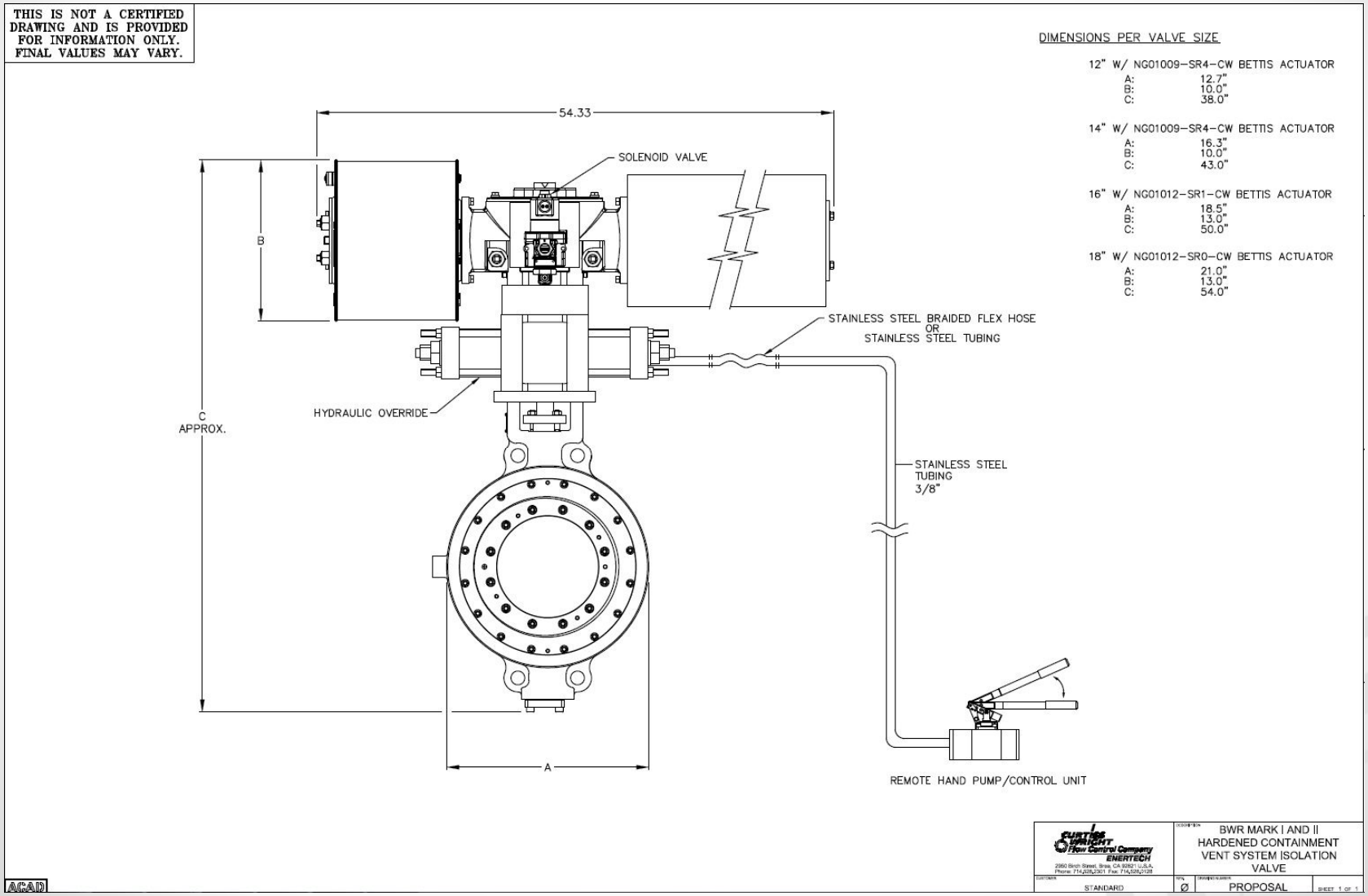
PRELIMINARY KJ 7/11

NONE

CURTISS WRIGHT Flow Control Company ENERTECH

Requirement 1.2.2 – HCVS Shall be Accessible to Plant Operators

Bettis Pneumatic Operator w/ Remotely Operated Hydraulic Override



Requirement 1.2.2 – HCVS Shall be Accessible to Plant Operators

Pneumatic Actuator Options

- Fail closed, open, last position or modulating control options
- Remote manual actuation with hydraulic hand pump
- Local manual actuation with hand wheel and reach rod
- IEEE Qualified pneumatic or digital proportional positioner for modulating service

Requirement 1.2.2 – HCVS Shall be Accessible to Plant Operators

SVI II AP Digital Positioner

- A Universal and Modular Design with Proven Non-Contact Position Sensors, Offering High Performance Valve Control with Real Time Diagnostics
- Receive a Set-Point from a Controller, Measure Valve Position, and Provide an Output Pressure to an Actuator to Position the Valve According to that Set Point

Nuclear Specific Qualifications

Environmental Parameter	Specification
Service Temperature	-20° to 55°C (-4° to 131°F)
Shelf Life	5 years at 30°C (86°F)
Abnormal Temperature and Humidity (EPRI TR-107330)	90% RH @ 55°C (140°F) for 48 Hours
Ambient Humidity Limits	10 to 95 percent RH non-condensing
Electromagnetic Interference / Radio Frequency	Criteria A – NRC Regulatory Guide 1.180 Rev.1
Thermal Life IEEE-323, version 1983/2003	6 years @ 55°C (131°F)
Cycles	100 full stroke cycles per year of qualified life 5,000 partial stroke cycles per year of qualified life
Radiation	30,000 rads (+ 10%)
Vibration Aging	0.75 g sine sweep at 2 octaves/minute from 5 to 100 to 5 hz for 90 minutes in each axis
Seismic (per IEEE-382-1996 and IEEE 344-2004)	Valve or structure mounted RIM: 6g (up to 100 Hz) Valve or structure mounted RRS: 14g @ 5% damping 4.5 - 16 Hz

Requirement 1.2.2 – HCVS Shall be Accessible to Plant Operators

Gas Spring EH Actuator for Coping with Prolonged Station Black Out

- Self contained stored energy, gas spring “diversified” actuator for extended mission 72 + hour cycling of Mark I and II hardened vent valves during prolonged SBO (without AC power or compressed air supply). Will survive and reset following restoration of AC power.

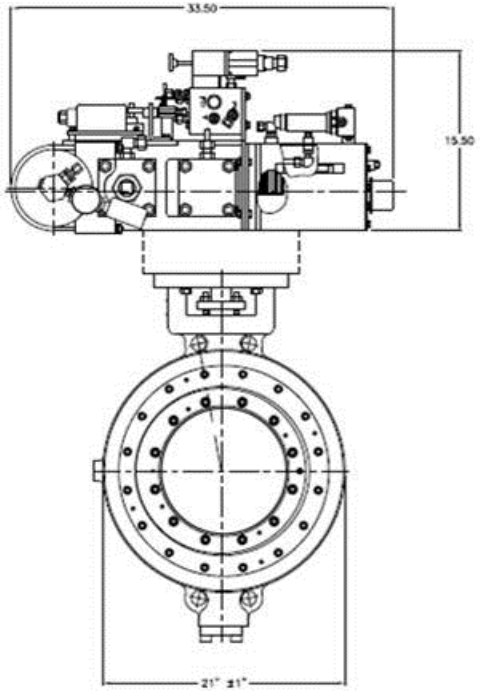
- Remote mount hand pump for Operator accessibility and intervention during SBO

- Multiple failure logics (in last position and fast close)

Requirement 1.2.2 – HCVS Shall be Accessible to Plant Operators

Gas Spring EH Actuator for Coping with Prolonged Station Black Out

THIS IS NOT A CERTIFIED DRAWING AND IS PROVIDED FOR INFORMATION ONLY. FINAL VALUES MAY VARY.



VALVE DATA:	
CUSTOMER:	LA SALLE
VALVE DATA:	
MODEL:	TDSV
SIZE:	18 INCH
CLASS:	150
RATING:	
PRESSURE:	275 PSIG
TEMP.:	100° F
ANSI SPEC.:	B16.34
CV:	8597
HYDROSTATIC TEST PRESSURE:	420 PSIG
SEAT LEAKAGE TEST	305 PSIG PER API 598
MIN. WALL:	0.48 IN.

CURTISS WRIGHT Flow Control Company
ENERTECH
2950 Birch Street, Brea, CA 92821 U.S.A.
Phone: 714.528.2301 Fax: 714.528.0128

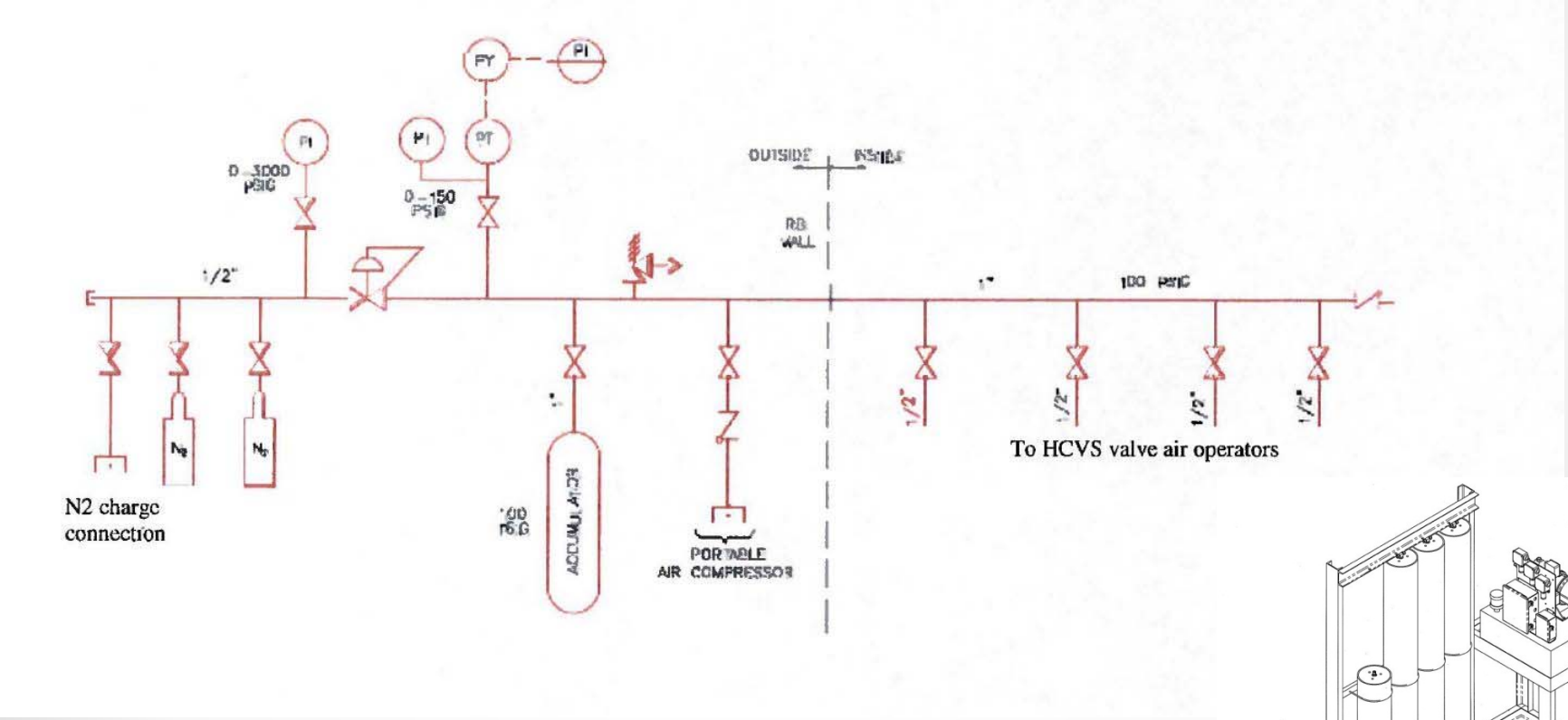
18" CLASS 150 VALVE
W/ 94K ROTARY ACTUATOR

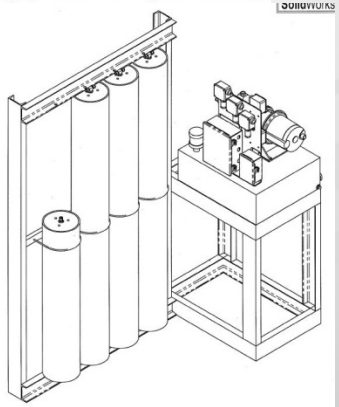
REV. A

SHT 1 OF 1

Requirement 1.2.2 – HCVS Shall be Accessible to Plant Operators

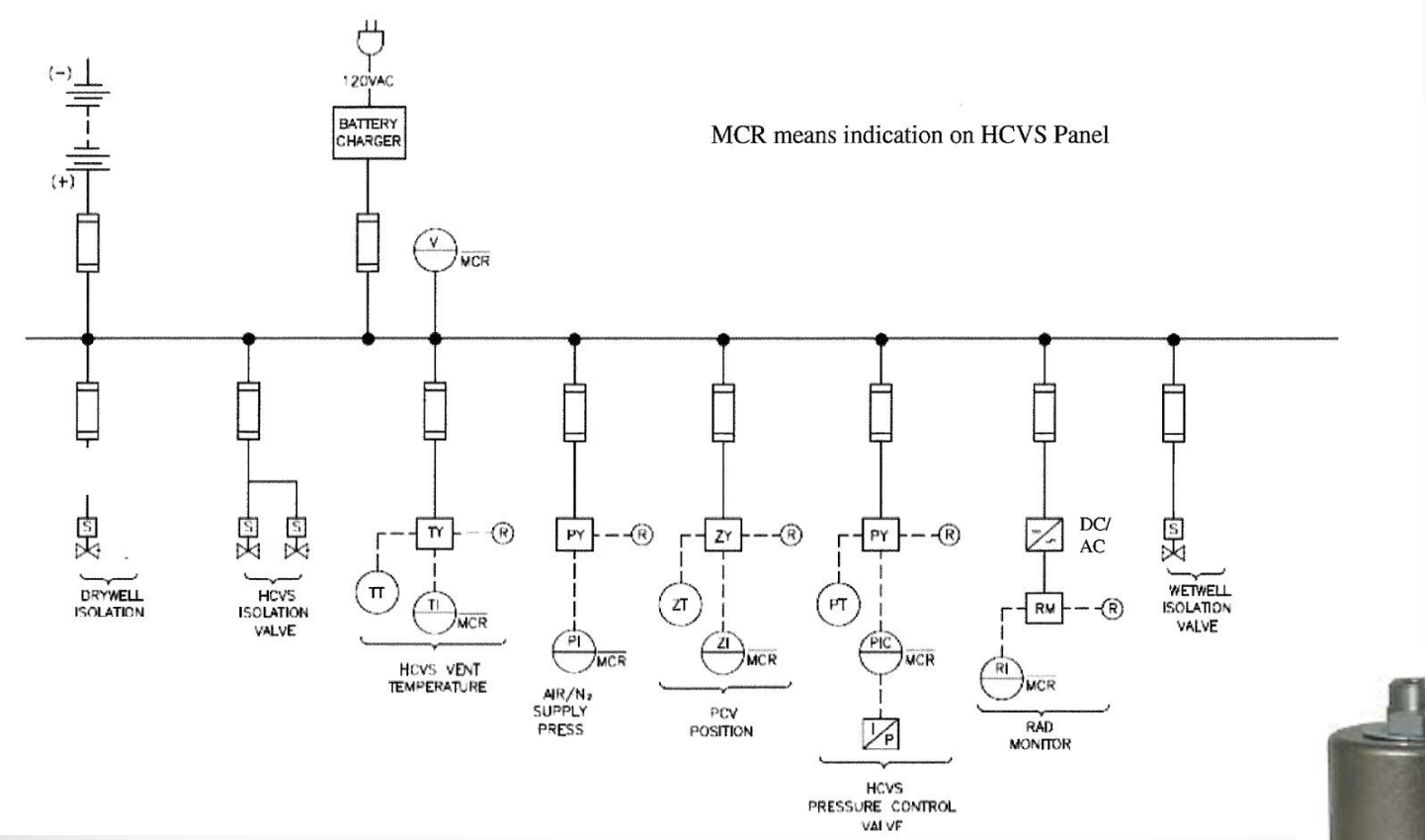
Nitrogen Back-Up Tanks





Requirement 1.2.2 – HCVS Shall be Accessible to Plant Operators

Remote Mounted 3-Way Solenoid Valves with Redundancy



Requirement 1.2.3 – Prevent Inadvertent Actuation

1.2.3 – The HCVS shall include a means to prevent inadvertent actuation

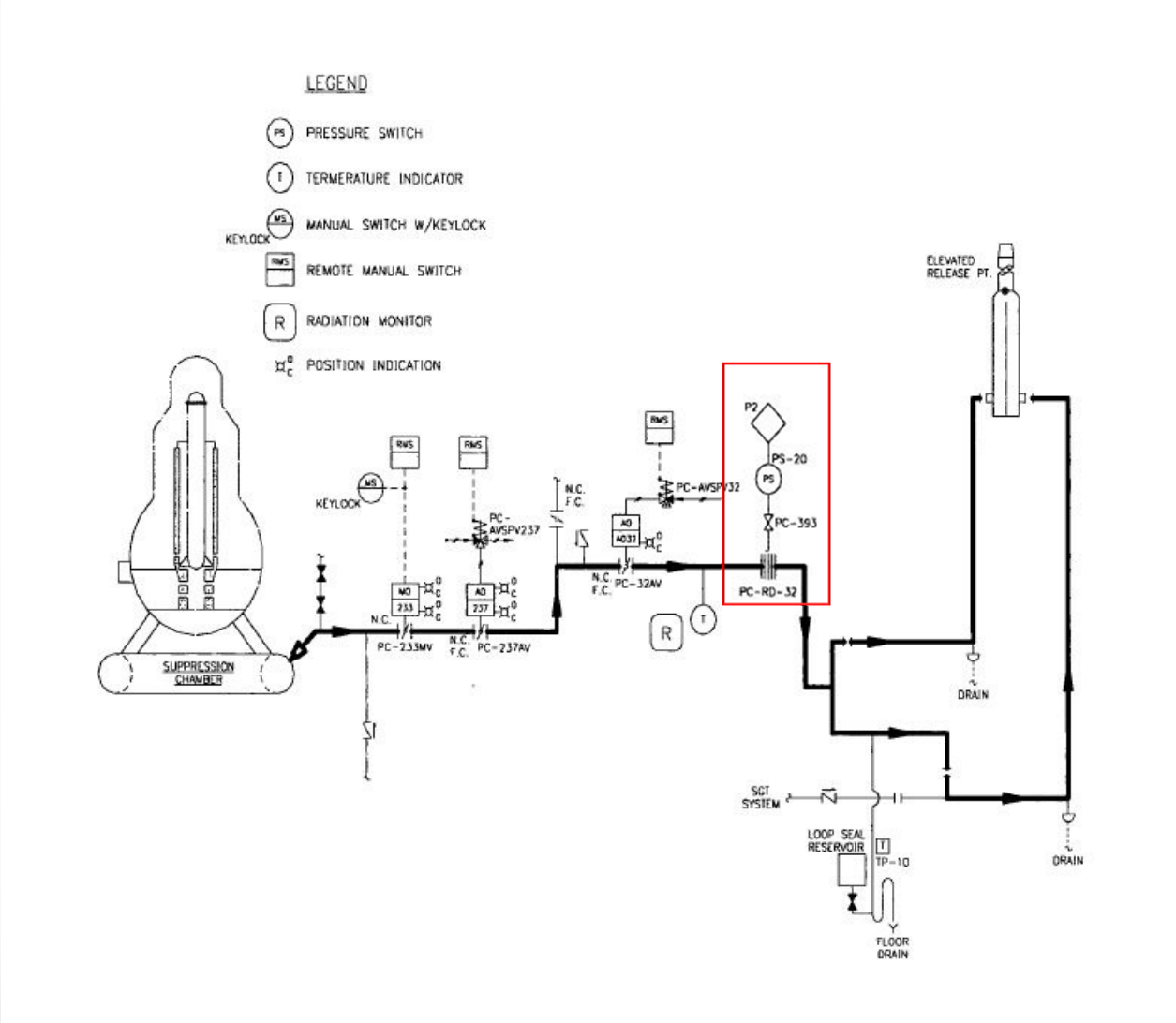
Enertech Solution

- Safety-Related Rupture Disc

- Pilot Operated Safety-Relief Valve
  - Allows for Reseating/Isolation Following a Reduction in Flow
  - Large Orifice Allows for High Relieving Capacities

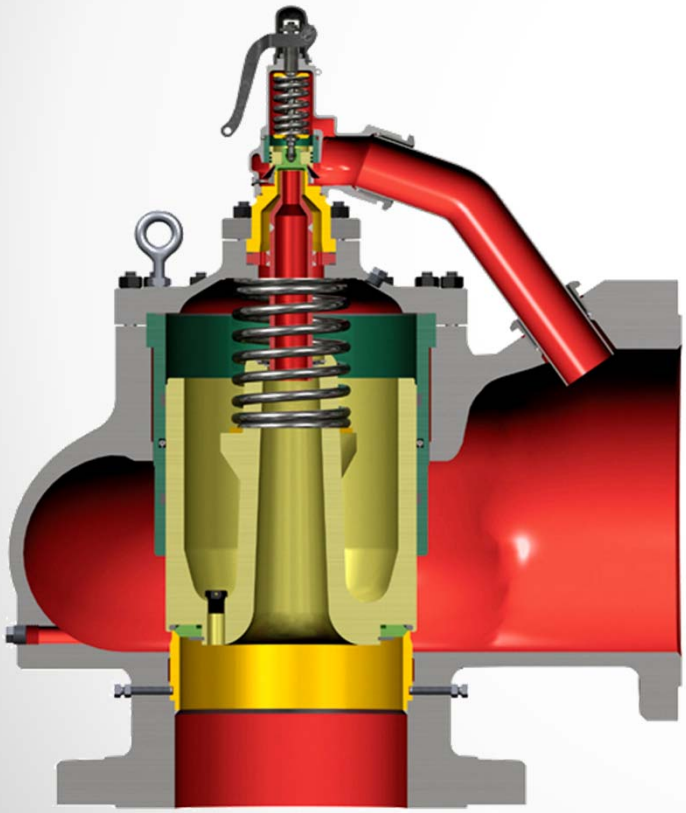
Requirement 1.2.3 – Prevent Inadvertent Actuation

Safety-Related Rupture Disc



Requirement 1.2.3 – Prevent Inadvertent Actuation

Pilot Operated Safety Relief Valve



Designed for extremely large relieving capacities for Steam and Compressible fluid applications.

- Allows for reseating/isolation of valve following a reduction in pressure
- Simple, rugged pilot construction assures long, dependable service
- Internal pressure sensing; no external lines subject to damage
- No human intervention required, passive solution

Requirement 1.2.4 – Monitor the Status of the Vent System

1.2.4 – The HCVS shall include a means to monitor the status of vent system (e.g., valve position indication) from the control room or other locations(s). The monitoring system shall be designed for sustained operation during a prolonged SBO

Enertech Solution

- FCI FLT-93 Temperature and Flow Switch
  - Precise Measurement and Accuracy
  - Nuclear Qualified for Harsh Environments

- Limit or Proximity Switches for Valve Assemblies
  - Mechanical or Non Contact Option
  - Comprehensive Valve Accessory Package with Optional Positioner

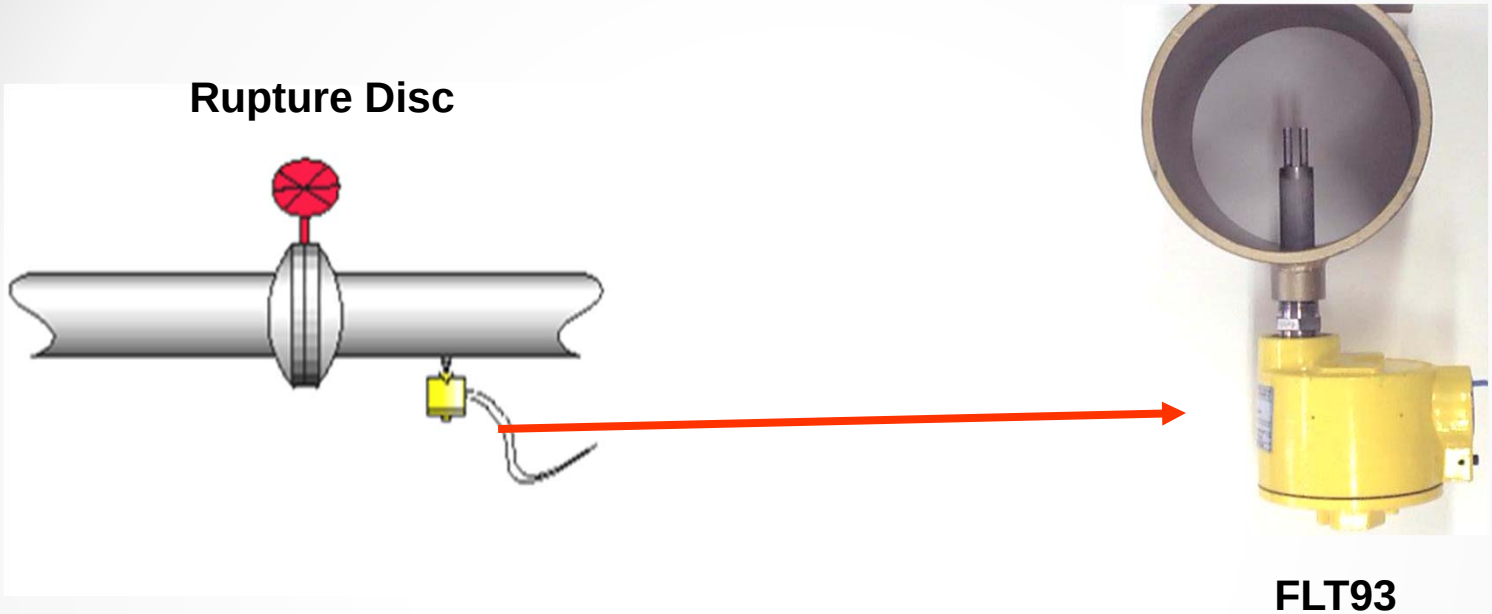
Requirement 1.2.4 – Monitor the Status of the Vent System

FLT 93 Temperature and Flow Switch

- Single switch monitors flow and temperature
- Remote calibration minimizes exposure in high radiation environments
- Remote diagnostics reduce maintenance
  - Calibrate only when required
- No moving parts to wear out
  - Fewer replacements
- 60 year qualified life

Requirement 1.2.4 – Monitor the Status of the Vent System

FLT 93 Temperature and Flow Switch



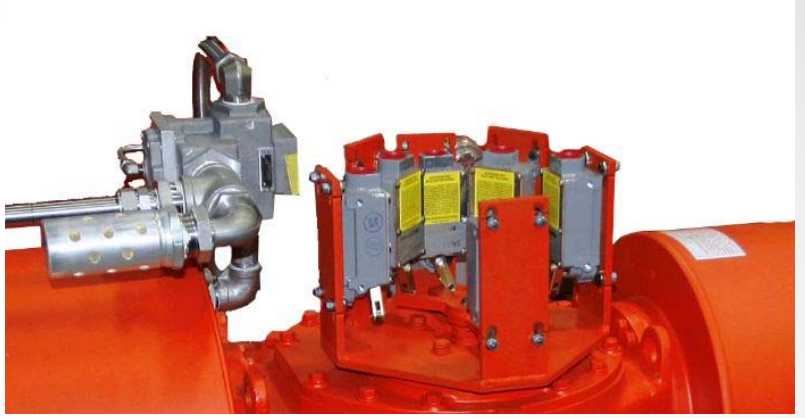
FLT93

Function	■ Detect early stage flow
Specifics	■ Extreme Low flow sensitive (0.003 m/sec on liquids) ■ Virtually no pressure drop ■ Available up to 800 Deg F ■ Temperature compensated for stable signal

Requirement 1.2.4 – Monitor the Status of the Vent System

Mechanical and Proximity Switches

- Valve Position Indication can be supplied with mechanical or non-contact proximity switches



- Both options are fully qualified for harsh environment

- Digital or Pneumatic Positioner Available for Throttling Pressure Let Down Valve

Requirement 1.2.5 – Monitor the Effluent Discharge of Radioactivity

1.2.5 – The HCVS shall include a means to monitor the effluent discharge for radioactivity that may be released from operations of the HCVS. The monitoring system shall provide indication in the control room or other location(s), and shall be designed for sustained operation during prolonged SBO.

Enertech Solution

- General Atomics Radiation Monitoring Equipment
  - Extensive Nuclear Installed Base
  - Fully Qualified for Harsh Environment
  - Small Envelop Dimensions and Light Weight

Requirement 1.2.5 – Monitor the Effluent Discharge of Radioactivity

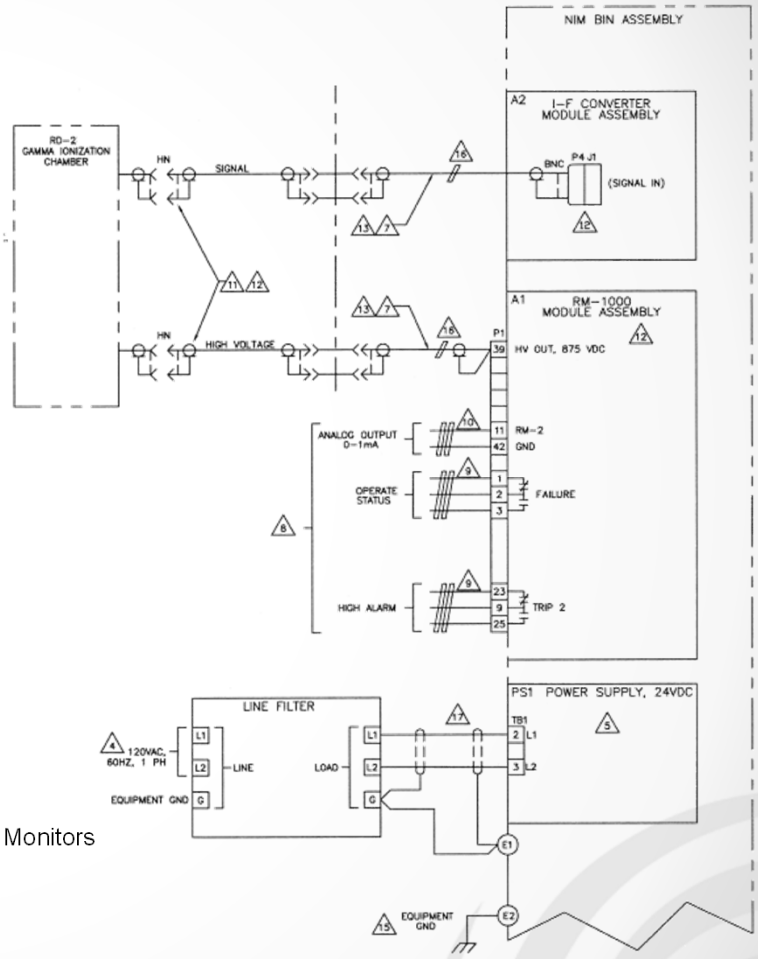
Radiation Monitoring

The NIM Bin will contain*:

- One RM-1000
- One Power Supply
- One I/F Converter
- NIM Bin Assembly: 35 Lbs (16 Kgs)
- Power requirement: 120VAC ±5%, 1.5A, 60Hz ,1 Phase

Detector – RD-2 or equivalent

- Range: 1 x 10^{-4} to 1 x 10^{1} R/Hr
- Temp: 300°F (149°C)
- Power Supplied by RM-1000
- Approx Weight: 11 Lbs. (5 Kgs)
- Lead Enclosure Wght: 463 Lbs (210 Kgs)**



* Note: NIM Bin not required on Non-Safety Related Monitors

** Note: Total for door and housing assembly

Requirement 1.2.6 – Minimize Unintended Cross Flow of Vented Fluids

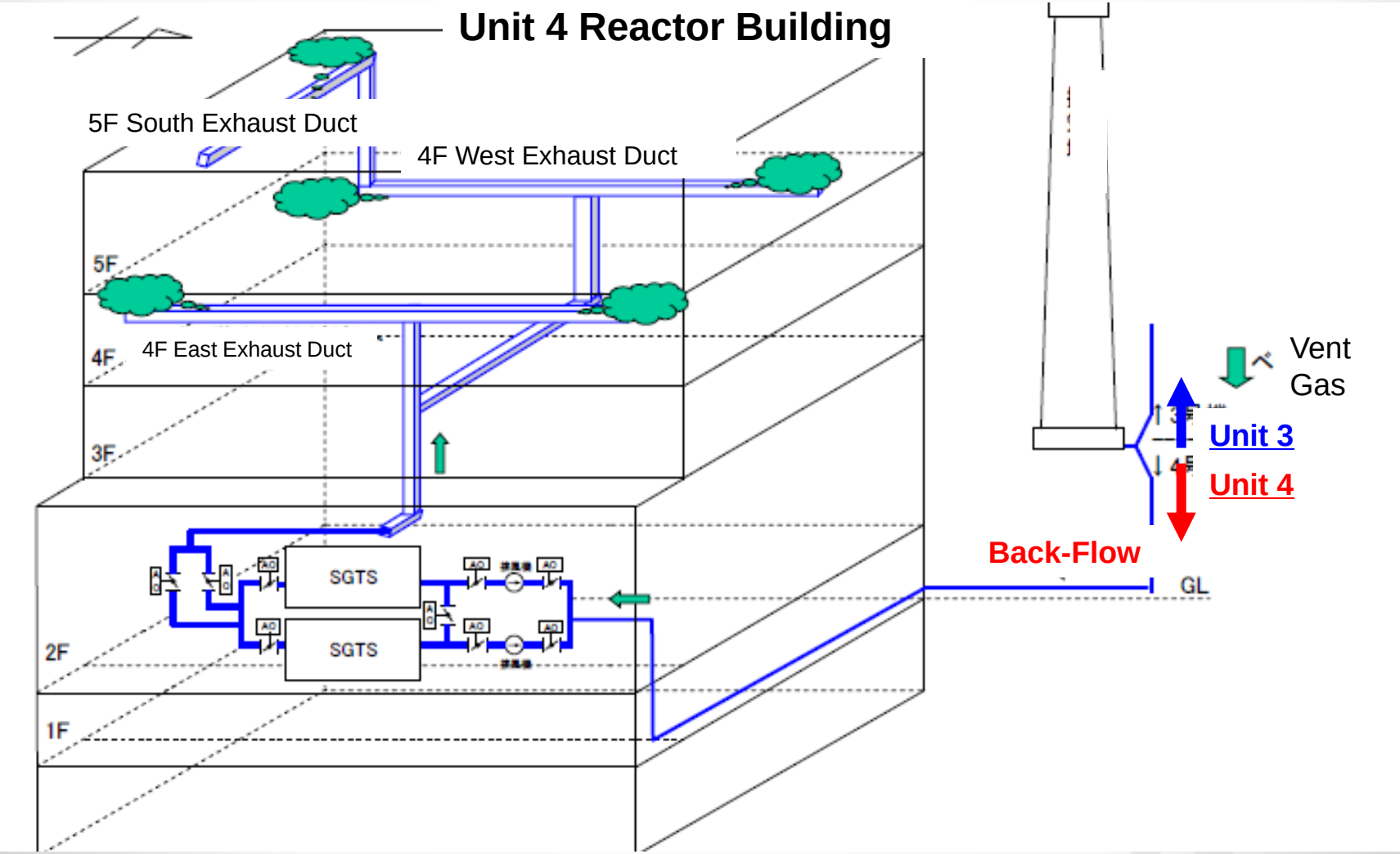
1.2.6 – The HCVS shall include design features to minimize unintended cross flows of vented fluids within a unit and between units on the site.

Enertech Solution

- Enertech NozzleCheck Axial Flow Check Valve
  - Metal Seat, Providing Class VI Shut-Off
  - Extensive Experience in Appendix J Applications
  - Able to Open Under Extremely Low Flow

Requirement 1.2.6 – Minimize Unintended Cross Flow of Vented Fluids

It is possible that vented gas from Unit 3 entered Unit 4 R/B



Requirement 1.2.6 – Minimize Unintended Cross Flow of Vented Fluids

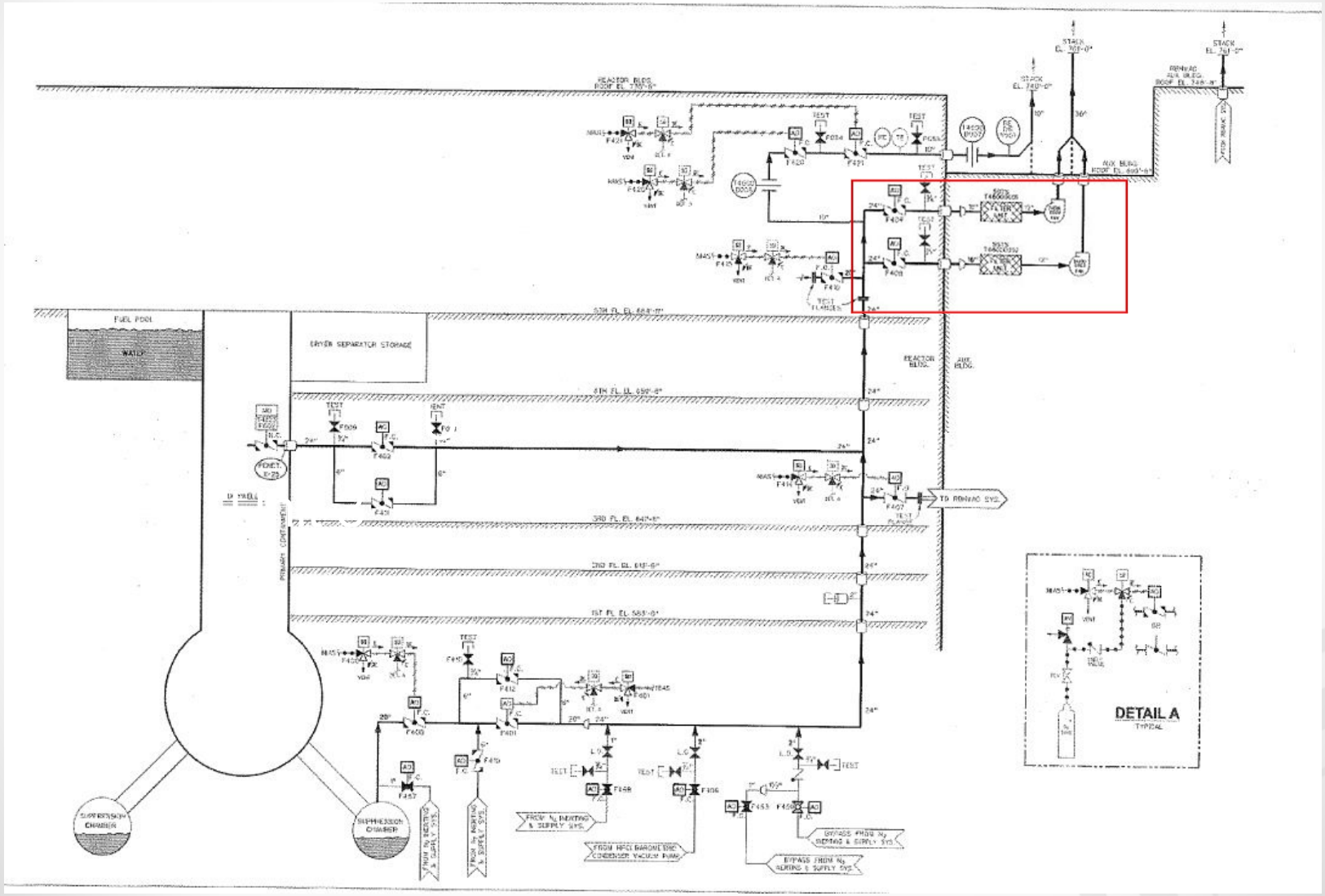
Reactor 4 Hydrogen Explosion

Hydrogen Explosion

- Unit 3: March 14,11:01 (Reactor Building)
- Unit 4: March 15, 6:00 (Reactor Building

Requirement 1.2.6 – Minimize Unintended Cross Flow of Vented Fluids

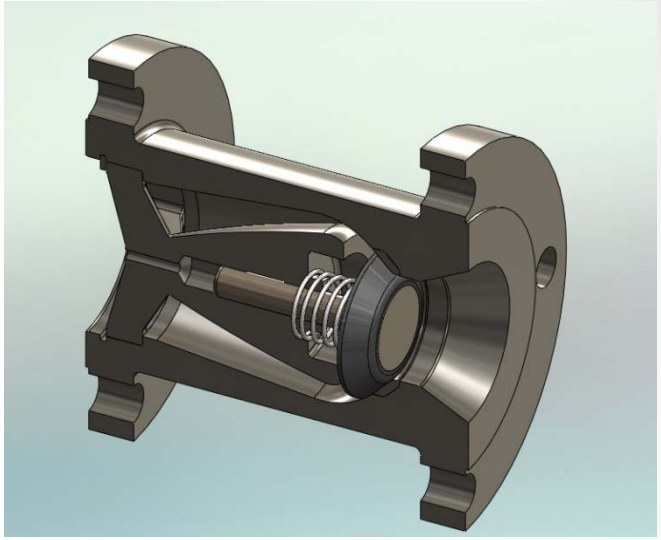
Potential for Unintended Cross Flow into SGTS

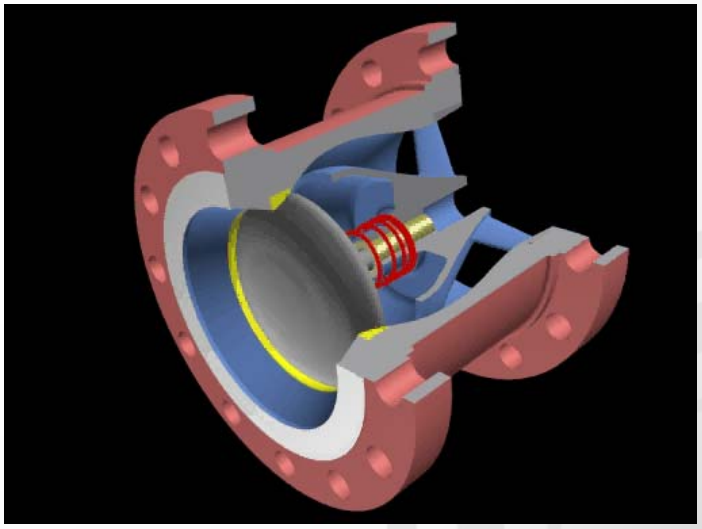


Requirement 1.2.6 – Minimize Unintended Cross Flow of Vented Fluids

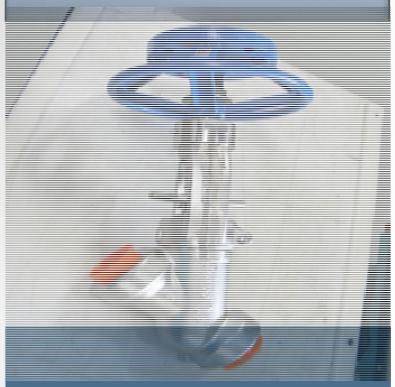
NozzleCheck Axial Flow Check Valve

- Valve Design is Normally Closed
- The Disc is opened and rested against the diffuser once the velocity in the line exceeds the required minimum velocity (Vmin) to fully open the valve
- When Flow is Stopped or Reduced, the Spring Assist Closes the Self Aligning Disc Before Reverse Flow Occurs
- Extremely short stroke length and ability to close rapidly upon flow reversal significantly reduces pressure surge and water hammer potential
- Size Ranges: 1” – 36”





Enertech Post Fukushima FLEX Capabilities



- High Pressure Gate, Globe, Check, and Ball Valves
- Metal Seat Design
- Extensive Nuclear Installed base
- Expedited Delivery Options
- Sizes 1” – 4”
- ANI Class 900-2500

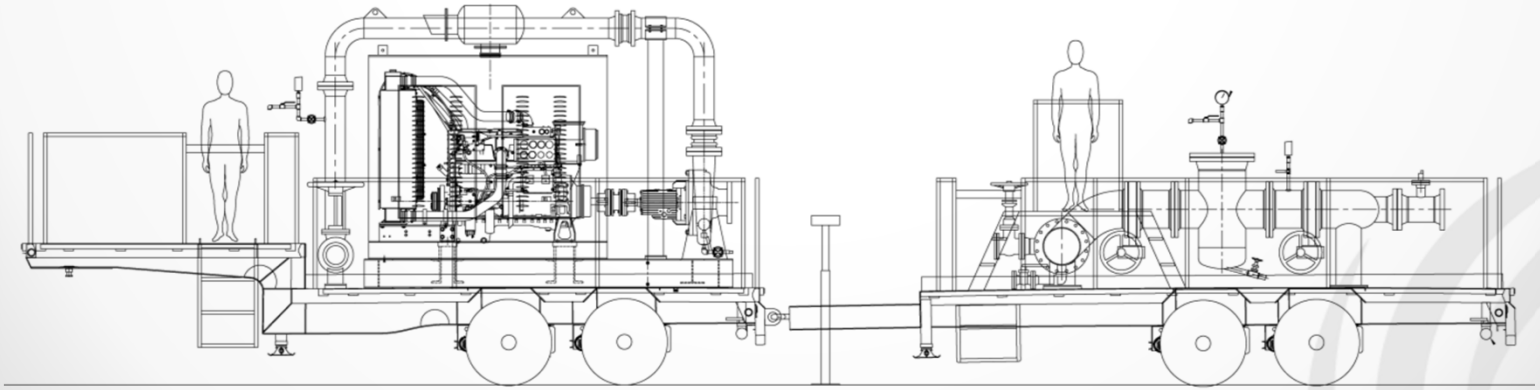
- Low Pressure Ball Valves
- Soft Seat Design
- Expedited Delivery Options
- Flanged and Weld End Configurations
- Sizes 1” – 6”
- ANSI Class 150-600

- Axial Flow Check Valves
- Metal Seat Design
- Expedited Delivery Options
- Flanged and Weld End Configurations
- Sizes ½” – 10”
- ANSI Class 150-1500

- Solenoid Valve
- Self Contained Isolation Valve
- Integral Position Indication and Actuation
- Essential DC Power Compatible
- Sizes 1” – 4”

Enertech Post Fukushima FLEX Capabilities

Enertech Mobile Spent Fuel Pool Make-up Pump and Heat Transfer Module



Enertech Post Fukushima Capabilities

Passive Autocatalytic Recombiners

PARs

Candu Energy Inc.

CANDU reactors have achieved worldwide recognition for their safe operation and Candu Energy Inc. is constantly working to help further enhance standards and plant safety. Our staff works with utilities to analyze plant performance and to ensure regulatory requirements are met. And we support utilities in their interaction with nuclear regulators.

We also design and help implement surveillance programs for reactor components and systems to collect, store and analyze data, allowing utilities to provide evidence of safe operation. And, we are continually developing new services, customized software and tools to assess and monitor key plant structures and components and to evaluate and improve existing maintenance programs.

Award-winning Design

The PAR offered by Candu was recognized by *R&D Magazine* as one of 1997's 100 most technically significant products of the year.

For Any Reactor Type

The PAR offered by Candu is designed for high-capacity hydrogen removal. It can be used in CANDU® or Pressurized Water Reactor (PWR) containment buildings following accidental hydrogen release. The PAR operates over a wide range of temperature and humidity levels, most notably at low temperatures and high humidity (condensing).

PAR Catalysts

PARs offered by Candu use catalysts that are proprietary Atomic Energy of Canada Ltd. (AECL) formulations that were developed specifically for application in nuclear reactor containment. The catalysts have high activity for hydrogen oxidation and are not deactivated by water vapour or steam and are specially formulated to operate over a wide range of temperatures. The catalysts have also been shown to be unaffected by high radiation doses or PWR molten-core aerosols.

	PAR-1	PAR-2	PAR-3
Size h x d x w (cm)	80 x 62 x 32	80 x 62 x 32	100 x 100 x 60
Number of Plates	31	47	67
Capacity (kg H_2/hr) with 4% vol. H_2 at 25°C and 1 bar	0.82	1.15	2.8

How It Works

An exothermic reaction occurs at the surface of the catalyst plates when hydrogen and oxygen are present in the atmosphere. The heat of the reaction, combined with the vertical arrangement and spacing of the catalyst plates promote natural convectivea flow through the recombiner. Warm humid air and unreacted hydrogen are exhausted through the top grating while fresh air and hydrogen are drawn through the bottom.

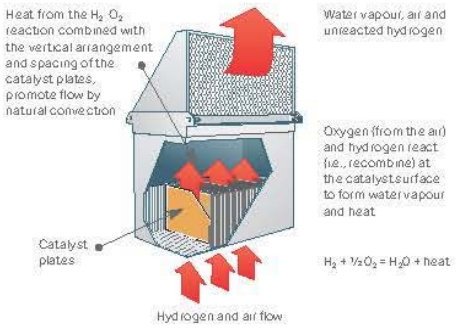
Easy Installation & Maintenance

The compact stainless steel PAR housing is designed for ease of installation and minimal maintenance. Catalyst plates can be accessed easily for inspection and on-site verification using a PAR whole plate tester.

The PAR unit is installed in a mounting support, which is anchored to containment concrete or welded to structural steel. Supports for floor- and wall-mounting were seismically-qualified for use in a design basis earthquake.

Passive Autocatalytic Recombiner

A Hydrogen Management System



- Self starting
- No power required
- No operator required
- Easily retro fitted to any existing facility
- Removes hydrogen in non flammable atmospheres

Enertech Post Fukushima Technologies for BWR Mark I & II Hardened Containment Vent

Enertech, a business unit of
Curtiss-Wright Flow Control Company