AP1000® Nuclear Power Plant Squib Valve Design Challenges & Regulatory Interface

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Overview

- Purpose and Function of the Squib Valves
- Key Design Requirements
- Technical Challenges
- Regulatory Interfaces
- Key points

Some details associated with the product are subject to US Export Controls and cannot be presented.

Purpose and Function of Squib Valves

- Part of the innovative **AP1000**® design passive features
- Safety related valves designed to open and depressurize the Reactor Coolant System (RCS) during Loss of Coolant Accident (LOCA) and permit passive Emergency Core Cooling System (ECCS) flow.
- Part of flow path for Containment Recirculation and also isolation of the In-Containment Refueling Water Storage Tank (IRWST).
- On each unit there are 2 groups of valves located inside containment that can open to allow depressurization from:
  - Pressurizer Safety Line
  - Both RCS Hot Legs
- There are 8 of the 8” (203mm) and 4 of the 14” (356mm) valves

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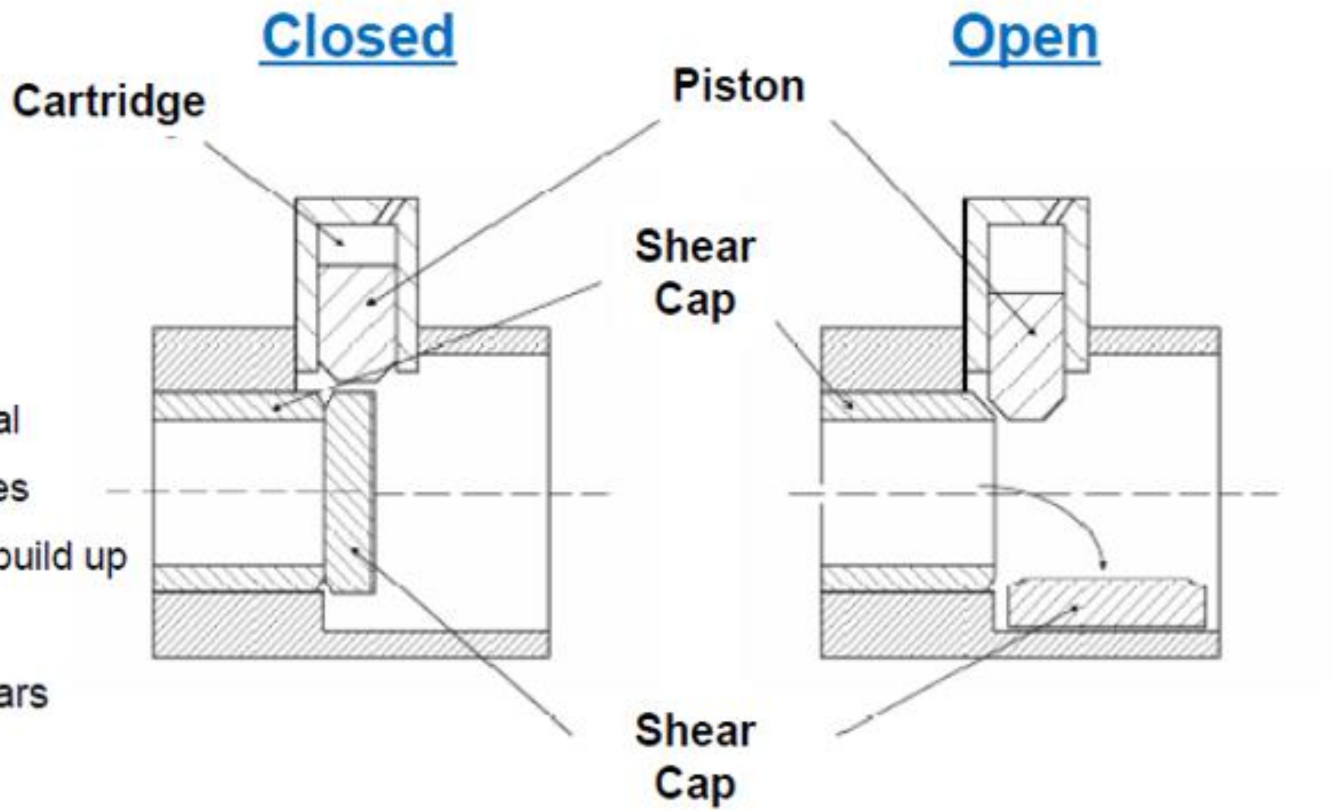
Conceptual Squib Valve



1. Actuation signal
2. Cartridge ignites
3. Gas/pressure build up
4. Piston moves
5. Shear cap shears

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Key Design Requirements

- Objective was to design two major components – the valve and the actuator both which had unique features and requirements
- Safety Function – opens and remains full open
- Seismically qualified
- Environmentally qualified (EQ)
- Components meet 72 hour post accident operability
- Pressure retaining parts meet ASME Section III
- Internal valve leakage criteria – ZERO
- Valve flow requirements - piping and support requirements
- Design provides adequate level of diversity and redundancy
- Material requirements

FOAK – due to size and being part of the RCS pressure boundary

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Technical Challenges - Valve

Some challenges during design, qualification, and testing

- The 8” (203mm) valves were not originally designed to be submerged
- When submerged, the External “Zero leakage” test kept failing
  - Valve seals and shear cap bolting were redesigned
  - Thermal shields added to minimize thermal expansion

- Shear Cap Design
  - Internal leakage design – the 14” (356mm) shear caps are one time use component which required somewhat longer to test than a conventional disc and seat design which can be simply repositioned.
  - Inside diameter of the flow area is a critical parameter. Clamping device to retain shear cap after opening must ensure the flow area remains strictly within design flow requirements.
  - Shear cap is essentially the weak link of a finite element analysis (reference provided at end of presentation for more detail)

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Technical Challenges – Actuators

Actuators

- Explosive actuators originally scoped as integral part of pressure boundary. Early reviews determined configuration would make maintenance, inspection, and testing complicated. The actuator was not ASME Section III qualified design required.
- Decided to move actuator outside the valve pressure boundary.
- NRC questioned potential effects of thermal, neutron, and gamma on the explosive powder. Subsequent tests and analysis resulted in additional margin being built in to adjust for effects.
- Used ASME QME testing technique of 80% loaded charge for EQ portion of testing, and full 100% charge during functional testing.

Technical Challenges – Testing

Testing and Surveillance Program

- There was no standard for pyrotechnically activated actuators
- Challenge to develop a surveillance program for explosively actuated valves for pre-service testing and operational surveillance.
- In service operational testing
  - Actuator fired in 20% of valves once every 2 years
    - If any charge fails, all charges from same batch will be replaced
- At least once every 2 years each valve has visual external examination and remote internal examination.
- At least once every 10 years, each valve will be disassembled for internal examination of valve and actuator with testing schedule set for samples of each type of valve to be disassembled every 2 years.
- Design and build to facilitate optimum ease for testing and maintenance

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Regulatory Interfaces

- Westinghouse invited regulatory engagement early.
- US, China, and UK regulators were invited and involved as early as the preliminary design reviews.
- The NRC was very engaged and observed preliminary design through final design reviews and provided challenging official concerns and comments which were insightful and very helpful.
- As a result of several NRC vendor inspections, the NRC asked additional probing questions which led to a series of new tests on both the valve and actuator.

Key Points

- Invite regulatory participation early in the design process
- Include customer participation and input throughout process
- Consider ideas and insights from other industries
  - Margin testing initiators for actuators at 80% loading
  - NRC brought in a NASA expert for some design reviews
- Use existing Operating Experience throughout the process
  - Your internal OE from previous projects
  - External OE
    - Errors in Preparation and Implementation of Modifications – WANO
    - Design Knowledge Management (INSAG-19) - IAEA
    - Safety of Nuclear Power Plants; Design (SSR-2/1) – IAEA

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References

- L. Ezekoye, G. Riegel, D. Ristau, R. Way - *"ASME Section III Treatment of Stress Distribution in Cylindrical Vessels With Symmetric Thin-Walled Discontinuity"* – Journal of Pressure Volume Technology, Vol. 136, June 2014.
- **AP1000**® Design Specific Working Group, Squib Valve Subgroup - "The Design and Use of Explosive Actuated (Squib) Valves in Nuclear Power Plants." MDEP Common Position No AP1000-01, December 2010.
- World Association of Nuclear Operators – *"Errors in the Preparation and Implementation of Modifications"* - WANO Significant Event Report SER 2005-3.
- Institute of Nuclear Power Operations - *"Guidance for Owner Oversight of New Plant Component Fabrication"* – INPO 11-006.
- International Atomic Energy Agency - *"Design Knowledge Management"* INSAG-19 – IAEA.
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