FISA EURADWASTE 2025

SNETP Forum

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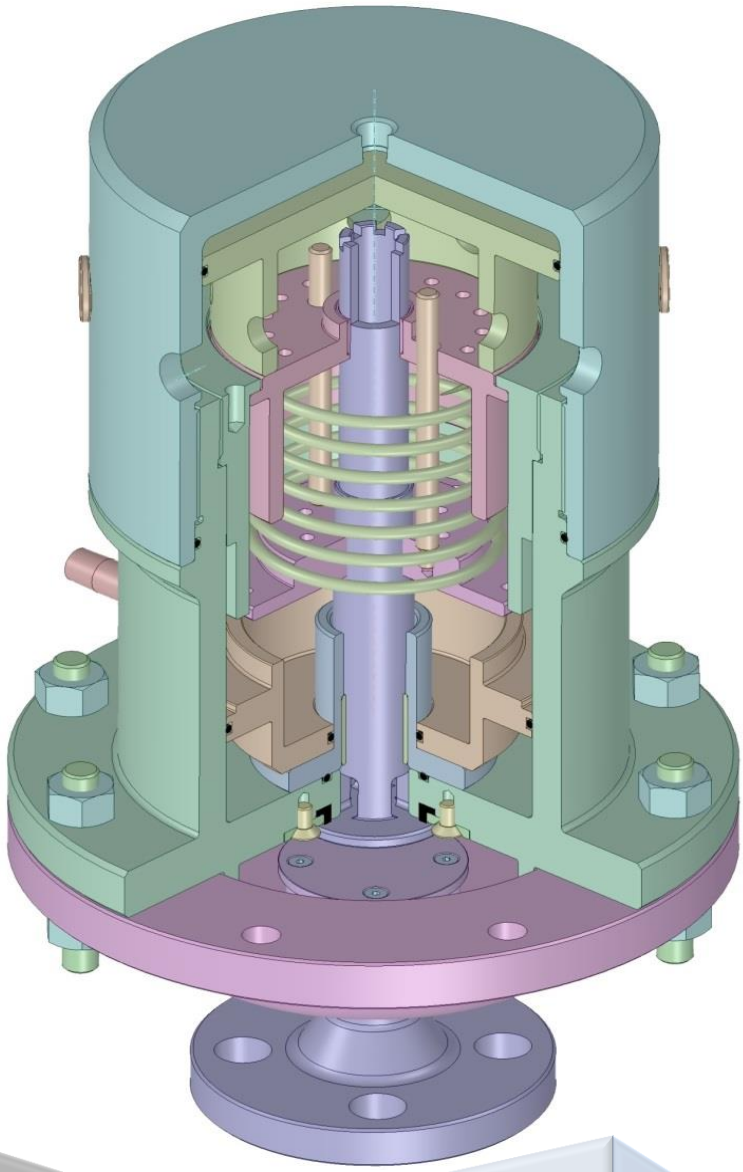
ASVAD

AUTOMATIC AND PASSIVE VALVE

NITROGEN-FREE REACTORS



WINNER of EURATOM Nuclear Innovation Prize* 2025

Funded by the European Union

ASVAD INTL SL

www.asvad-nuclear.com

The ASVAD valve

The Simple & SAFEST SOLUTION
to the nitrogen injection problem.

WHY ASVAD IS NEEDED?

The worst accident that a nuclear plant might face is the total loss of electric power. This accident also known as **S**tation **B**lack-**O**ut (SBO), prevents the reactor's safe shut down activities. The Fukushima disaster in 2011 is a clear example of this kind of accident.

During these situations, the operator activities are very limited to cope with the accident by the loss of power. Furthermore, the SBO also unleashes a new serious challenge. Losing the auxiliary cooling systems produces the rapid degradation of the main coolant pump seals. In a few time, the seals fails and the coolant starts to leak. This becomes a **S**mall **B**reak **L**oss **of** **C**oolant **A**ccident (SBLOCA), an additional complication, which stems from the SBO.

The permanent leak makes the pressure at the **R**eactor **C**ooling **S**ystem (RCS) continuously decrease. This pressure drop continues until the passive equipment, such as the safety accumulators or **C**ore **M**ake-up **T**anks (CMT), starts injecting borated water to compensate for the loss of coolant.

This equipment doesn't need power, and can maintain the core covered for some time. However, after all the accumulator's water is depleted, another serious problem occurs: the remaining Nitrogen, still pressurized, starts to enter the RCS. **This is the Nitrogen Injection problem**. This injected nitrogen will travel through the reactor, soon reaching the **S**team **G**enerators (SG's). This gas **strongly degrades the steam condensation** in the SG's hindering the core cooling!

The harmful effects of nitrogen inside the RCS

- **It stops the passive core cooling**. As nitrogen is accumulated in the upper side of the SG's U tubes, this gas blocks the natural circulation flow. It also **strongly diminishes the steam condensation** in the tubes. Reflux Core Cooling will be also compromised.

- **It will difficult the RCS pressure control**. RCS pressure will rise due to the heating of the nitrogen bubble. The pressure will remain high for a long time, which will increase the leak rate, and will make difficult or even impede the water injection from the emergency **L**ow **P**ressure **S**afety **I**njection pumps (LPSI).

- LPSI emergency pumps **can't work while the RCS pressure remains too high**. The nitrogen inside the pipes will hinder also its proper work due to air binding, cavitation or water-hammer issues, which can make them useless.

- **Acceleration of the Fuel cladding oxidation**. The interaction of high-temperature steam-nitrogen mixtures with the Zircaloy cladding produces a rapid cladding degradation in the fuel. This accelerated degradation **will diminish the time available before the core damage**. Hence, a core meltdown will occur sooner than expected, accelerated by the presence of nitrogen.

The (high) probability of the Nitrogen Injection

- **There is a LARGE AMOUNT of nitrogen ALREADY INSIDE the RCS.**
- **Nitrogen has an OPEN and DIRECT path to the reactor core**.
- **Nitrogen is CONSTANTLY PUSHING to enter into the RCS**. It just needs a lower pressure in the RCS.
- **The RCS pressure will continuously drop** due to the permanent LOCA. Operators can only maintain the pressure by restoring the power.

All this, will facilitate the nitrogen injection into the RCS

The facts are clear, and these are not just assumptions or opinions, as there have been past events related to nitrogen intrusion into the pipes from the safety accumulators.

Despite the harmful effects and high probability of occurrence, this risk to the reactor's safe operation has not been adequately addressed by the nuclear industry and its importance has not gained much consideration. **Nitrogen threat is not even considered in the Probabilistic Risk Assessment (PRA)**. This risk is too great to continue being underestimated. Avoiding consideration of this risk can lead to serious consequences. Fukushima was a clear example of what happens when a risk is underestimated.

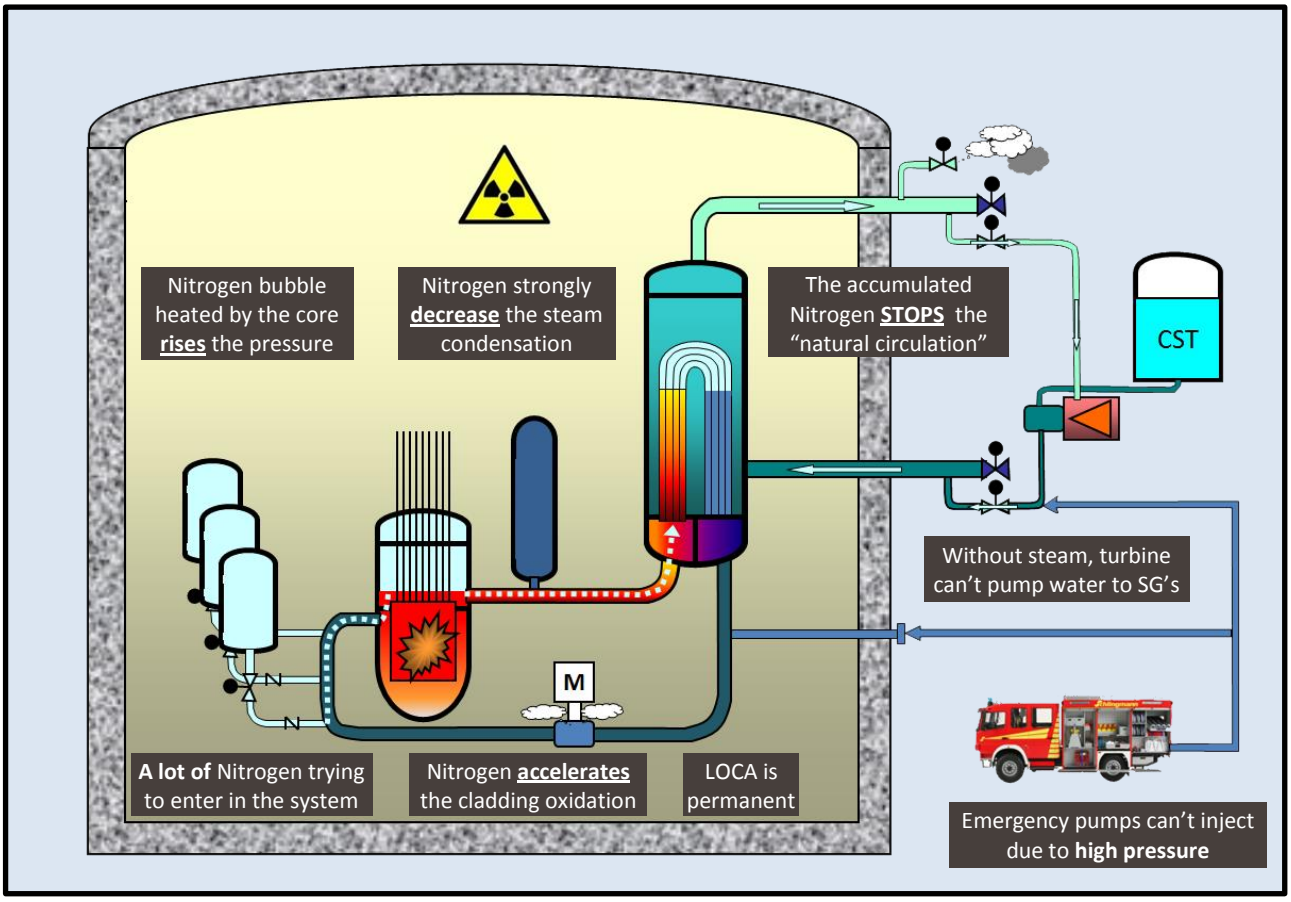


Figure 1. The harmful effects of nitrogen.

CURRENT STRATEGIES

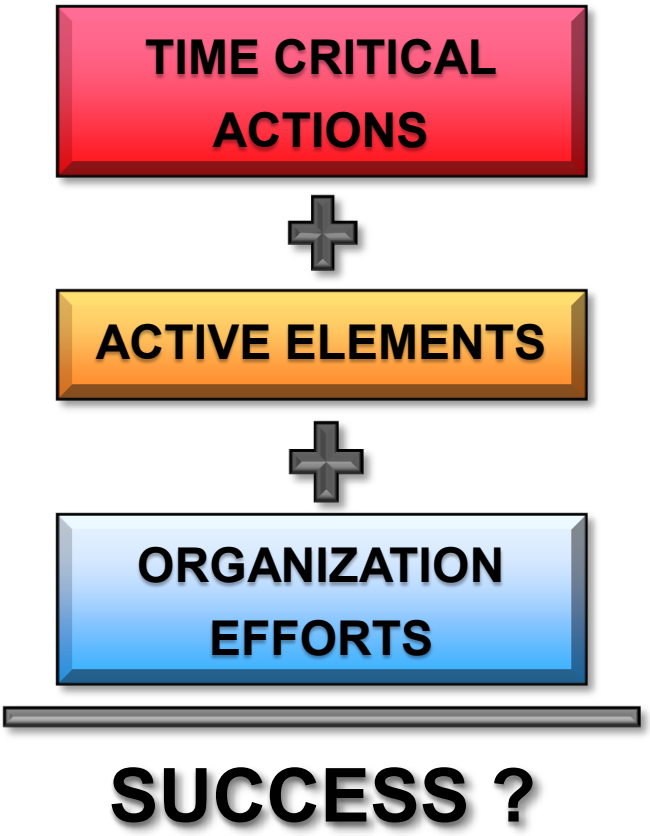
To prevent this nitrogen intrusion, **only 3 strategies can be taken:**

1. **Closing (on time)** the accumulator output isolation valve.
2. **Venting (on time)** the residual nitrogen to the containment building.
3. **Maintaining the RCS pressure** over the nitrogen pressure.

These strategies **have common drawbacks and weaknesses** during an SBO accident:

- It **needs the deployment** and the proper actuation of **ACTIVE ELEMENTS**. All these elements are complex elements, which need power to work.
- It also **NEEDS THE OPERATOR'S WORK**. All these elements are not automatic, they have to be deployed and operated. A **well-trained team** are needed.
- **TIME IS CRITICAL**: It's not easy to determine **WHEN the isolation has to be done**. On one hand, if it is done too early, the water will be wasted in the accumulator. On the other hand, if it is done too late, there will be nitrogen intrusion into the RCS. Moreover, these actions must be taken **simultaneously in all the accumulators**. Hence, these strategies are **TIME CRITICAL**.
- All these strategies rely on a **long chain of active components**. If any link fails in this chain, nitrogen injection will inevitably occur. For example, the isolation valves: even while closed, they will leak nitrogen into RCS, because they are not gas-tight.
- The last strategy maintaining the RCS pressure **is just a temporary strategy**. Sooner or later, the RCS will be fully depressurized, allowing nitrogen to enter.

With so many disadvantages… who could rely on them?



THE ASVAD VALVE

The **A**utomatic **S**afety **V**alve for **A**ccumulator **D**epressurization (**ASVAD**) is the solution to the Nitrogen Injection. It's a unique kind of safety valve:
ASVAD only actuates when the pressure drops below a set point pressure. This set point can be adjusted to detect the accumulator emptiness.

Figure 2 illustrates a simplified concept of the ASVAD Valve. It consists of a pressurized chamber (1) connected to the accumulator nitrogen side. A hollow obturator (2) seals this chamber with a gasket. There is a preloaded spring (3) with an adjustment disc (4) threaded over the actuator.

The basis of the ASVAD valve operation is **the imbalance between the forces** exerted over the obturator. On the bottom side, there is the force exerted by the accumulator's internal pressure. This force firmly pushes up the obturator keeping it closed. On the upper side, there is the force exerted by the preloaded spring. This force is constant and pushes down the obturator, trying to open it. As long as the force exerted by the accumulator's normal pressure (thick arrow) is greater than the force exerted by the spring (thin arrow), the obturator will remain closed. During normal operation, this force ratio is **3:1**.

The spring is pre-set to the same value as the nitrogen pressure when the accumulator is empty. So, when the accumulator becomes empty, the spring can overcome the residual pressure and rapidly pushes down the obturator. This opens the pathway from the pressure chamber through the obturator hollow center, to the outside. Once the obturator is lowered, the valve remains permanently open due to the spring action.

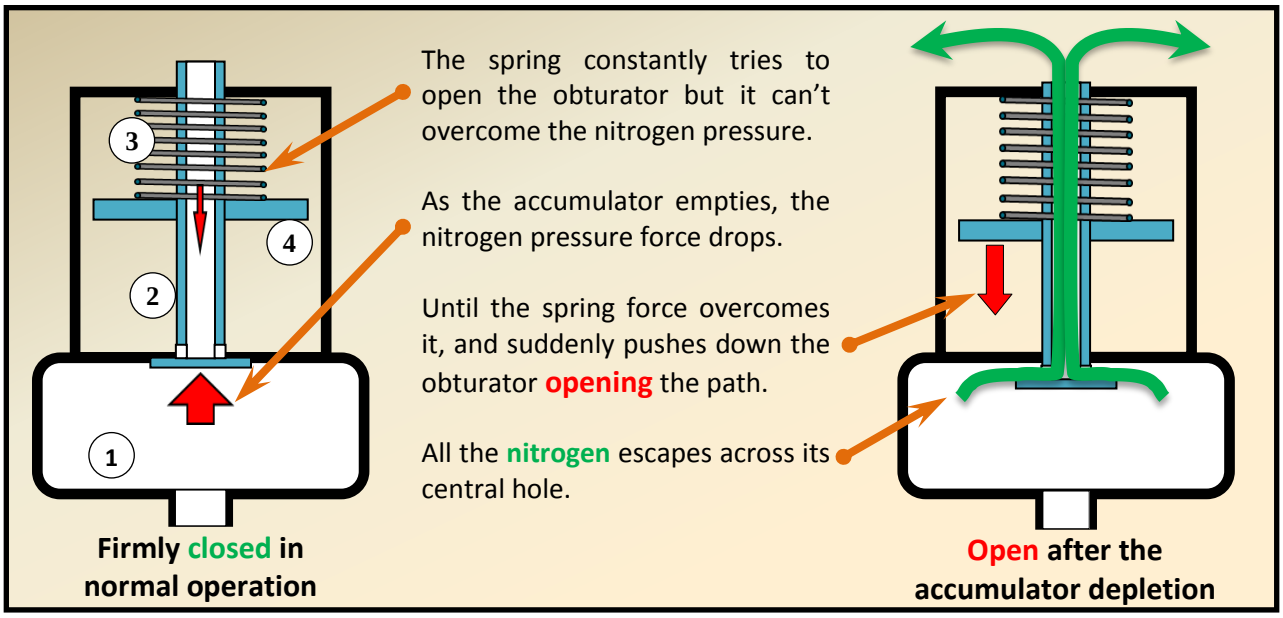


Figure 2. ASVAD valve simplified operation diagram.

The Valve opening results in **total accumulator depressurization** to the containment atmosphere, and thereby prevents the nitrogen from getting into the RCS. In addition, the expanding nitrogen gas can cool down the containment atmosphere. ASVAD valve description and configuration is illustrated in Figure 3.

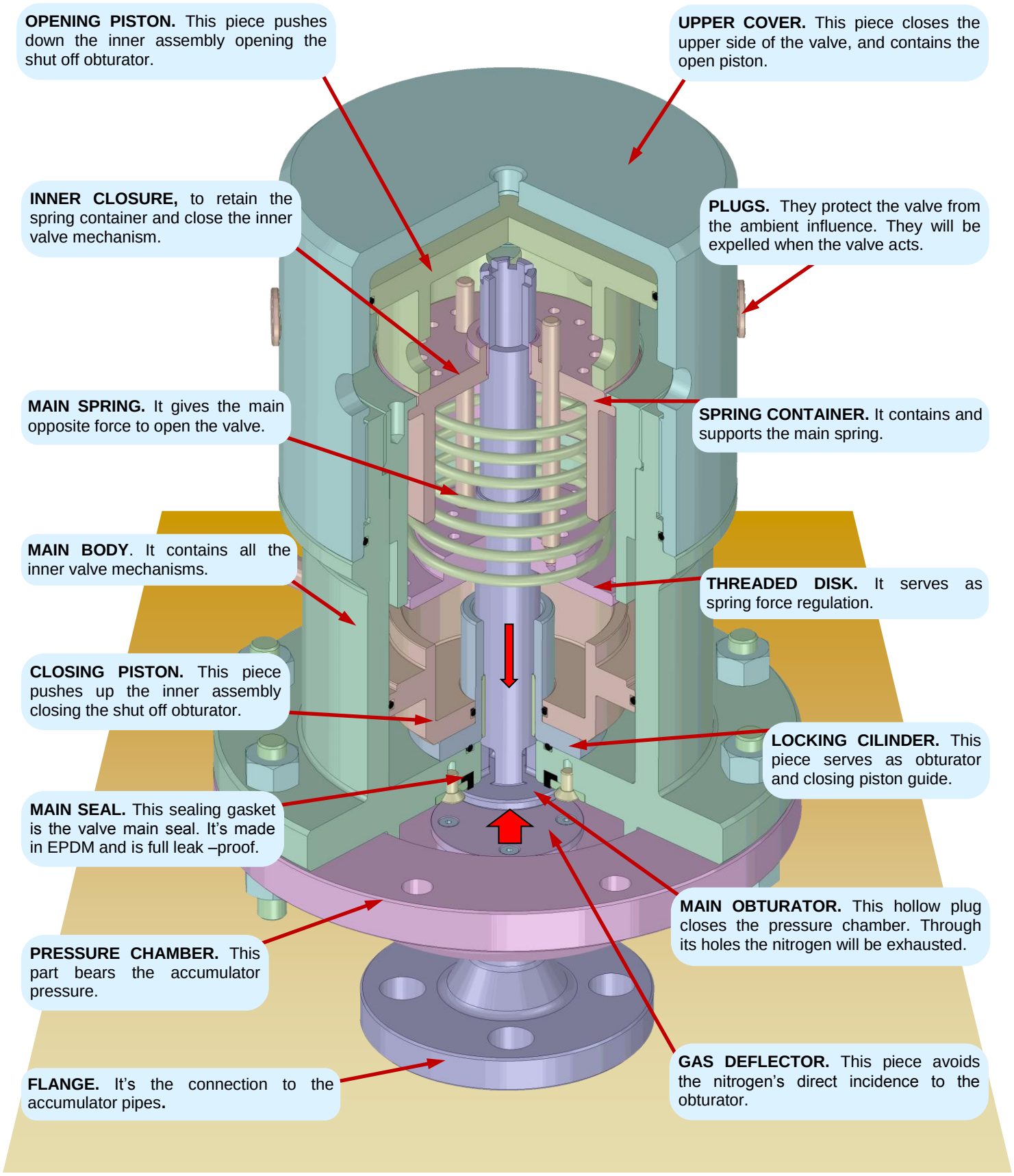


Figure 3. The ASVAD Valve configuration.

ASVAD valve specifications

WORK PARAMETERS					
PARAMETER		**MIN. VALUE**	**MAX. VALUE**	**UNIT**	**COMMENTS**
Nominal Pressure	PN	n/a	50	Bar	Other pressures available
Work temperature	T	0	50	ºC	Standard values
Ambient Pressure	PA	0,9	1,1	Bar (abs)	Standard values
Actuation Pressure	PD	13	19	Bar	Adjustable, depending on temperature/pressure
Trip point uncertainty		-	±1% PN	Bar	
Leak flow	-	-	0	l/min	Measured during 10 min.
Air pressure to close	Ppc	4	15	Bar	
Air pressure to open	Ppa	4	15	Bar	
Radiation		-	$<10^5$	Rad	Not affected
Work Cycling		1	<500	cycles	Revision when reaching number
ACCIDENT PARAMETERS					
Max.Temperature	Tmax	-	>150	ºC	Tested during 10 h bearing this temperature
Max. internal overpressure		-	>75	Bar	Until 150% nominal pressure
Ambient Pressure	PA	0,9	>5	Bar	Tested during 96 h bearing this pressure
Humidity		0	100	%	Not affected
Radiation		0	>150	MRad	Not affected
Acceleration		6,0(Z axis) 8,5(X axis)		g	Based on calculations
Resonance Freq.		>52	-	Hz	Based on calculations
Temp. drift ratio	RPDT	0	≤0,025	Bar / ºC	(25ºC-150ºC)
Chemical spray		pH 4.3	pH 11		Not affected
Flooding		N/A	N/A		Not affected
DIMENSIONAL PARAMETERS					
Ratio		-	#300		Other ratios available
Venting Diameter		-	1	inch	Other diameters available
Hydraulic connection		-	DN25	-	Other connections available on demand
Weight		-	53	Kg	
Volume		-	14,72	l	
Long		-	414,5	mm	
Max. Diameter		-	250	mm	
Main material		A182 F316L		-	Stainless Steel
Gaskets		EPDM		-	
Qualified life		9 *	indefinite	years	* no metallic elements

Advantages using ASVAD

MAIN ADVANTAGES:

1. The ASVAD Valve will be available **at all times** protecting your system.
2. **It completely prevents** the nitrogen injection.
3. It is based on simple and universal physical principles (force & pressure).
4. **It is fully passive**. It does not require external power to function.
5. **It is fully automatic.** It does not need any operator assistance.
6. It acts at **the right time** and **over all the accumulators**. No time critical operations are needed. It functions automatically by sensing the accumulator's pressure. It is also able to adapt its opening point to the existing environmental conditions, maximizing the accumulator's water volume.
7. **It completely vents** the accumulator. No further injections will be possible.
8. It allows the depressurization of the RCS to lower pressures, which will **greatly facilitate further accident recovery** (This could be its best advantage).
9. It will **save operator's effort,** allowing them to focus on other recovery tasks.
10. **It does not interfere** with the normal operation.

SECONDARY ADVANTAGES:

1. It is very **reliable** due to its **simple and robust design**.
2. Its hard stainless-steel design enables it to withstand the post-LOCA environment.
3. It is very **easy to install** in the system. It does not require a major modification.
4. It **does not add any new failure mode** beyond those already analyzed.
5. It is **intrinsically safe**. No electromagnetic compatibility problems. Does not require any software. Cyber-attack and fire proof. It does not add any fire load. It is not impacted by radiation, moisture or even flood.
6. It supports manual operation and can be remotely actuated when required.
7. Its maintenance is simple. **There is no wearing out components**. It just needs a few spare parts. Minimum maintenance cost: "**Install & Forget**".
8. The desired actuating pressure is **easy to adjust and to check**.
9. **It is economical**. It does not need a complex and expensive system modification.
10. **Long qualified life**. No further investments will be needed. **"Buy it once, use it forever".**

The installation of this valve **will also allow depressurizing the RCS to lower levels (70-90 psi or less)**, compared to the current limit of 200-300 psi.

This further depressurization **will reduce the leakage rate**. This low pressure allows for the use of **additional means** (such as the firefighting system, other low-pressure pumps, etc.) to inject water into the RCS, thus greatly facilitating accident recovery.

Less pressure, Fewer problems.

Advantages during normal operation.

- The ASVAD **will remain permanently closed**, as long as there is enough pressure in the accumulator. This ensures that the accumulator's operability will not be disturbed during the normal plant operation.
- **It does not leak**. In the unlikely event of any nitrogen leaks, it can be easily isolated from the accumulator and removed for maintenance without affecting the accumulator's operability.
- Installing the remote actuation option, the valve can be operated from the control room. Therefore, both opening and closing demand can be executed remotely. Anyway, usually this is not needed.
- Being located on the nitrogen side of the accumulator, and at a higher level, there is no possibility of boron deposits that could impact and or compromise its operation. Even in the case of an accidental accumulator overfilling that could reach the pressure chamber, the valve's internal components would not be compromised due to the seal produced by the plug (Obturator) against the gasket.

Advantages during the accident.

- The installed ASVAD **is available at all times to perform its safety function and prevent nitrogen injection**. It does not have periods of inoperability.
- The valve prevents the accident complications caused by nitrogen injection and subsequent operational interventions to manage them. Therefore, operators have more time to focus on other, more critical accident mitigation tasks.
- It is a **fully passive element** (type C). It does not require any external power source. It will work perfectly during the accident period because the actuation energy is already stored in its mainspring. It works based on **simple and universal physical principles** (pressure & force).
- It does not require any operator intervention and **automatically opens to vent the nitrogen** to containment atmosphere when the accumulator is empty
- **Acts at the right time when the water injection is finished**. Since the valve depends mainly on the accumulator residual pressure, it will only open when the accumulator pressure falls low enough. This can only happen when there is small amount of liquid left inside the accumulator.
- It can also compensate for the effect of temperature rise in the containment. The increase in temperature will heat the gas inside the accumulator raising its pressure. The valve's response to this environment will automatically raise the valve opening setpoint pressure to compensate for this circumstance.
- The water injection from the accumulators to RCS happens nearly simultaneously, so its depletion of water will be simultaneous too. They start from a similar water level and pressure, and they discharge to the same RCS pressure. By installing the ASVAD in each accumulator, they will be individually protected to prevent the nitrogen injection. All the valves will open when their respective accumulator is nearly depleted.
- Once the valve is actuated, it **will fully depressurize the accumulator**, preventing any nitrogen injections. The accumulators cannot be repressurized again while the valve remains permanently open

- The accumulators venting will help to inert and cool the containment. This venting will slightly increase the containment pressure but not to the level that would be detrimental or dangerous to containment integrity.
- Its actuation can be easily detected and verified by the available instrumentation (accumulator's pressure, or containment pressure and temperature). This can be done even with instruments that suffered miscalibration. The pressure change in the accumulator is so important that it will be easily detected.
- If needed, it is also possible to use the direct path to the containment atmosphere across the valve, to make further inertizations with nitrogen. This can also be used to prevent the containment pressure from falling below the normal atmospheric pressure.

- Once the threat of nitrogen injection is prevented, the RCS can be depressurized to lower safe levels. This may be considered as one of the **MAIN ADVANTAGES OF HAVING ASVAD INSTALLED IN THE SYSTEM**, which will serve the following objectives:
    - This further depressurization **will reduce the cooling leakage rate**.
    - Working at lower pressures **will facilitate the emergency equipment operation** to work in more relaxed conditions during the entire accident recovery including lower fuel consumption, lower flow rates, and less stress on the hoses.
    - In addition, lower RCS pressure makes other systems that operate at lower pressure becoming available for RCS level recovery. One example would be the firefighting equipment and other lower pressure pumps that may be used to assist with recovery.

Safety related features.

- The **simple design of ASVAD** which is based on simple physical principles (force and pressure) makes it very **robust and reliable equipment**. Since it is immune to most of the known fault precursors, its risk of failure is very small to none.
- It **does not add any failure mode** to the system other than those already analyzed. In fact, its design makes it intrinsically safe because as long as the pressure in the accumulator remains normal, the valve tends to remain closed all the time.
- Since it is a simple mechanical element, its qualification as a safety element is also simple. The ASVAD Valve is qualified as **nuclear class 2** since it is not part of the RCS pressure boundary.
- It will **decrease the Core Damage Frequency (CDF)** by preventing nitrogen injection into the RCS.
- Its light weight (53 Kg) (117 lb) makes it **insensitive to seismic effects**.
- Due to its metallic construction, it can easily withstand the aggressive LOCA accident environments.
- The ASVAD's weakest components are only two gaskets. Since none of them work dynamically (as they are completely static), they **can maintain their functionality** even if their elastic properties are degraded.

- Due to its design and material construction (stainless steel F316), the valve is **intrinsically immune** to the following conditions:
    - Ambient pressure changes
    - Unaffected by changes in temperature.
    - Immune to radiation.
    - Immune to liquids or moisture.
    - Immune to accelerations in the X,Y and Z planes
    - Immune to electromagnetic fields
    - Immune to corrosion and chemical attacks.
    - Immune to dust and dirt.
    - Immune to cyber-attacks, as no software is used.
    - Immune to electrical discharges or other electrical phenomena.
    - Immune to fire and does not contribute to fire load.
    - Extremely robust against projectiles due to its hard and rounded body.
    - Does not include materials that can be radiologically activated.

Installation related advantages.

- Its installation in the system **is very simple**. Only a connection to the accumulator and one manual valve is required to isolate it for maintenance activities.
- **Minimal modification** to the accumulator system is needed. When the remote manual control option is installed, it only requires a standard control system without the need for nuclear qualification.
- Its implementation has no adverse effects on the existing installation.
- Being a relatively small valve with a light weight, it will not require strong seismic supports or a large free space around it.
- Its installation does not affect the critical path during the plant outages since the accumulators are inoperable and practically depressurized during the entire outage.
- Given its simplicity, its installation cost is minimal. **No further investments will be necessary** as its qualified life is very long and requires minimal maintenance.
- Although the standard installation is vertical, it can be installed in a horizontal position, or even inverted. However, if installed in a position other than vertical, the pressure trigger setpoint should be reconsidered.

Maintenance related advantages.

- All the components of the ASVAD valve can be easily disassembled for inspection and reassembled back.
- Its adjustment is very simple and like any other standard relief valves.
- Being a completely passive with only static elements, its parts **do not suffer any wear out over time,** except for its gaskets, which require replacement according to its qualified life.
- The presence of an isolation valve allows it to be maintained even with the accumulator in service and without compromising its operability. The valve can be removed and replaced with another ASVAD valve very easily if necessary.
- The valve maintenance or repair can be done in the conventional workshop, as it is unlikely to be contaminated either externally or internally. In the unlikely event of its contamination, its surfaces can be easily decontaminated.

- **Due to Its stainless steel F316 construction, its qualified life is indefinite** and will **last for all the remainder plant life**. Only the internal EPDM gaskets will require replacement based on their qualified life.

ASVAD Nuclear class 2 Validation

The validation testing of ASVAD was conducted according to **ASME QME** standards for normal operating conditions, as well during accident and post-accident conditions.

The ASVAD Valve was tested at the facilities of Ringo Valves in Zaragoza, Spain. **The ASVAD prototype satisfactorily met all the specific requirements and criteria**. The valve was subjected to the DBA accident environment with temperatures up to 165ºC and environmental pressures of up to 5,5 Bar for 5 consecutive days of testing. **ASVAD valve passed all inspections and performed as expected**.

A special test bench was designed and constructed for the ASVAD validation testing as shown in Figure 4.

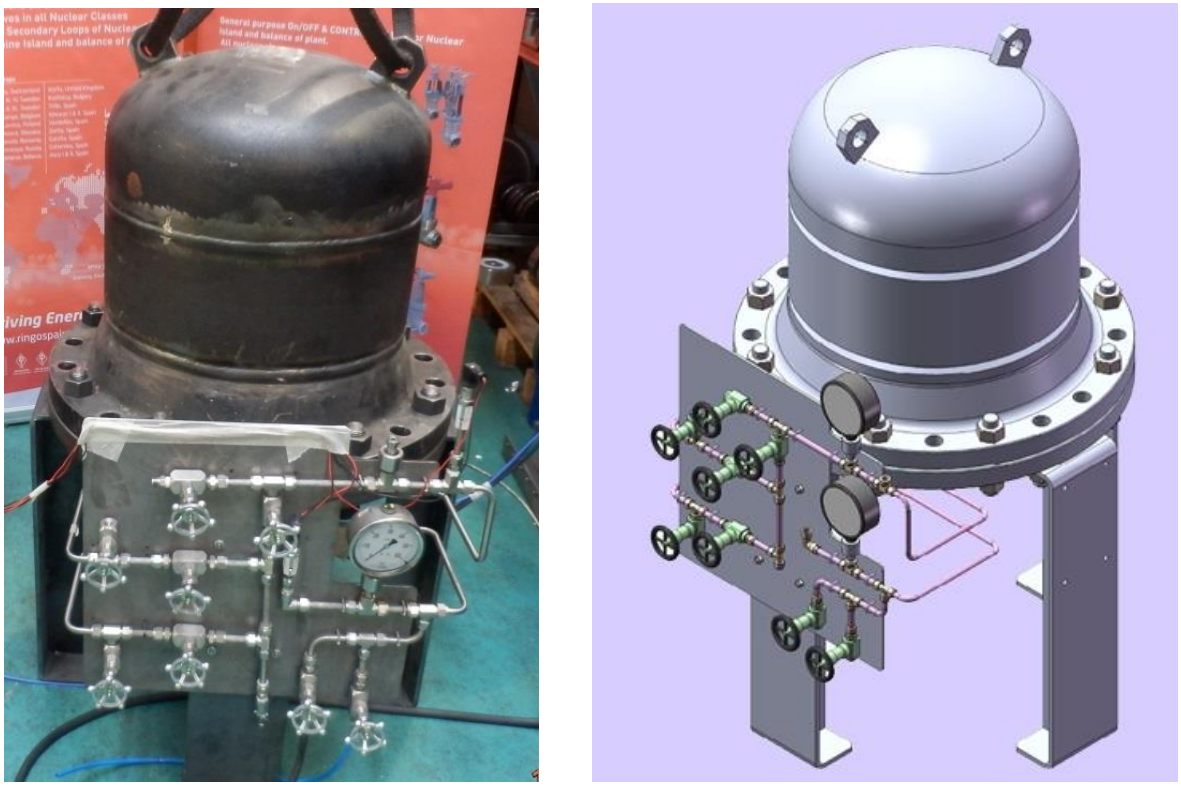


Figure 4. The ASVAD Valve testing bench.

After a long process and thorough examination of the ASVAD Valve physical characteristics and the results of its validation tests, **the Spanish Regulator (CSN) gave its approval** to use the ASVAD valve in the Spanish Nuclear Plants.

Validation Program

- **Initial Inspection.** The valve was preliminarily inspected to verify their initial state.
- **Overpressure test.** To certify the valve pressure endurance. The valve was subjected to a nitrogen pressure till the 150% of its rating (75 bar). No issues or leaks observed.
- **Leak test.** The valve should not leak. With an inner pressure only 10% above its opening pressure, no leaks were observed during the test time.
- **Remote actuation test.** Opening & Closing. The valve was remotely opened & closed at its worst operational situations. The results met its specifications. It works with air pressure from just 4 bar to 15 bar.
- **Automatic opening test.** To verify the valve opening at the setpoint pressure it was subjected to different operating conditions from 20ºC to 140ºC and ambient pressures changes from 1 to 6 bar. Some test results are presented in Figure 5.
  - The Temperature ratio obtained was less than -0,0055 bar/ºC.
  - Its opening dispersion was always below 0,1 bar.
  - The valve opening pressure was determined as ± 0,4 bar as expected**.**
- **DBA ambient test.** To verify that the valve can withstand the DBA harsh ambient, it was subjected to the DBA ambient pressure & temperature for 5 days. After the test, the valve still worked as expected.
- **Post DBA inspection.** The valve continued to operate satisfactorily after the DBA test as expected. The valve was fully disassembled and inspected without any anomalies
- **Seismic Calculations.** The valve will withstand the SSE/OBE

The Spanish Nuclear Regulator (CSN) gave its approval in 2024.

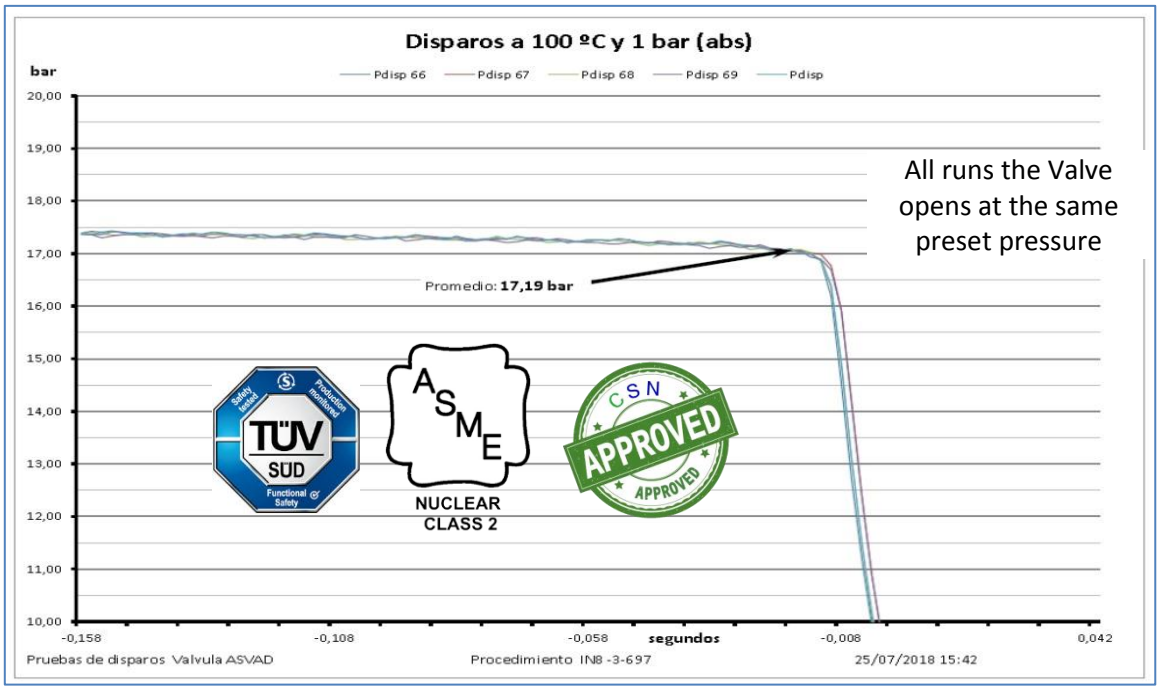


Figure 5. ASVAD opening pressure tests results.

AVAILABILITY

ASVAD Intl SL is a Spanish company that was founded in 2015 to provide product and installation services of the ASVAD© valve to all the PWR plants in the world.

ASVAD is patented over the world. ASVAD INTL SL has its full patent rights. Our company has open agreements with **Ringo Valves (Spain)**, which is a member of SAMSON Group, to build the ASVAD valve and offer it to Europe, US, and Asian market. New partners are welcomed to join our vibrant team.

ASVAD INTL SL is especially interested and welcomes partners from the US, Russia, Ukraine, China, South Korea, and Japan, so if you're interested in joining our team, **don't hesitate to contact us** at **info@asvad-nuclear.com**. Other questions as technical details, or quotations, please contact also to **ringo@ringospain.com**.

ASVAD Intl SL is the ONLY authorized supplier in the world.

CONCLUSIONS

The nitrogen Injection to RCS is a complication which has a high probability of occurrence that can **threaten the core cooling** and the fuel integrity during an SBO/LOCA accident.

The current mitigation practices to prevent the nitrogen Injection **are not reliable and prone to failure**. This is because they all use active components which require power to operate. All need for operator efforts during in an accident environment. They have many other challenging tasks to handle during this time-critical period.

Using the ASVAD, the RCS nitrogen injection **can be prevented easily** without any need for operation assistance and allowing them to focus on the core cooling, or other recovering tasks, including RCS depressurization that can facilitate the accident recovery, **providing a longer coping time.**

ASVAD is a passive element, which **automatically** vents the nitrogen **at the right time**. Installing ASVAD on each accumulator the overall plant safety will be improved.

The ASVAD Valve has been awarded with the EURATOM Nuclear Innovation Prize* 2025 in safety of reactor systems

* Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Commission, DG RTD. Neither the European Union nor the awarding authority can be held responsible for them. "This entity was winner of the Nuclear Innovation Prize from the 2023-2025 Euratom Research and Training Programme"

ASVAD

THE SAFE SOLUTION

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