THE ASVAD BENEFITS

The origin of this new element was in 2014 in the Asco NPP (Spain), during a training session about new procedures after the Fukushima lessons (our FLEX response and procedures). I realized that despite of all the new improvements made to our installation, and to our emergency procedures, there are still some important holes that seem to be still underestimated related to the nitrogen injection and the way to avoid it. Soon the main idea of ASVAD came to my mind… And now I'm trying to give this solution to the PWR plants.

Despite the main idea being simple, writing about its benefits takes some time. That is because this element can be considered from different perspectives. But **this simplicity is the source of most of its benefits**. This paper talks about the ASVAD advantages in relation to the existent solutions, and it tries to clear the main doubts or questions about ASVAD.

I suppose that you have seen the whole presentation about ASVAD and know its principle of operation and its basic design. Now, we will focus on its advantages.

ASVAD VALVE ADVANTAGES.

The inherent advantages of this valve are very numerous and cover several areas. This is the following summary:

Main advantages:

1. The ASVAD valve will be available **all the time** after its installation.
2. **It completely avoids** 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 energy.
5. **It Is fully autonomous.** It does not need any operator assistance.
6. It acts at **the right time** and over **all** the accumulators.
7. It does it automatically by sensing the accumulator pressure. It can also adapt its opening point to the existing environmental conditions maximizing the accumulator's water volume.
8. **It completely vents** the accumulator. There will not be further injection.
9. It allows the depressurizing of the RCS at lower pressures, which will **greatly facilitate the further accident recovery**.
10. It will **save the organization's efforts**, allowing it to be focused on other recovery tasks.
11. **It does not interfere** with the normal operation.

Secondary advantages:

1. It is very **reliable** due to its **simple and robust design**.
2. It is **hard** enough to withstand the post-LOCA environment.
3. It is easy **to be installed** in the system. It does not require a big modification.
4. It is easy to be licensed. It **does not add any new failure mode** different from those already analyzed.
5. It is **intrinsically safe**. No electromagnetic compatibility problems. No software. Cyberattack proof. Fireproof. It does not add any fire load. It is not sensitive to radiation, nor is it sensitive to moisture or even flood.
6. It is a nuclear class 2 valve. Not needed to be class 1.
7. **Its operation is easy**. It can act remotely when required.
8. Its maintenance is simple. **There is no wear**. It just needs a few spare parts. Minimum maintenance cost: "Install & Forget". Its maintenance can be done in the repair workshop as it is easy to remove.
9. It is also **easy to be checked**. It is very similar to checking a standard relief valve.
10. The desired actuating pressure is easy to adjust.
11. **It is economic**. It does not need a complex and expensive system modification.
12. **Its qualified life is very long**. You will not need future investments. "Buy once, use it forever."

Below, all these advantages are explained in detail according to their scope.

During normal operation.

- Due to the aforementioned physical principles, the ASVAD valve **will remain permanently closed** as long as there is enough pressure in the accumulator. This ensures that the accumulator's operability will not be altered during the normal plant operation. Then the valve **only acts after the accumulator system becomes inoperable.**
- It **does not present appreciable leaks** that can put the accumulator operability at risk. In the unlikely event of nitrogen leaking to the atmosphere, it can be easily isolated from the accumulator and removed for maintenance without affecting the accumulator operability (by the manual isolation valve).
- When remote actuation option is installed, the valve can be operated remotely from the control room. This option requires the installation of an air supply system and at least two solenoid valves. Then, both orders (opening and closing) can be executed remotely. This can facilitate its operation even when installed where access is difficult.

- Being located on the nitrogen side of the accumulator and at a higher level, there is no possibility of being influenced by boron deposits that can compromise its operation. Even in the hypothetical case of an accidental accumulator overfilling that could reach the pressure chamber, its internal elements would not be compromised due to the seal produced by the obturator against the gasket.

During the emergency.

- While the ASVAD valve is permanently installed in the system, **it is available during the whole time** to perform its safety function. It does not have inoperability periods.
- The valve fully avoids the accident complications due to nitrogen injection, **unloading the organization from having to manage them**. Operators can redirect their efforts to other more relevant tasks.
- It is a **fully passive element** (type C). It does not require any external energy source. It will perfectly work during the whole accident given that the necessary energy for its opening is already stored in its main spring. It works according to simple and universal physical principles.
- It is a **completely autonomous and automatic** element. It does not require any operator attention nor any other associated system to perform its safety function.
- **Acts at the right time** and always when the water injection is finished. There is **no need to take any decision about when to isolate or vent the accumulators.** ASVAD will do it for us sensing the internal pressure in the accumulator. Since its opening point depends mainly on the accumulator residual pressure, it will only open when the accumulator internal pressure falls enough. This can only happen when there is a low amount of liquid inside the accumulator or it is quite depressurized.
- It can also compensate for the effect produced by the containment temperature rise. This temperature will heat the gas inside the accumulator raising its pressure. The containment environment will automatically raise the valve opening pressure point to compensate for these ambient circumstances.
- The water injection from the accumulators will be done simultaneously, since they start from similar levels and pressures, and they discharge to the same RCS pressure. Then, its emptying moment will also happen simultaneously. By installing the ASVAD valve in each accumulator, they will be individually protected from the nitrogen injection.
- Once actuated, it **will fully depressurize the accumulator**, avoiding any further nitrogen injections. There is no way to repressurize the accumulators again since the valve will remain permanently open after its action.
- The accumulators venting will help to inert and cool the containment. This venting, although the pressure inside the containment building might

be slightly increased, does not entail dangerous containment pressurization.

- 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 in the case of significant instrumentation miscalibration. The pressure change in the accumulator is so important that it will be easily detected. There will also be a small increase in the containment pressure, together with a foreseeable momentary temperature fall produced by the gas expansion.
- Once the nitrogen injection is completely avoided, the RCS can be depressurized to lower levels. **This can be one of the main advantages when installing the valve in the system**. This implies three consequences:
    - This further depressurization **will reduce the leakage rate**.
    - Working at lower pressures **will facilitate the emergency equipment operation** in more relaxed conditions during the whole accident recovery (the fuel consumption will be lower, the hoses will be subject to lesser efforts, the flow rates will be lesser and will last longer, etc.).
    - The RCS depressurization will also mean that **additional systems will be available for recovering the RCS level**. A clear example of this is the fire safety systems that could also be used in these circumstances at lower pressures. Even other lower-pressure pumps that were available could be used instead.
- If needed (and when the rest of the required elements can be aligned), it is also possible to use the direct path to the atmosphere of containment 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.

Safety-related features.

- Its simplicity and the physical principles on which it is based make the valve a **very robust and reliable equipment**. Its failure possibility is very low, since it is immune to most of the known fault precursors. Having a very simple design and an operation **based on universal physical principles** (pressure, temperature, and force) maximizes its reliability.
- Once installed and armed, it **will be available the whole time** and from the first moment. It does not have inoperability periods.
- 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. See section 6 in regarding the detailed analysis of failures.

- Since it is a simple mechanical element, its qualification as a safety element is also simple. It is qualified Nuclear class 2.
- It will give a **decrease in the CDF** (Core Damage Frequency). By avoiding the nitrogen injection into the RCS, it also avoids its derived complications. Therefore, the core damage probability will be reduced.
- Its low weight (53 kg / 117 lb) makes the valve **quite insensitive to seismic effects**.
- The valve weakest elements are the gaskets. Only 2 of them perform a safety function. Since none of them work dynamically (they are completely static), they **can maintain their functionality** even in the worst case of suffering higher degradation in their elastic properties.

- Due to its design and construction (Stainless steel F316), it is **intrinsically immune** to many of the postulated risks:
    - About the external pressure. It uses the ambient pressure for its operation, so its affectation is already considered. It does not pose any risk to its structural integrity.
    - Very robust against the temperature effects.
    - Immune to radiation.
    - Immune to liquids or moisture.
    - Immune to accelerations in the X and Y planes. Very robust in the Z plane.
    - Immune to electromagnetic fields, it does not generate them either.
    - Immune to corrosion and chemical attacks.
    - Immune to dust and dirt.
    - Immune to cyber-attacks, no software is necessary.
    - Immune to electrical discharges or other electrical phenomena.
    - Immune to fire and does not contribute as fire load.
    - Very robust against projectiles due to its hard and rounded body.
    - Does not include materials that can be easily radiologically activated.

- ASVAD is safe. It **does not add any different failure mode** to the accumulator system than the other already installed elements. There are three ways to fail:

    - Failed open. This failure can happen when the valve or its seal loses its mechanical integrity. It is a similar failure than the rest of the elements bearing the accumulator pressure. The result of this failure is the depressurization of the accumulator. This failure cannot be hidden because the pressure of the accumulator is always monitored and alarmed. It has **similar effects** than when any other valve in the system fails open, or when a pipe connection fails, or a pipe breaks. Once discovered, it can be easily fixed by closing the manual isolation valve upstream.
    - Failed closed (or in position). This failure can happen when the spring breaks or by the blockage of the shut-off element. It has the

same (or fewer) failure possibilities as any other valve in the system. But in this case, and during normal operation, **nothing happens** because its default position is closed. It will be discovered when tested (this is a similar case as the PORV).
    - Failed Leaking. This fail has similar consequences as the fail open.

- ASVAD can be **even safer than other elements installed in the system because,** by its design, the pressure in the accumulator always tends to keep the valve closed. In the other elements, the pressure tends to open the element (ex. PORV).

Design.

- It is an element with a **very simple design**, and therefore **robust and reliable**.
- The valve only needs to be **nuclear class 2**, since it does not constitute an RCS pressure barrier (same as the accumulator injection system).
- It is a fully metallic valve (except for some sealing gaskets). It can easily withstand the aggressive environments that can occur during a LOCA accident.
- The non-metallic parts of the valve (gaskets), since they do not work dynamically, can **maintain its functionality** even with significant degradation. However, they also have a specified qualified life.
- Its design complies with the **ASME** standards.
- All of its pieces are also very simple. They do not require special efforts for their manufacture and assembly.
- Its size and weight can be customized, but it will be small, because it doesn't need to be bigger than 2" - 3" (the standard design is 1"). The only difference between sizes is their capacity to exhaust the gas in a shorter time. This small size and weight also mean that ASVAD is less sensitive and less demanding to the seismic effects.

Installation.

- Its installation in the system **is very simple**. Only a connection to the accumulator and one manual valve is necessary (to isolate it during maintenance).
- The modification to the accumulator system **may be minimal**. When the remote manual control option is installed, it only requires a standard control system like any other pneumatic valve. This system is not required to be qualified. This is an optional feature.

- Its implementation has no negative impact on the existing installation. The valve does not add any failure mode different from those already analyzed for the system.
- Being a relatively small valve with a limited weight, it will not require strong seismic supports or a big free space around it.
- It can be easily adapted to the existing accumulator connections. It does not require an exclusive connection to the accumulator, and it can share any of the existing connections.
- It can usually be installed in a radiologically non-compromised area that can facilitate its maintenance at any time, even during normal operation.
- 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 can be small. **No further investments will be necessary**, since its qualified life is very long and its maintenance is minimal.
- Although its standard installation is vertical, its installation is also allowed in any other position, even inverted. When installed in a different position than the vertical one, the pressure trigger setpoint should be reconsidered.

Maintenance.

- Its simple design also facilitates its maintenance. The ASVAD valve can be easily disassembled into its components, being able to inspect all of them completely and over all its surfaces.
- Its adjustment and checking are very simple. It is similar to other standard relief valves.
- Being a completely passive and static element, its parts **do not suffer any wear over time**. The material quality of their gaskets only requires their preventive replacement according to their qualified life.
- The presence of an isolation valve allows it to be maintained even with the accumulator in service and without compromising its operability. This allows it to be removed and replaced by another ASVAD valve easily (just if necessary).
- The subsequent revision of the removed valve can be done in the conventional workshop as it is very difficult for the valve to be contaminated neither externally nor internally. Even in the unlikely case that it happens, its surfaces can be easily decontaminated.
- **Its qualified life is indefinite**, since the material in which it is manufactured is stainless steel F316. This ensures that it will be able to work during the rest of the plant's life. On the other hand, it will usually not be subjected to aggressive environments that could degrade it.

Special cases are the internal EPDM gaskets that will require their preventive replacement based on their qualified life.

- All these gaskets are internal, so they are protected from the external environment.
- Due to its robustness and long life, **the main investment WILL BE ONLY ONCE**. No further investments are needed. Properly maintained, **it can work until the closure of the plant**. It can be enough to have one or two full valve spares in the warehouse to be able to do online maintenance. “Buy once, use it forever.”