**WHY NITROGEN INJECTION MATTERS?**

The focus of this paper is on how people perceive the risks associated with the nitrogen injection.

All the studies done to justify the level of safety in the nuclear plants usually share some axioms like the relative independence between the accident precursors. Statistics show that the likelihood of two or more accident precursors occurring simultaneously in space and time is extremely low. In theory, the probability can be expressed as the product of all the individual probabilities. As these probabilities are very small numbers, their product will be lower... but ONLY assuming that these events are really independent.

However, in cases where there is a direct correlation between these events, the correct number may not be their product but rather their addition. Furthermore, in certain instances, a single accident **can be directly caused by a previous one**, resulting in a sequence of subsequent complications. A distinct aspect is the "common mode failure," which is typically associated with a specific event that **can simultaneously impact numerous pieces of equipment**.

The tsunami that swept the **Fukushima** plant was a hard example of both. The three reactors were melted simultaneously and in a similar way as a result of this single event. The subsequent hydrogen explosions and the radioactive release were only secondary consequences **of the same event:** the extended power loss in the plant which induced the whole control loss over the equipment.

Then, the loss of the power (ie. the loss of the control equipment) **could be the riskiest accident to which our nuclear plants are subjected**. When the operators can’t take actions to cope with the accident, the core melts 100%.

The best way to avoid this threat is using passive safety systems or, intrinsically, safe designs that can sustain the process control even in these circumstances and with own autonomy. But usually there is a limited quantity of these systems, not covering all the recovery. By now, the work of the operators **is always needed** to cope with the accident. And they also require the help of additional equipment (FLEX) outside the containment building, to do recovery actions inside.

Relying in the ability of the operators to cope with the accident could be a flexible tool to fight to these consequences. However, the operators are also our “weakest equipment,” which can also suffer the effects of the main event (i.e., darkness, inundation, high radiation, heat, stress…). Despite their weakness, their actuation can represent the difference between a simple incident and the whole disaster.

In the specific event of an ELAP/SBO accident and its subsequent consequences, we can deduce these facts:

- The plant that suffers an ELAP accident has a **high probability (near to 1) to also have an LOCA** (at least a small one). But these LOCA will be multiple over all the RCP seals. The sum of these coolant leaks can lead to having a medium LOCA... and this LOCA will be **PERMANENT**.

- If there is a LOCA at one point of the RCS, the probability of having another different LOCA can rise, as the containment ambient worsen. (Again, the RCP seals, or a PORV valve stuck open, can be a clear example).

- If there is a LOCA, even a small one, **sooner or later the Safety Accumulator Tanks will act injecting their water** (if no other actions as recovering the power, are taken to avoid it).

- This highly probable LOCA **will contaminate** the containment building in more or lesser extent, hindering (or directly avoiding) all the operators actions inside it.

- Even when the FLEX equipment has been successfully deployed, and operators can keep the RCS pressure above the point of nitrogen injection, working at higher pressure causes that the RCS leak will be bigger. Then, all the equipment must work in a more exigent way. This is the chain: Higher pressure → higher leak → higher pump injection needed (flow & pressure) → higher pump power needed → higher fuel consumed… and so on.

- If the nitrogen injection in the RCS from the accumulators happens, **this nitrogen will heavily disturb the core cooling**. And their effects will be permanent **during all the accident recovery**, because there is not an easy way to remove this nitrogen from the system.

- When this nitrogen reaches the core, the robustness of the fuel cladding will be compromised, as the nitrogen presence will accelerate the cladding oxidation. **This diminishes the time available before the fuel damage occurs**.

- To avoid this nitrogen injection, with our current plant designs, we must choose one of these two different ways:
  - **Isolating the accumulators**. To do this, we need the combination of the operator's proper work with the proper response of the installed equipment (and their energization from FLEX sources). Even with all this work done, we still cannot guarantee that small -but continuous- nitrogen leaks go into the RCS system across the valve internal leaks.
  - **Venting the nitrogen** from the accumulators. To do this, we require the same combination of operators' work and installed equipment. But in this case, as soon as this operation is

completed, this strategy can guarantee the whole avoidance of the nitrogen threat. But this strategy is even more difficult to achieve.

- When the nitrogen injection issue is avoided, **all the FLEX equipment can work at lower pressures,** and this way this equipment will be less demanding, and the recovery will be easier.

- To avoid the nitrogen injection with our current resources, **all the equipment must work properly** (ie. The FLEX power sources, the operators with their procedures, and the installed equipment until their last screw). If just one of these elements fails, it will be the nitrogen injection. This “system” is not a passive system, and it is threatened by the accident environment. Then **their likelihood of success diminishes** as the accident gets worse.

- In this case, the use of a passive system is the best option to avoid this threat. ASVAD is specifically designed to do **all this work autonomously** and with high guarantees of success.

Which is the best? Relying on FLEX equipment and the operators' preparedness to address these issues, **OR incorporating intrinsically safe and passive elements into the design to prevent them?**

My current opinion is clear about it… What's your opinion?