SAFETY CONTROL OF THE SPIRAL2 RADIOACTIVE GAS STORAGE SYSTEM

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ICALEPCS – Oct 2017 – Barcelona, Spain

Ref THPHA107

SPIRAL2 RADIOACTIVE GAS STORAGE SYSTEM

The SPIRAL2 facility, in the GANIL laboratory, will produce high intensity ion beams for experimental nuclear physics. The ion beams are accelerated and sent to experiment rooms through vacuum chambers. The extracted gas, mainly composed of hydrogen, are radioactivated, and have to be stored and monitored. After a predefined length of time, the radioactive decay is checked and the gas is released in the environment.

Extracted gas composition at the start of the irradiation	
dihydrogen	17 %
water	69 %
nitrogen	4 %
Carbon dioxide	10 %
Extracted gas composition at the end of the irradiation	
dihydrogen	52 %
water	43 %
nitrogen	4 %
Carbon dioxide	1 %

Table 1: Extracted gas composition

Origin	Vol. (litre/5 days)	Vol. H_2 (litre/5 days)
LINAC	9.6	7.8
NFS Experiment	1.4	1.2
S3 Experiment	7.2	5.8
Sum	18.2	14.8

Table 2: Expected gas volumes

Figure 1: The storage tanks and electrical control boxes

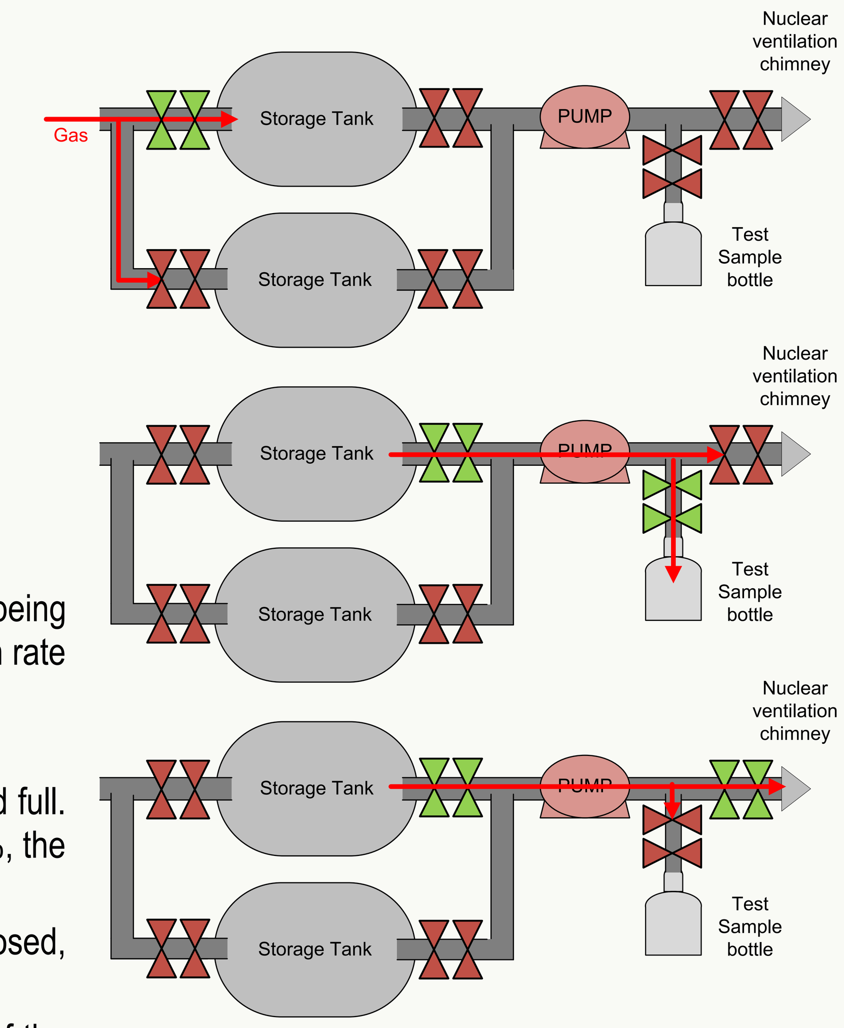


Figure 2: Storage process phases

The tanks of the radioactive gas storage system are the first containment barrier. To prevent any risk of dissemination, the storage system fulfils two protection functions, regarding two accidental events :

- **The uncontrolled released of activated gas towards the chimney of the nuclear ventilation system.**
- **The leak of a tank or a pipe, or the burst of a tank because of an excess of hydrogen rate in the tank.**

The storage system is made of two tanks of 1.6 m^3. The dimension of their volume was calculated to allow an uninterrupted filling of one tank during the decay of the other one, while diluting the gas being stored to prevent any risk of burst caused by the hydrogen. The whole storage system is working under low pressure to prevent gas leaks towards the outside of the tanks. In the same way, the hydrogen rate analyzer systems are set up in low pressure ventilated electrical boxes.

The process cycle of each tank is composed of several phases. Only one phase is running at a time on each tank.

- **The filling stage:** The tanks are empty at first, at a pressure of 1mbar. The input valves of the tanks are opened to allow the gas in, until a maximal pressure of 0.95 bars. The tank is then considered full. During the filling phase, a hydrogen rate analyzer system measures the hydrogen rate in the tank. The gas is diluted with air to keep the hydrogen rate under 1%. If the hydrogen rate still goes over 2%, the filling is interrupted.
- **The isolation phase:** the input and the output valves of the tank are closed during the length of time of the radioactive decay, estimated to a few days. During this phase all the safety valves are closed, making it a safe situation.
- **The sampling phase:** the output valves of the tank are opened, as well as the sampling valves at the input of the test sample bottle. The sample will be analyzed by the Radiation Protection team of the GANIL. They will determine if the decay is adequate to allow the release of the stored gas into the environment.
- **The emptying phase:** the output valves of the tanks are opened, as well as the valves of the nuclear ventilation chimney. A pump is started to transfer the gas into the environment, emptying the tanks to a low pressure of 1mbar. This phase must be specifically allowed by the Radiation Protection team of the GANIL, and by the operations supervisor of the SPIRAL2 facility.

CONTROL STRUCTURE OF SAFETY SYSTEMS

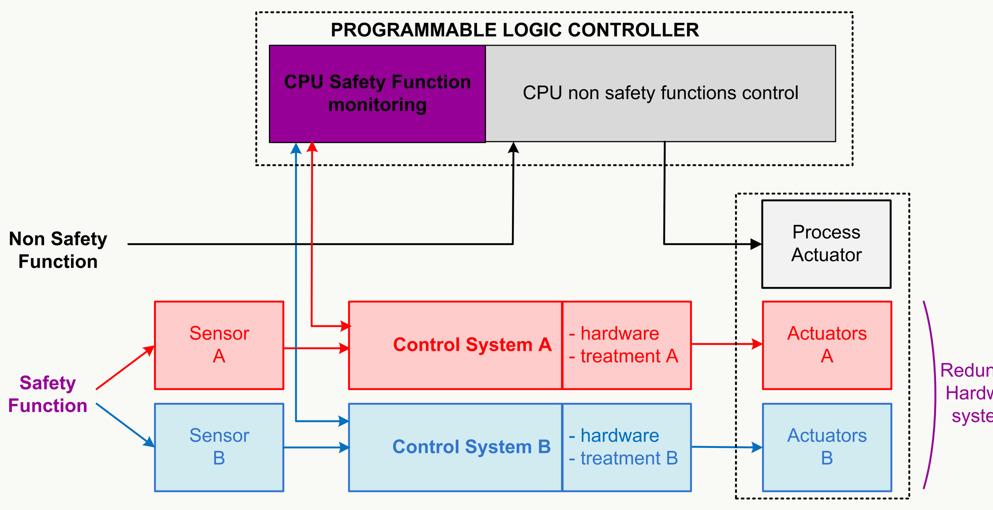


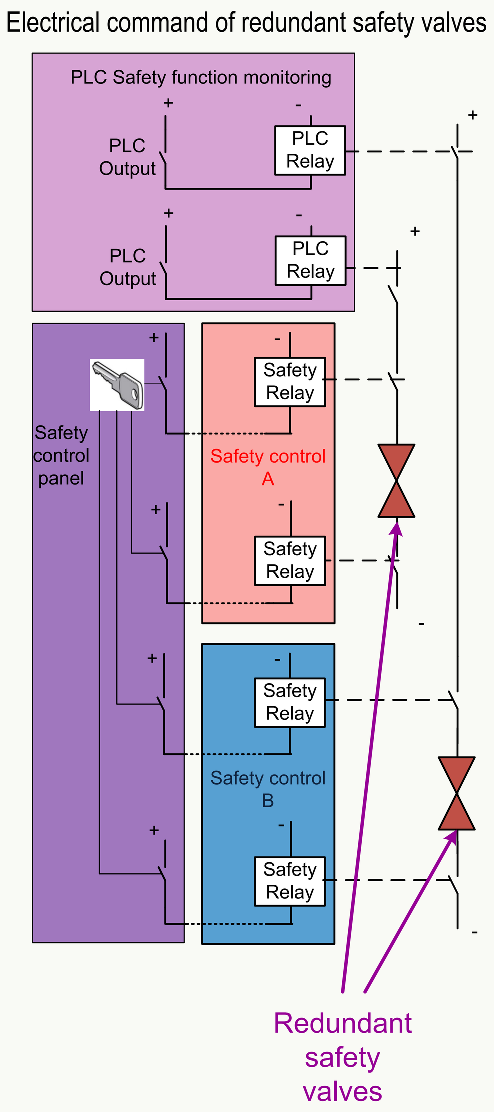
Figure 3: Safety control and non-safety control architecture

A **Failure Mode and Effects Analysis (FMEA)** was made to eliminate dangerous failure of the safety control system. The singe failure criterion was selected as reliability criterion. The FMEA shows the necessity of the redundancy of the safety items and of the safety control. **The whole control chain is doubled, from the sensor to the actuator**. The two subsystems are segregated and dissimilar to avoid common-mode failure risks. During the life of the facility, the system will be periodically inspected.

The safety control system is based on **electrical hardware technologies**, such as relays with forcibly guided contacts, making it a robust and dependable control system.The system, thanks to its monostable valves and its relays, is designed to be a passive safety system.

On top of the safety system based on hardware technologies, a **Programmable Logic Controller (PLC) fulfils the non-safety control**. Both the safety control system and the PLC have to be consistent for the safety valves to open, otherwise they stay closed. The PLC is composed of two CPUs : one is dedicated to the monitoring of the consistency of the two redundant safety subsystems, and the other one manages the non safety-functions of the storage process. Those two CPUs communicate with each other through a dedicated local network.

Figure 4: Electrical command of redundant safety valves



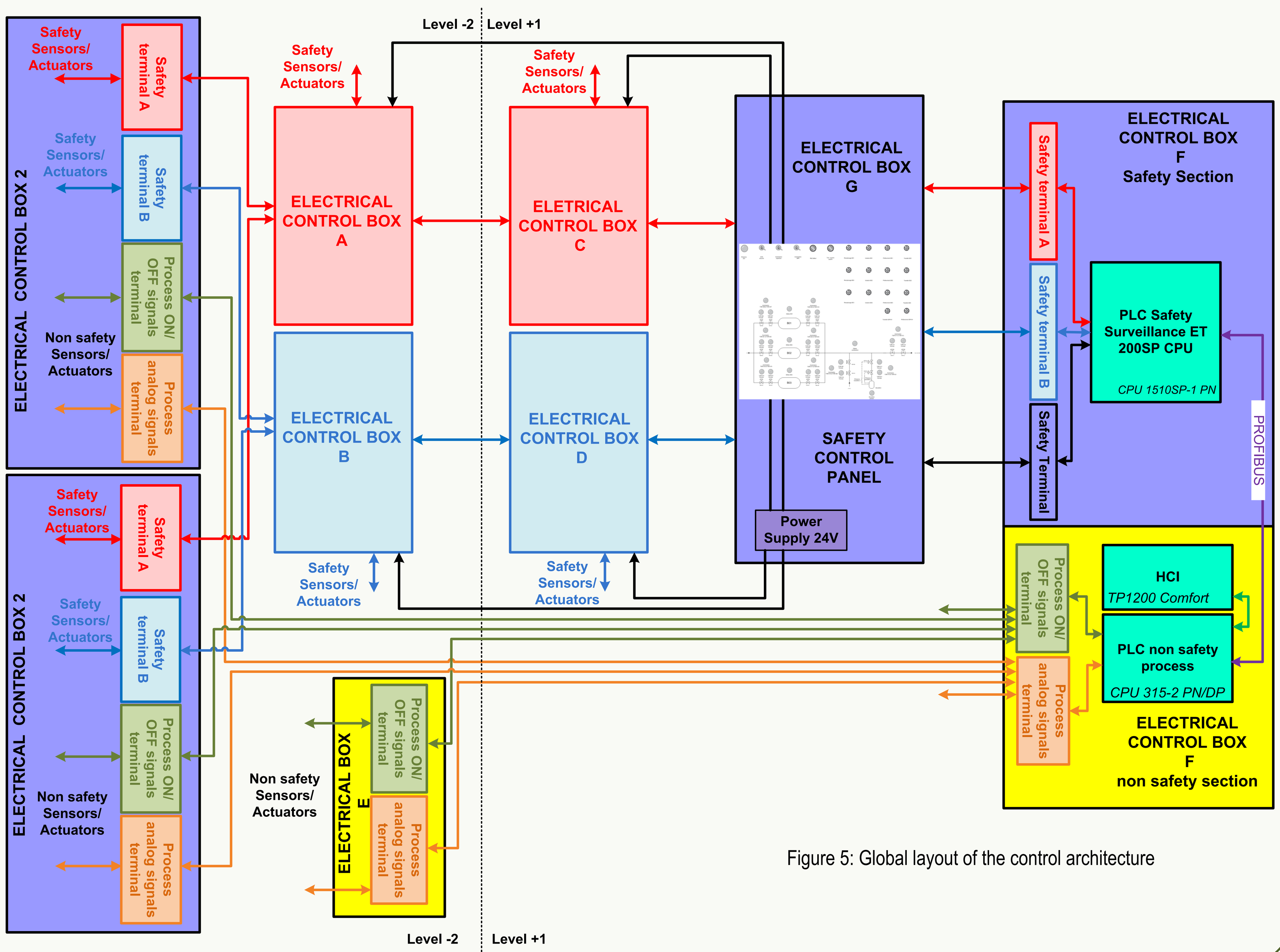


Figure 5: Global layout of the control architecture

FUNCTIONAL DESIGN OF THE SAFETY CONTROL OF ONE STORAGE TANK

The A and B safety electrical control boxes monitor the pressure level and the hydrogen rate in each tank. If those measures are over a threshold, or if a sensor is defective or unavailable, the tanks are withdrawn to a safe situation : the current phase is interrupted and all the valves of the faulty tank are closed. A and B also forbid :

- The simultaneous opening of the output and input valves of each tank
- The simultaneous opening of the input valves of two different tanks
- The simultaneous opening of the output valves of two different tanks

The C and D safety electrical control boxes forbid the simultaneous opening of the sampling valves and of the valves of the nuclear ventilation chimney. They also check the adequate position of the test sample bottle, and the authorization of release given by the Radiation Protection team and by the operation supervisor.

The phases controls are given from a safety control panel, in the box G, with keyed switches and luminous hardware indicators.

The PLC manages the non-safety control such as the dilution of the stored gas, the monitoring of the flow through the hydrogen analysers, the displaying of analog measures, and the communication with the other systems of the facility.

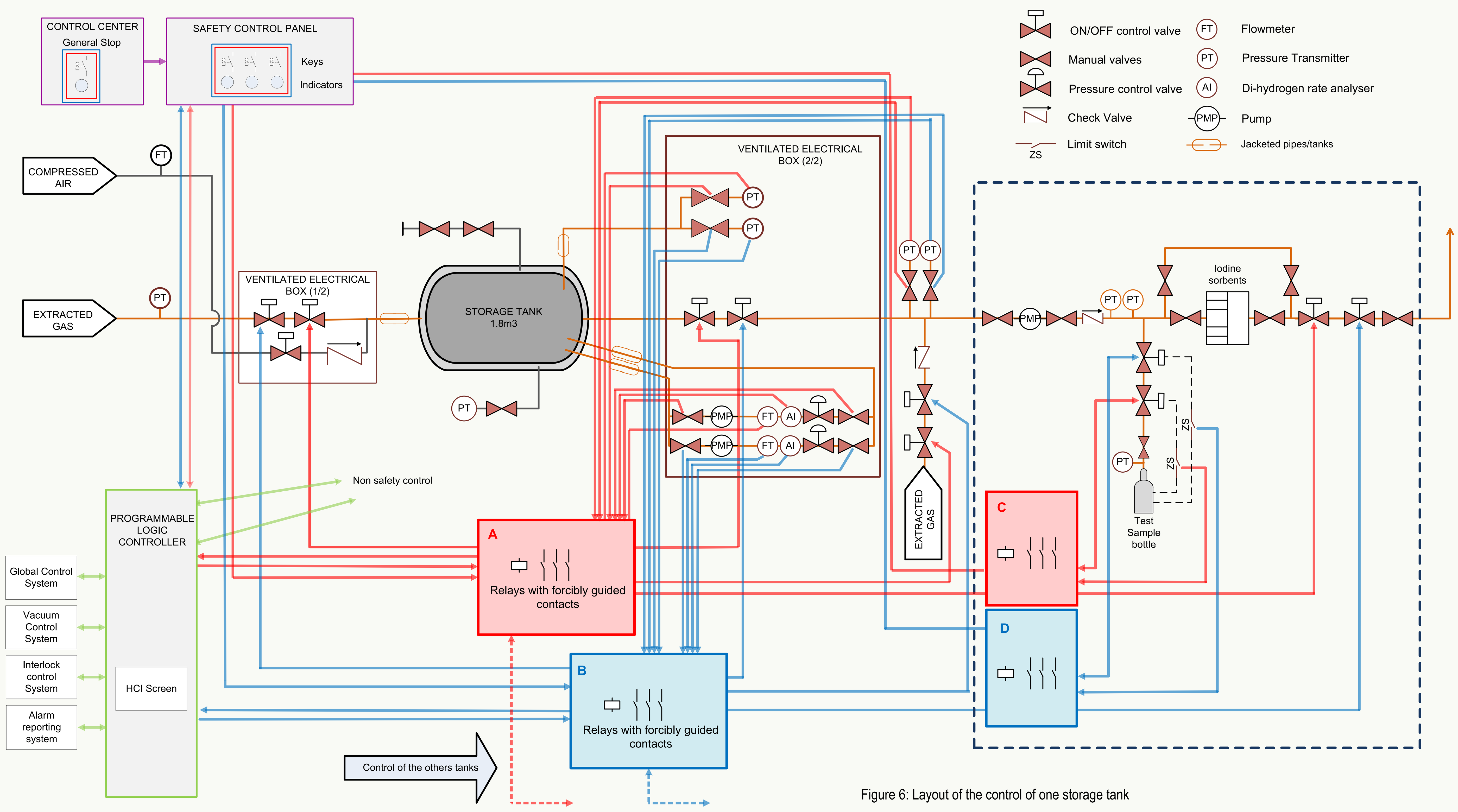


Figure 6: Layout of the control of one storage tank