TEMPERATURE AND LEVEL MEASUREMENTS IMPLEMENTED FOR NUCLEAR SAFETY UPGRADING AT SLOVAK NUCLEAR POWER PLANTS

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In Slovak nuclear power plants, a process of gradual operational safety upgrading of individual units started at the beginning of nineties with the aim to enhance safety level of units in operation up to the level of European standards. Within such activities, safety instrumentation systems with 1E qualification have been built and added for the control of parameters in VVER reactor coolant systems. In the paper presented procedures for the implementation of safety instrumentation systems for the measurements of temperature and level in reactor coolant systems at individual Slovak plants are shown with the purpose and the way of their implementation given.

1. Introduction

Currently such activities are in progress at nuclear power plants in Slovakia which are motivated by efforts to enhance unit operational safety by refurbishing unit instrumentation with the objective to ensure safety during operation, during accidents, res. during seismic events and following unit accident till its safe shut-down. Within the above mentioned activities, various special instrumentation qualified against accidents were implemented according to decisions of czech-slowak commision for atomic energy (ČSKAE) or Slowak national nuclear authority (ÚJD) in line with the need of safety level of instrumentation at individual nuclear units in comparison with European standards. A summary of the implementation at individual nuclear units and description of the way of implementation is presented below.

2. History of implementation of special instrumentation at individual nuclear power units n Slovakia

The implementation of special safety related instrumentation systems at Slovak plants has begun in 1992 when the so called "small reconstruction" of Bohunice V1 started and continued by the so called "gradual reconstruction" of Bohunice V1, by the completion of Mochovce and now continues by the modernization of Bohunice V2. During individual phases of V1 reconstruction, special instrumentation systems were implemented in line with the requirements of nuclear plant operators, starting with design preparation up to the commissioning and working out of operational documentation. The work mentioned was carried out in cooperation with both national and international partners.

2.1 Work related to the implementation of special safety related instrumentation systems during the so called „small reconstruction of V1"

The work on the implementation of instrumentation systems started based on the ČSKAE Decision No. 5/91, paragraph I&C – provision No. 1. Work on the reconstruction of selected measurements of temperature, pressure and pressure difference was made. Technical design was developed for their implementation, which addressed the following temperature measurements:

- temperature in reactor circulation loops – hot leg with output into reactor protection system (RPS)
- temperature in reactor circulation loops – hot leg with output into post-accident monitoring system (PAMS)
- coolant temperature in reactor coolant pump (RCP) autonomous circuits.

The reason for the implementation of the above mentioned system was an effort of Bohunice V1 personnel in cooperation with ČSKAE staff to draw the technical level of V1 unit instrumentation near to European standards for the qualification of instrumentation circuits in safety systems under the conditions of seizmicity and of the newly-defined design basis accident for V1 units.

The essence of the implemented work on the measurement system of temperature in hot legs of circulation loops with the output to RPS consisted in accident strengthening of measuring circuits, in seismic strengthening of their components, and in the improvement of reliability and resistance against electromagnetic interference and fire conditions.

While in the original design solution standard technical equipment produced in sixties was used in which thermometer signal from measuring train was a thermoelectric voltage at the level of about 20 mV led by standard cabling with teflon insulation exposed to the effects of radiation in confinement, the new solution should create measuring trains qualified for 1E class. In the new solution, the original sensors were replaced by sensors, cabling, stands and components of measuring trains qualified for LOCA conditions and local seismic loading, thermoelectric signal was transferred into a signal of unified form 0 ÷ 20 mA and fire resistant cabling was used according to IEC 331 to ensure performance under fire conditions during 180 minutes. Implementation of the system for temperature measurement in hot legs of circulation loops for PAMS was carried out in cooperation with ŠKODA ZJE using the same equipment as in the case of temperature measurements for RPS. Key issue was how to obtain accident-qualified signal from sensor situated in one of the original wells in circulation piping. The solution was implemented by designing a sensor compatible with the well for triple thermoelectric sensor in V1 plant process systems in which two non-qualified and one qualified temperature sensors (Fig. 1) were built. The rest of the measuring train was designed in the same way as the measuring train for RPS.

The measurement of coolant temperature in RCP autonomous circuit for RPS was implemented in its measuring train in the same way as in the case of RPS and PAMS, only with the difference that it was necessary to establish a new temperature extraction from RCP autonomous circuit line as the original temperature sensor could not be replaced by a qualified one with a possibility to install it into the original well. A new qualified temperature extraction with thermoelectric sensor was developed, designed and installed on the surface of circulation piping of RCP autonomous circuit (Fig. 2).

During the implementation of the above mentioned instrumentation systems, new process and testing procedures and components were used, not used previously at VVER-440 reactors. The solutions were developed at such a technical level that they could be used also during the gradual reconstruction of V1 units in the following period of 1996 ÷ 2000.

2.2 Work on the implementation of special safety related instrumentation systems during V1 gradual reconstruction

The work on the V1 gradual reconstruction started after establishing the REKON consortium consisting of SIEMENS KWU and VÚJE Trnava. The object of the reconstruction was defined by the ÚJD SR Decision No. 1/94. Within the reconstruction, work was split into various functional process systems (FTS). Within FTS with the designation I&C – instrumentation and control systems – several special safety related measurements of temperature and level in reactor were soluted:

- temperature at fuel assembly exits for PAMS
- temperature in legs of circulation loops for use in RPS and other safety systems

- level meter in RPV

During the selection of instrumentation systems for the gradual reconstruction, VÚJE working out analyses of current situation and proposals how to implement measuring systems qualified to accident conditions for V1 [2].

The implementation of the system for measurement of fuel assembly exit temperatures is described in a paper at the symposium [8].

For leading signals out of the heads for temperature control, a special solution was designed and implemented in which PAMS signal was led out at a connector on side wall of intermediate flange in the temperature control head. It was also necessary to provide possibilities for seismically strengthened fixing of cables at reactor electric platform and to find vacant wells for accident steam release that would be equipped with qualified penetrations with connectors for PAMS cables.

The implementation of measuring trains for temperature measurement for RPS and for other safety systems was done by adding measuring trains at cold legs in circulation loops using the same solution for sensors and cable trains including U/I transducers as at hot legs in reactor circulation loops during the so called „small reconstruction. Qualified lead of temperature signals out of standard temperature wells for V1 unit process systems was implemented, tests were executed during PKV, as well as during PKV and KV of standard instrumentation circuits used by operating personnel that operated with signals obtained from the same wells as safety systems following the replacement of the original sensors by combined ones with accident-qualified sensor for safety needs of V1 unit systems. PKV and KV of temperature instrumentation systems for the operational control of V1 units following the completion of the reconstruction also in a part of panels in main control room were done also in a part of panels in main control room. Experimental work for bringing into service the complete reconstructed systems for temperature measurements in reactor circulation loops was performed to achieve maximum measurement accuracy in the above mentioned systems. To achieve maximum measurement accuracy in the above mentioned instrumentation systems, temperature reactor etalon [9] has been used for calibration under actual conditions, which is in fact a system for accurate measurement of temperature and temperature difference in circulation loops. In this way metrology assurance is obtained simultaneously. The RPS system by means of measured data transferred from RPS to process information system (TIS) currently enables to control deviations in its measuring trains from the operational temperature etalon with sensors situated at the same piping as sensors for RPS in a minimum distance and evaluated by the TIS system. Data from the reactor temperature etalon are thus used by I&C personnel for checking the accuracy of instrumentation systems, or alternatively for correcting activation temperature boundaries for the reactor protection system. In this way it is also possible to remedy shifts in transfer characteristics of components in instrumentation circuits resulting from their temperature dependency and long-term degradation of material in individual components due to the effects of environment at the point of their installation.

The implementation of reactor pressure vessel (RPV) level meter was done during the establishment of the PAMS system at the V1 plant.

RPV level meter and experience from its implementation at V1 units is described in details in other papers at the symposium [10,11].

2.3 Implementation of safety related instrumentation systems for the measurement of temperature and level in reactors VVER-440, V-213 type

Nuclear units with V213 reactors are operated in Slovakia at the Bohunice V2 and Mochovce plants.

The condition for Mochovce completion given by the ÚJD SR as a mandatory requirement for the Mochovce management is to build a PAMS system at units 1 and 2 during plant completion. Based on this, a proposal for process modification No. 616/E,M was working out and Basic Engineering for Mochovce PAMS was working out by Mochovce. Within PAMS special measurements, implementation of the following PAMS instrumentation systems was required:

- temperature at reactor core outlet for PAMS

- temperature in reactor circulation loops
- coolant level meter in RPV
- coolant level in steam generation (SG) compartment during accident

Because of difficulties with provisions of supplies and with financial funds for the action by Mochovce, the above mentioned systems have not be implemented up to now. After discussions with ÚJD a decision was made to implement temporary instrumentation systems for temperature measurement at fuel assembly exits and level in SG compartment as a temporary solution of PAMS instrumentation at Mochovce units 1 and 2 [5,6].

The measuring system for temperature measurement at fuel assembly exits was implemented in such a way that it processes a single signal from each sixth part of reactor core, which it obtains from standard measuring trains after their galvanic separation from the measuring trains of PTK OK system. The signals are then processed by PC type computer with I/O interface with integration A/D transducer in the range of 0 ÷ 1260°C.

The instrumentation system for level measurement in steam generator compartment in the temporary realization measures levels in SG compartment in two elevation points 0.58 m and 1.82 m by means of conductive probes made in Russia. The processing of probe signals is provided by switching relays with conductive input which switch on electric circuits of annunciation lamps and provide signals for display at PC monitor in the temporary measurement equipment PAMS (Fig.3).

Both measuring systems are shared in a cabinet at main control rooms at Mochovce units 1 and 2 and are not qualified for permanent function in PAMS systems as in the future they will be replaced by instrumentation systems fully qualified for 1E class according to US NRC RG 1.97 together with systems for RPV level measurement and for temperature measurement in reactor circulation loops.

Currently a project to design measuring systems for V2 modernization is being prepared for which VÚJE developed safety concepts at the level of Basic Engineering [7] in 1999 to 2001. During V2 modernization also all safety related measuring systems used at V2 units will be reconstructed using technical solutions implemented at other nuclear power plants in Slovakia.

3 Conclusions

The current level of assurance of operational safety is different at various plants in Slovakia. While the Bohunice V1 plant is at the end of innovation process for safety related systems and the Mochovce plant is close to the completion at units 1 and 2, the Bohunice V2 plant is at the beginning of the process of modernization and safety level upgrading. VÚJE fully monitors these processes and uses its technical potential for the implementation of particular steps during upgrading of the safety level of nuclear power plants in Slovakia. VÚJE does not limits its activities only in Slovakia, but takes part also in activities within safety enhancement of nuclear power plants abroad and is able to provide its services in all phases of implementation of systems improving nuclear safety level of units in Slovakia.

Appendices

Fig. 1 Combined triple sensor for temperature measurement in circulation loops with qualified instrumentation circuits for PAMS.
Fig. 2 Solution of temperature extraction in circulation piping at RCP autonomous cooling circuit
Fig. 3 Principal scheme of instrumentation circuits for level in PG compartments

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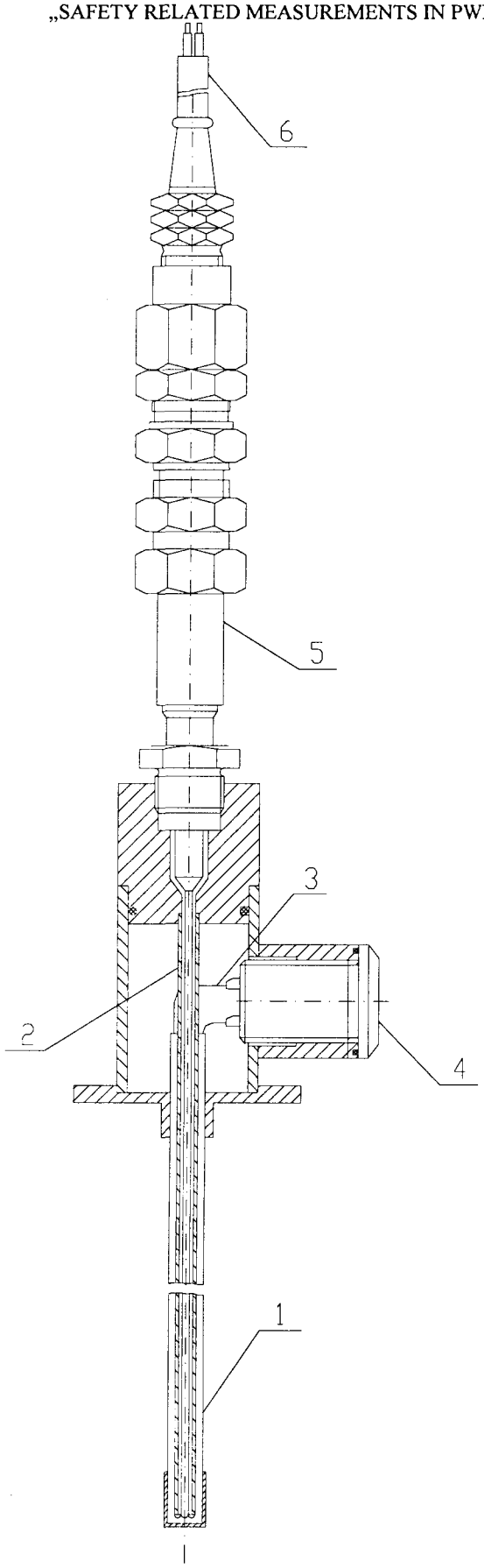

Fig. 1 Combined triple sensor for temperature measurement in circulation loops with qualified instrumentation circuits for PAMS.

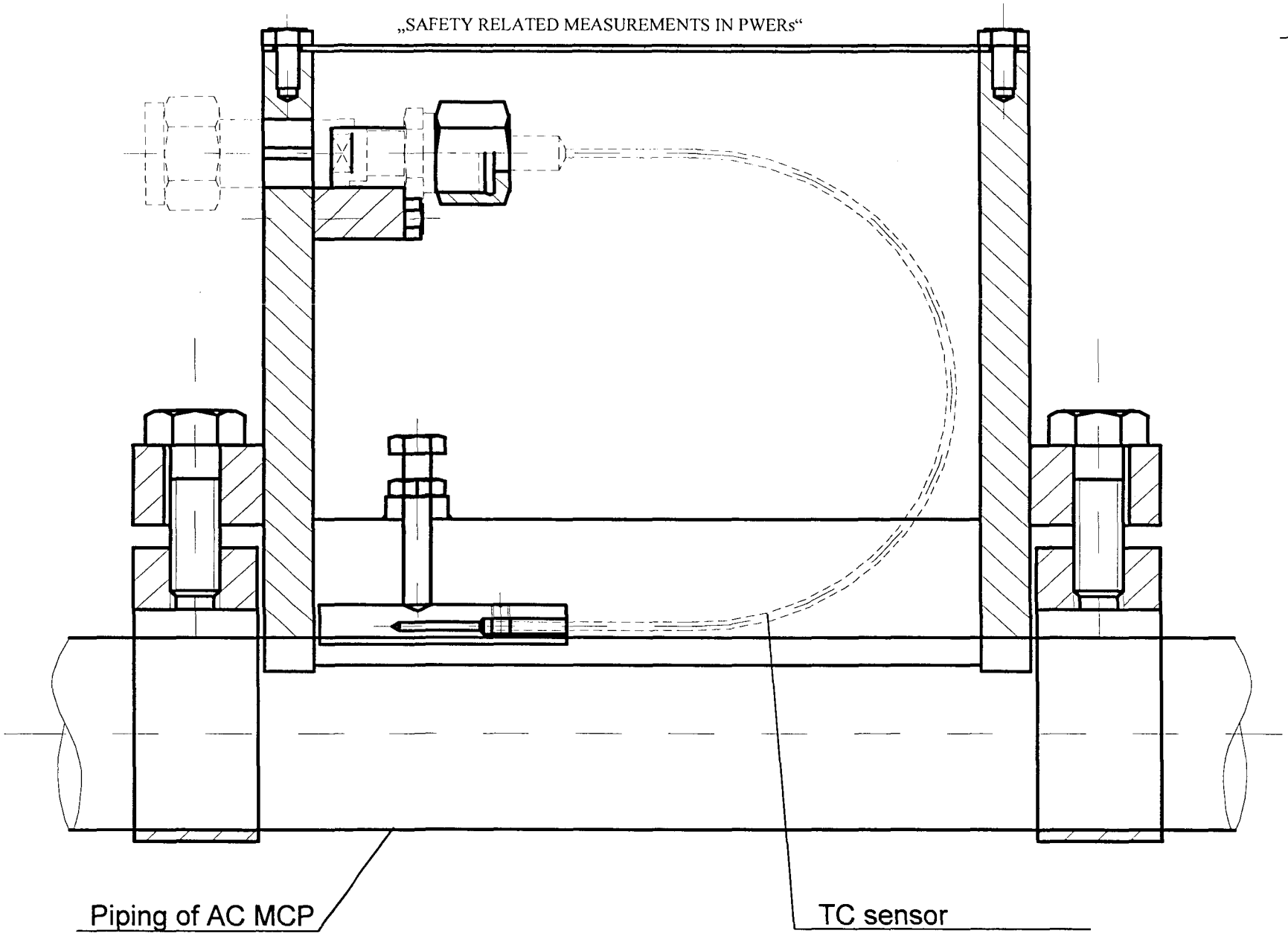

Fig. 2 Solution of temperature extraction in circulation piping at RCP autonomous cooling circuit

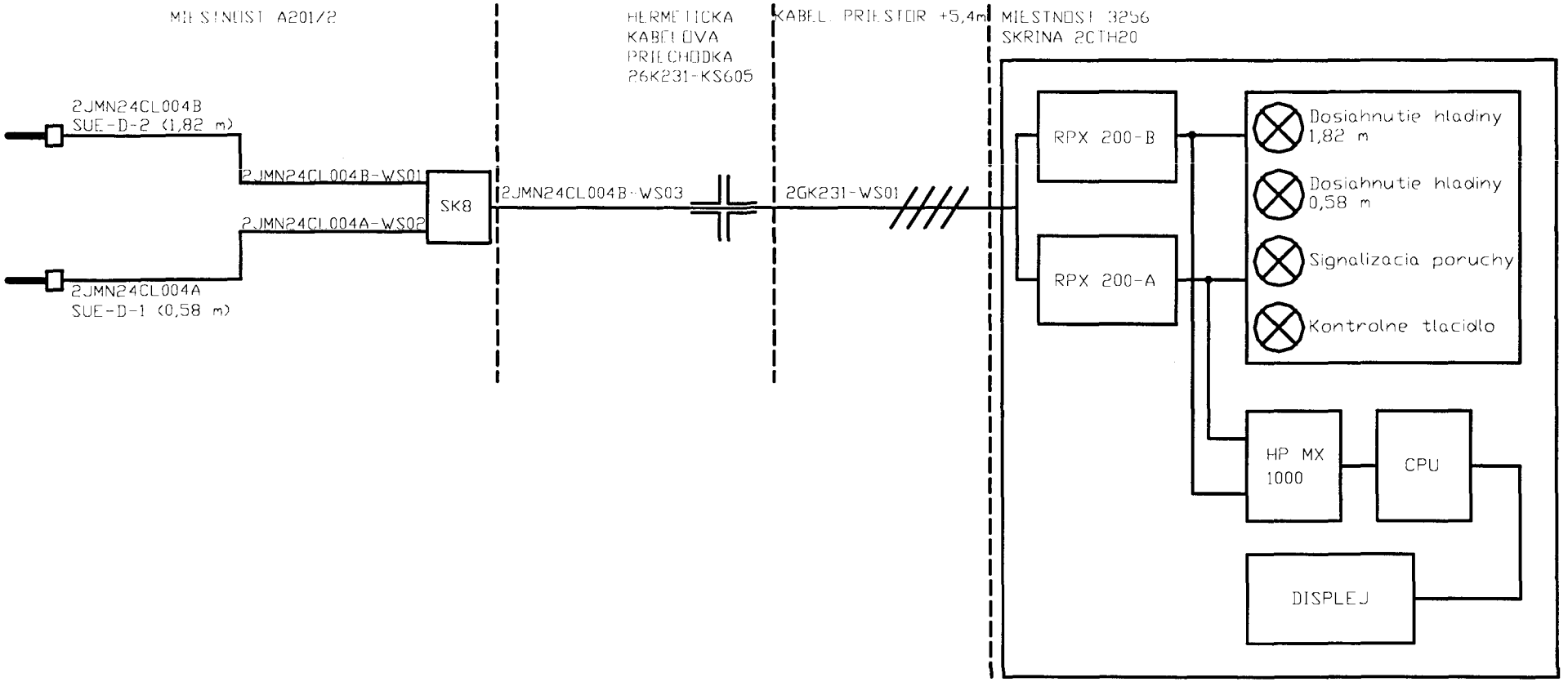

Fig. 3 Principal scheme of instrumentation circuits for level in PG compartments