EXPERIENCE FROM START-UP AND USE OF FAIL-SAFE REACTOR LEVEL METER WITH KNITU PROBES

S. Badiar, J. Šipka, P. Vančo, Marek Slanina
VÚJE Trnava Inc.

Ľ. Líška, D. Gavora
SE a.s., EBO o.z.

ANNOTATION

Within gradual reconstruction of V1 NPP, VÚJE Trnava a.s. has implemented in co-operation with SIEMENS KWU a level meter for V1 reactor pressure vessel in V1 units in Jaslovské Bohunice. This report presents experience gathered by VÚJE Trnava a.s. during elaboration and implementation of final design, QAIP, design and implementation of PCT and CT. Within experience from final design elaboration are described problems of adaptation of solution to technology and local legislation. Within experience from implementation of quality assurance individual program results of acceptance tests of level meter component parts are listed. Great attention is given to special equipment that has been developed on basis of PCT, CT and QAIP programs for level meter operation for purposes of pre-operational and in-service inspection of level meter functionality.

1. INTRODUCTION

Coolant level measuring during and after a LOCA type accident in reactor pressure vessel is one of the main requirements expected from implementation of system of post-accident monitoring of a NPP parameters – PAMS.

Measuring systems for PAMS have to meet requirement of high functionality and reliability in all states of NPP unit. Therefore it is necessary give them increased attention during implementation and operation and ensure thoroughgoing inspection of component parts functionality before and after mounting.

Scope of this report is to inform a forum of experts specialised in NPP operation about experience gathered by group of experts of VÚJE Trnava a.s. during implementation of level meter for reactor pressure vessel in V1 NPP units in Jaslovské Bohunice in Slovakia. This implementation has been performed in co-operation with SIEMENS KWU experts within REKON consortium during gradual reconstruction of V1 NPP and with experts of INKOR Moscow that is the supplier of KNITU 11 probes and connecting cables for SIEMENS KWU.

Technical requirements for mounting, dispositions in NPP units and needs of design documentation as well as implementation quality assurance program have been considered within the process of level meter implantation into V1 plant units in Jaslovské Bohunice. Special procedures and testing equipment have been worked out and used for smooth start-up of the level meter. Within design documentation of level meter in V1 units a technical study has been worked-out that considers technical and disposition requirements for level meter implementation and final design including besides organisation and technical solution for implementation also the implementation quality assurance programs. Within implementation of quality assurance program have been developed and implemented program of acceptance tests for level meter component parts as well as testing equipment for pre-operation implementation phase – pre-operational testing equipment. Testing equipment has been used for pre-operational phase of level meter implementation. Scope of documentation and facilities mentioned above as well as results obtained are described in the following paragraphs.

2. Experience from implementation of level meter in reactor pressure vessel within PAMS in plant units with VVER-440 – 230 reactors

During level meter implementation in V1 NPP units in Jaslovské Bohunice a necessity emerged to identify requirements in following areas in order to implement level meter into unit technology.

- technical requirements for design of level meter in reactor pressure vessel for use in PAMS of V1 NPP units
- requirements for dispositions of V1 NPP units technology
- requirements for design documentation of level meter

2.1 Technical requirements for level meter design in reactor pressure vessel for use in PAMS of V1 NPP units

In order to be able to install the level meter in a specific unit it is necessary to specify technical requirements and verify their fulfilment or suggest modifications to its component parts. Technical requirements have to be specified with respect to needs of the unit's technology. In case of V1 NPP units the technical requirements have been specified similarly to those described in FRAMATOME report [6].

2.2 Requirements for technology dispositions in V1 NPP units

In order to bring out signals from reactor to the main control room and emergency control room and locate display and evaluation devices and ensure their operation in reactor environment it was necessary to verify and ensure availability of following dispositions in order to ensure successful implementation process.

- free KNI channels or suitable configuration of KNI channels in relation to optimal level monitoring along the reactor core cross section.
- free positions on reactor electro-platform for placing level meter connecting cable branches
- free penetrations for level meter cable lines on the charging area of reactor cavity
- dispositions for placing qualified cable routes for level meter in 1E class
- free space for mounting and placing of electronic cabinet
- free positions for signalling and measuring equipment of level meter on PAMS panels
- dispositions of power supplies and power supply cable routes qualified for 1E for level meter component parts power supply
- additional dispositions in compliance with requirements of operating staff for utilisation of the output signals

2.3 Requirements for design documentation of level meter in reactor pressure vessel

2.3.1. Final design

Level meter final design must typically meet requirements set by actual standards for required quality of equipment with respect to legislative regulations for NPP where the implementation takes place. Further it must co-ordinate proceedings for implementation quality assurance by means of implementation quality assurance program. Final design has to consider interfaces with existing technology by means of its design documentation creating mutual connections within design documentation. An important procedure in the use of data of the existing design documentation is their verification on the spot of the future implementation and assurance of quality of existing or additional unit technology parts by qualification or re-qualification to the level required for level meter operation.

Final designs for 1st and 2nd V1 units have been worked out for the purposes of level meter implementation in reactor pressure vessel using the described procedure. [2], [7]

2.3.2. Quality assurance program and its implementation

Individual parts of quality assurance program have been worked out for the purposes of quality assurance program and its implementation within final design and subsequently to final design. These are necessary for determination of steps within implementation quality assurance process and for documenting fulfilment of requirements for implementation quality and they include following:

- quality assurance individual program for specific equipment
- quality assurance program for reserved technical facilities
- technological proceedings
- testing procedures
- implementation works co-ordination + schedule

2.3.2.1. Most important steps of quality assurance program

Experience from level meter implementation in reactor pressure vessel shows that following steps of quality assurance program are the most important and most exigent in phase of preparation, implementation and start-up of level meter. These steps have been designed in sense of regulation No. 436/1990 and regulation 74/1996.

2.3.2.1.1. Acceptance tests of delivery for level meter in reactor pressure vessel within QAIP

Component parts acceptance tests within delivery for level meter implementation are important in the light of early identification of faulty component parts, which are subject to claim proceedings. It is important to perform tests of all component parts right after delivery so that the longest possible time for possible claim proceedings is gained, i.e. so that the faulty component doesn't hinder availability for installation.

2.3.2.1.2. Tests during implementation of QAIP and QAP

For component parts quality assurance in the implementation process are important tests within QAIP and QAP in the process of transport, storage and mounting of component parts. These tests have to comply with technological mounting proceedings. In every step they allow early identification of failures caused by incorrect handling of component parts or incorrect mounting procedure. This allows early delivery of spare component parts or correction of faulty mounting operations or elimination of defects caused by intervention of unauthorised person, which is a frequent case in implementation process during unit outages.

2.3.2.1.3. Tests of complete level meter equipment in reactor pressure vessel

Complete level meter equipment in reactor pressure vessel requires functionality tests including metrology tests in 2 main states of NPP units:

- before start-up of the unit
- during operation of the unit

Pre-operational tests are performed in 2 phases:

- cold experiments or pre-complex test
- hot testing or complex test

Significance of cold experiments (PCT) consists in possibility to eliminate identified failures and backlog before start-up of the unit while there is possibility to intervene into measuring chains without influencing the unit operation. However in the case of level meter in reactor pressure vessel this time is limited by the moment of KNITU probe mounting into reactor and beginning of compression tests. This period is rather short (in order of hours) and therefore an automatic testing device has been developed in VÚJE Trnava a.s., by means of which it is possible to perform PCT in a short time.
Significance of hot testing consists in inspection of reliability and stability of component parts parameters or of accuracy of their conversion features during reactor start-up as well as in performing demonstration system lift. In this case, too, the testing device used within PCT is of good help as it allows reducing level meter functionality outages for the reason of testing proceedings to the minimum during startup power operation of the unit.

In-service inspection are recommended by RG 1.97 normative document and proper standards for measuring systems whose data aren't displayed during normal operation or technological parameter isn't displayed simultaneously by another system. Among such systems belongs level meter in reactor pressure vessel. Because the standard in-service inspection would require disconnection of measuring circuits with danger of provoking failures during repetitive disconnection and reconnection of circuits, VÚJE Trnava a.s. has developed operational testing device that doesn't require the described interventions into measuring circuits during measuring system testing. The equipment will be implemented into measuring chains of level meter in reactor pressure vessel of the 2nd V1 unit in Jaslovské Bohunice. The operation will take place within general maintenance of the 2nd V1 unit in 2001.

2.4 Description of testing programs and devices developed in VÚJE Trnava a.s. for the purposes of testing of level meter in reactor pressure vessel of V1 NPP in Jaslovské Bohunice

In order to ensure necessary time during level meter start-up in reactor pressure vessel and to test functionality of the equipment in operation, following products have been developed in VÚJE Trnava a.s.:

- acceptance tests program containing testing methods and procedures for identification of all level meter component parts failures that could threaten its functionality
- pre-operational computer-controlled testing equipment with option to simulate all kinds of failures and states of the measuring system
- operational testing equipment allowing to verify the equipment functionality during unit operation in minimum time without necessity to disconnect its measuring circuits

The above listed products are described in the following paragraphs.

2.4.1. Acceptance tests of component parts of level meter in reactor pressure vessel

In order to perform acceptance tests of level meter component parts in shortest time possible, acceptance tests program has been developed completely and transparently. This program contains program steps for assurance of quality and functionality of all level meter component parts with respect to assurance of its permanent functionality and preserving quality of signals bring-out from reactor. All of this is performed preserving integrity of pressure barrier between reactor core and reactor's environment. Testing methods has been worked-out and tested with KNITU probe model. [8]

Level meter component parts within implementation process have been tested in sense of the described program and spare component parts supplied for equipment in operation are further tested.
Acceptance tests program contains testing procedures for 9 main component parts of level meter. Altogether it contains 65 testing procedures for all of the main component parts. Among the testing procedures the following tests are technically the most interesting ones:

- test of temperature sensor positions alongside the KNITU probe
- test of compliance with specified thickness of the KNITU probe jacket by means of measuring the roughness of its surface
- test of time response of sensor in KNITU probe to temperature change in the measuring point
- tests of functionality and metrology features of KNITU probe temperature sensors

These critical parameters of KNITU 11 probe have been measured within acceptance tests repeatedly and the test results have been processed statistically. The results of parameters statistical processing are listed in [9] and [10].
During acceptance tests data processing the following anomalies have been identified:

1. deviations of thermocouples metrology features in KNITU probe
2. dimension of KNI channel extension piece doesn't meet requirements
3. faulty power supply 24 V, type USR 255 in electronic cabinet
4. deviations of branch resistance values of thermocouple lines in KNITU probe and Š-TIII connecting cable
5. surface of No. 99101701 probe damaged with a scrap of approximately 30 mm

Anomalies of parameters 2, 3 and 5 can cause malfunction of level meter in reactor pressure vessel during unit operation and therefore have been immediately returned to the supplier within claim proceedings. This helped to gain time necessary for preparation for level meter mounting in NPP unit.

Parameter anomalies 1 and 4 don't influence level meter functionality, as they haven't reached the extent that would cause malfunction. Their presence however indicates that it is necessary to monitor these parameters continuously within acceptance tests, when collecting the products from factory. Dispersion of these parameters outside dimension limits is caused by use of component parts from various suppliers.

Acceptance tests results have proved their foundation. The level meter component parts have been tested completely during 5 weeks within the testing process. The identified failures in measuring circuits component parts as well as in electrical circuits have been removed within the claim proceedings. In the course of the equipment mounting and after its assembling during complex tests haven't been identified further failures in level meter component parts. No failures of system that would cause its malfunction or rupture of reactor pressure barrier have occurred during operation.
The acceptance tests results have been passed to the manufacturer so that a feedback to manufacturing process quality was established. Low values of insulation resistance of some of the probes and connecting cables that would allow their operation on the limits of usability with danger of total failure haven't occurred in next supplies. The fig. 1 shows enables to observe increase of insulation resistance values as a result of feedback of acceptance tests results to the manufacturing process. The increase can be observed comparing the part 1a and part 1b of the figure. Similar quality modification can be observed on fig. 6. Here the difference between deviations of the KNITU 11 probe sensors features identified during acceptance tests of the 1st supply, visualised in part 6a, is clearly visible in comparison with deviations of features in next supplies, visualised in part 6b. The figures are results of monitoring of parameters' values of KNITU probes manufactured before passing the acceptance tests results to the manufacturer and those of probes manufactured afterwards.

2.4.2. Pre-operational testing equipment of level meter in reactor pressure vessel

The purpose of pre-operational testing equipment is to verify functionality and metrology parameters of level meter component parts during complex test after implementation or during restart-up after unit outage. During these tests it is necessary to meet the requirement of test time minimisation as the interval since KNITU 11 probes implementation until reactor start-up is rather short.

In order to meet this requirement the pre-operational testing equipment is designed as computer-controlled set containing a unit ensuring contact with environment that will allow simulation of operational and failure states of the system and sensing of its input and output parameters. Input data (real or simulated) are scanned and compared with system's output data. By combining input data and interventions into measuring routes by means of simulator it is possible to invoke various operational and failure states of the system, monitor the response of self-diagnostic and signalling circuits of evaluation device and also perform calibration of evaluation device measuring channels. The structure of the device is on the fig. 3.

Hardware and software equipment of the pre-operational testing equipment allows performing automatically complex test operations and printing out a testing report on the testing spot. A sample of the report from an automatically performed test is on fig. 4.

Pre-operational testing equipment is technically designed in such a way that it is possible to integrate it into measuring route by disconnecting connector on the reactor charging area, plugging the connecting cable to simulator and connecting cable from simulator to the charging area's connector. It is possible to connect to outlets of evaluation electronics by means of simulator testing conductors. The way of connection to level meter can be seen on fig. 3.

By means of pre-operational testing equipment it is possible to test all circuits that are necessary for maintenance of functionality of level meter in reactor pressure vessel and check or set metrology parameters of measuring channels in course of maximum 3 to 4 hours. Pre-operational testing equipment also allows functionality inspection of assembled level meter without necessity of water level change in reactor. Using the equipment helps to save time necessary to perform PCT and CT during the reactor start-up. Further information can be obtained on poster presentation of the equipment that is also displayed on fig. 2.

2.4.3. Operational testing equipment

The purpose of operational testing equipment is to test functionality of level meter in reactor pressure vessel during operation without necessity to disconnect measuring circuits and to allow functionality inspection of circuits of level meter evaluation device that cannot be tested by system's self-diagnostics.

Operational testing equipment consists of a power supply and a testing module and it is placed directly in the modular structure of operational units of the electronic cabinet.

Purpose of in-built digital voltmeter is to measure and display voltage value in checkpoints of the level meter. Outlets and inlets of the testing module are connected to the checkpoints by means of manual control on the equipment's panel through switching modules, which ensure at the same time galvanic separation of the testing equipment from the level meter circuits out of normal operation.

Operational testing equipment ensures supervision of signals level on the input terminals of level meter evaluation device and generating of defined input voltage on its measuring channels in testing operation as well as input information change of self-diagnostics circuits of the level meter evaluation device. The above listed operations are ensured by means of 11 testing channels.

Operational testing equipment is protected against accidental operation and unauthorised intervention by organisation of the control elements on the panel of the device and access restriction. The protection against accidental operation consists in the fact that the initialisation of the testing channel is only possible after the following sequence of operations:

1. switching the power supply by means of lockable switch using the appropriate key
2. switchover of function option button from the gauge zero to one of the testing gauges
3. striking the activation button of the testing function

These steps must be observed completely. Performing of one of them doesn't activate the desired testing channel.

The protection of the device against unauthorised intervention consists in locking the switch of power supply and doors of the casing of level meter evaluation device. Block diagram of the operational testing equipment with a short technical description on fig. 5.

2.5 Experience from long-term utilisation of level meter in reactor pressure vessel in V1 NPP units in Jaslovské Bohunice

Level meter in reactor pressure vessel in the V1 plant 2nd unit has been used within the PAMS system as long as 4 years and in the V1 1st unit since 2 years. No malfunctions have been identified during its operation in the circuits of neutron flux measuring in reactor core coupled with level meter within KNITU probe neither in level meter circuits that would cause outage of the level meter system or decrease of accuracy or outage of neutron flux measuring in reactor core. Failures of electric modules have been identified in part that doesn't directly affect the function of level meter. Further have been identified failures of insulation resistors of neutron flux measuring and failures during manipulation on the reactor charging area during unit outage. No defect of integrity of reactor pressure barrier has been identified point of KNITU probe mounting either.
No ineligible operation has been detected of level signalling in reactor or level meter failure signalling even not during reactor testing operation.
Measuring channels in level meter analogue part constantly monitor coolant temperature during operation in vertical points for level monitoring in reactor and it's possible to use them for the purposes of temperature mapping vertically alongside reactor pressure vessel in places where temperature monitoring doesn't exist.

Claims for intermittent use of these measuring data have been already laid in the V1 NPP units in Jaslovské Bohunice.
Operational personnel in V1 units confirmed in unit refuelling intervals up to now state without danger of level meter functionality constraint. Despite this certain problems occur that have to be solved in order to ensure the full control of the level meter. It's a case of following problems:

- absence of functionality check for certain component parts during operation
- absence of monitoring of level meter measuring chains parameters by means of TIS
- recurring problems concerning connecting cable insulation resistance whose tendency indicates possibility of measuring chains malfunction in future
- deficiencies in operation of recorder of measured values from level meter measuring chains

The described problems, despite the fact that they didn't cause reduction of level meter functionality, have to be solved in order to achieve the maximum degree of control and assurance of level meter functionality during operation. By means of use of operational monitoring equipment will be solved the problems of functionality control of all component parts as well as functional units of level meter, especially continuity of signal routes for discrete signals that are important for level meter functionality during accident.
Measuring chains control by means of TIS can be realized by bringing in signals from outlet of electronic cabinet into JSP TIS.
Problems of insulation resistance of connecting cables and of measured quantities recording by recording equipment have to be solved by revaluation of further use of these component parts and by successive repair. In case that permanent elimination of these problems isn't possible using the existing component parts that have to be replaced with other, more reliable types.

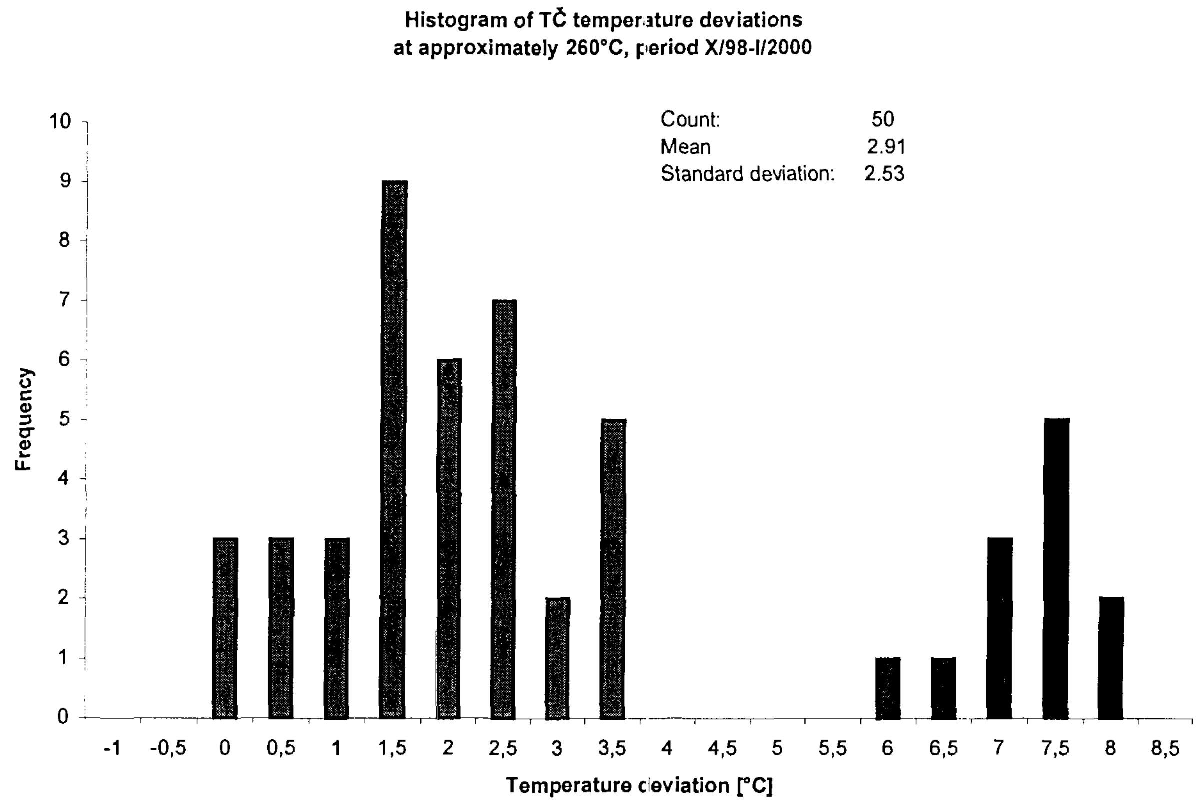
3. SUMMARY

Experience from implementation and use of level meter in reactor pressure vessel in V1 NPP in Jaslovské Bohunice document high-quality project planning and necessity to use pre-operational and operational testing equipment in order to attain operative level meter start-up and its continual functionality. A real result of this process was fail-safe and time unassuming level meter start-up and his fail-safe operation up to now. The positive result of the level meter implementation in V1 NPP units is also due to working-out of quality assurance program and its implementation, while the most important process of QAIP were acceptance tests of its component parts. Operability and little time consuming of level meter implementation have been enabled by use of pre-operational testing equipment. The level meter operation in V1 NPP proves necessity to use operational testing equipment that allows fast check of level meter functionality and inspection of circuits for which it isn't possible to create self-diagnostic circuits and isn't possible to monitor their function during operation of unit.

4. FIGURES AND ANNEXES

5. LITERATURE

1. REKOV1/SKR/ST/0266a/NLL3/Dr.Ha Leittechnische Beschreibung
2. REKOV1/SKR/ST/8705/V240/Ba Final design – Level meter in reactor pressure vessel of V1 NPP 2nd unit
3. REKOV1/SKR/KV/6068/V240/Mr Results of acceptance tests of level meter component parts in reactor pressure vessel
4. NW-D/98/340 Funktiontest der RDB – Füllstandssonde
5. US NRC RG 1.97 Instrumentation for light-water-cooled NPP to assess plant and environs Conditions during and following an accident.
6. Harfst: Water level monitoring inside reactor pressure level, Symposium in Smolenice, September 2001
7. Final design No. REKOV1/SKR/ST/8707/V240/Ba - Level meter in reactor pressure vessel of V1 NPP 1st unit
8. Acceptance tests guide for level meter component parts in reactor pressure vessel – VÚJE; 24.2.2000
9. Statistical processing of data from acceptance tests of KNITU 11 probes and ŠT-III connecting cables; VÚJE report No. 74/2000
10. Statistical processing of data from acceptance tests of KNITU 11 probes and ŠT-III connecting cables; VÚJE report No. 74/2001



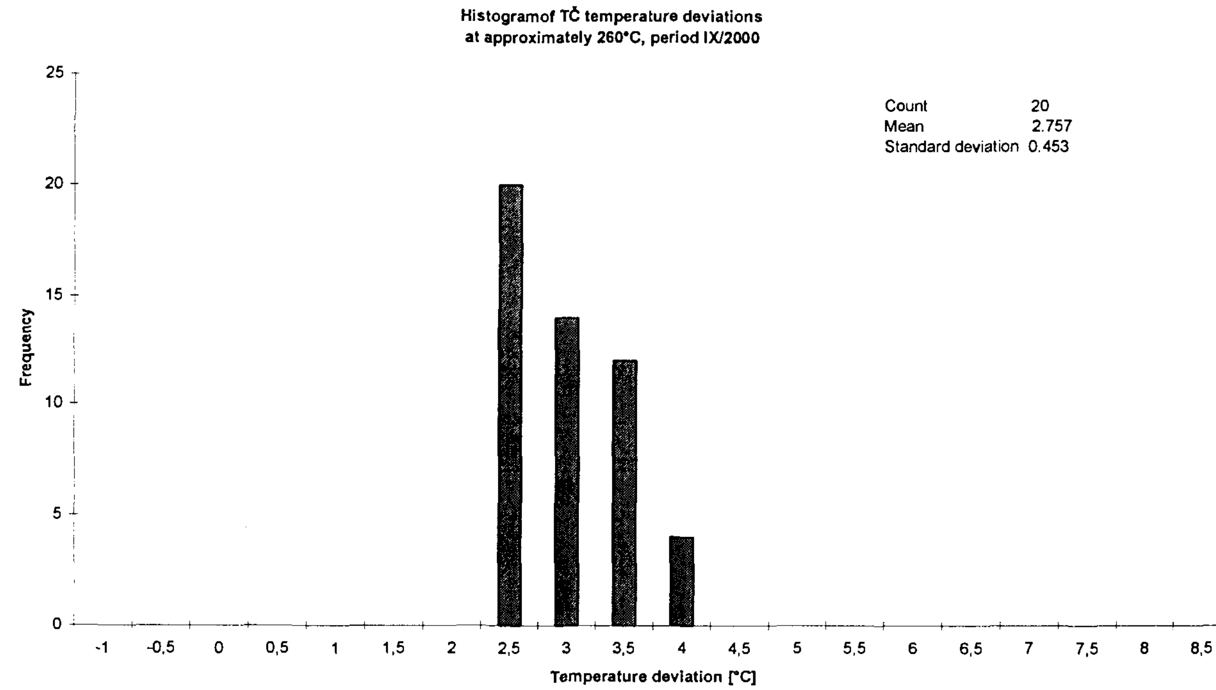


Fig.1 Histograms of insulation resistance values of KNITU 11 probes

Fig.1 Pre-Operational Test Equipment

PRE-OPERATIONAL TEST EQUIPMENT FOR LEVEL METER IN REACTOR PRESSURE VESSEL

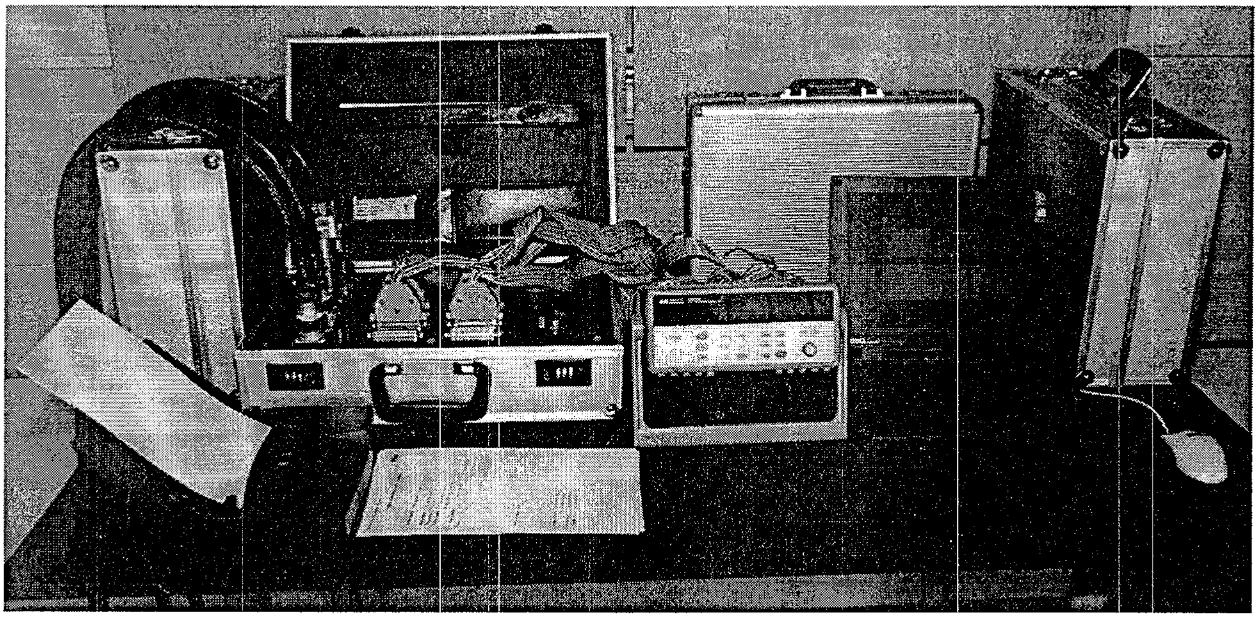


Fig. 2 Pre-operational testing equipment

Pre-Operational Test Equipment is a comprehensive system for testing the complete measurement circuit of level meter in reactor pressure vessel (RPV) with KNITU probes and of its individual parts during unit commissioning and restarts. By means of this equipment it is possible to carry out pre-complex testing (PKV) and complex testing (KV) of level meter (it is also possible to use it during entry testing of level meter components).

Description and way of connection of the Pre-Operational Test Equipment

- The Pre-Operational Test Equipment is shown in Fig. 1. It consists of computer, measurement processor, simulators of level meter conditions, printer and connecting cabling.
- Block diagram of connection of the Pre-Operational Test Equipment to level meter is shown in Fig. 2.

Properties of the Pre-Operational Test Equipment

- performance of functional PKV and KV tests of level meter without necessity to vary water level in reactor
- possibility of simulation of reactor coolant level and of possible failures in measurement circuit
- ~~minimization of the time needed for carrying out~~ PKV and KV tests, reduction of the time period during reactor outage needed for PKV, KV tests of level meter
- simple manipulation and service
- automatic test execution and evaluation
- results of all tests are stored in database
- simple and rapid printing of protocols from tests
- elimination of human factor effects during recurrent testing cycles
- possibility to carry out simultaneously the system testing and operation without any installation interference with its functional modules
- possibility to use the system for various types of probes and various amount of levels

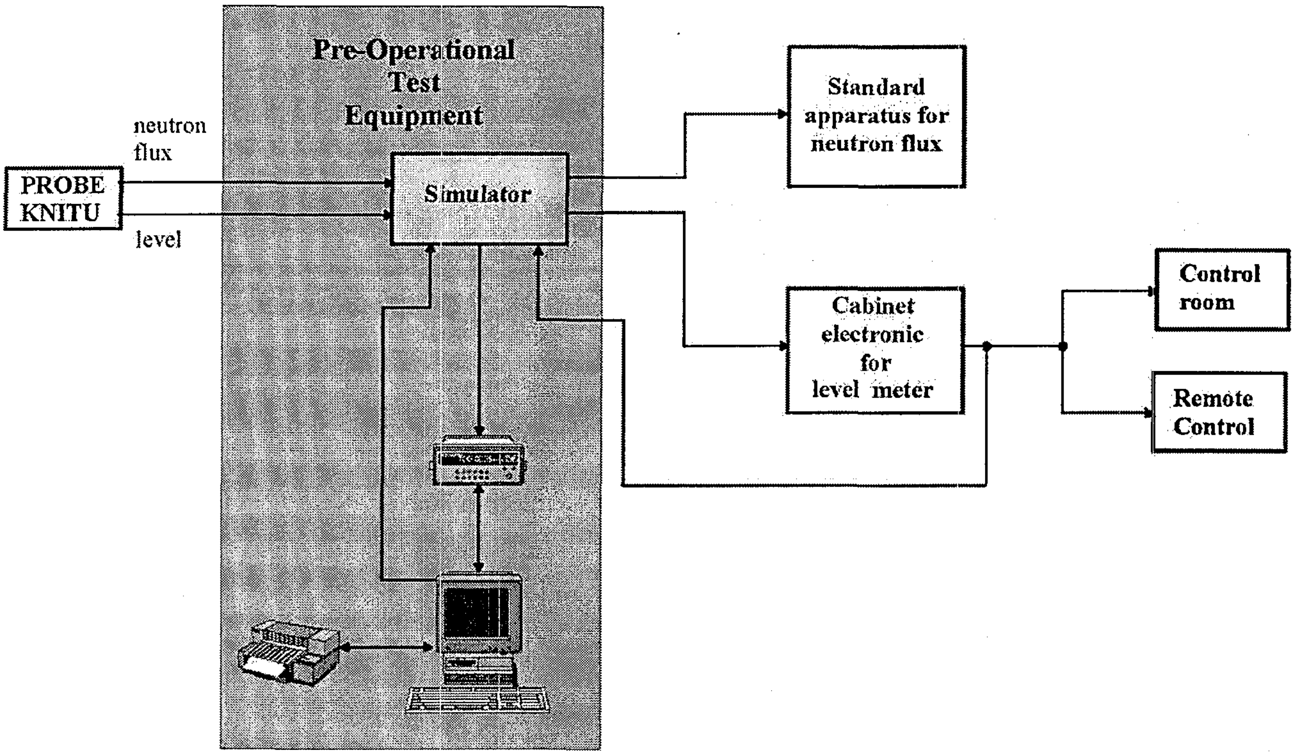


Fig.2 Schematic outline of the way for connecting Pre-Operational Test Equipment to level meter during testing

Content of pre-complex testing

- measurement of loop and isolation resistance of KNITU probe, sleeve and measurement circuit
- test of electronic cabinet by simulating system conditions by means of simulator (hysteresis of comparators, transition characteristics of analog measurement channels, annunciation of short and open circuits, of over-current and below-current)
- check of performance of main and remote control room panels for PAMS by means of signal simulation for recorders and lamp fields
- check of performance of the complete system of RPV level meter by means of input signal simulation
- check of diagnostic of measurement circuit conditions by means of simulation of open and short circuits in measurement circuits of sensors

Content of complex testing

- check of performance of electric circuits for level meter sensors and for heat-up
- check of measurement accuracy in channels (thermocouples and resistance temperature sensors), check of performance of electronics, of recording and annunciation elements in level meter
- determination of set-point level of trip voltages in comparators and setting of working current for probe heating based on the value of temperature difference between measurement and reference thermocouples

Possibility to obtain additional information
The Pre-Operational Test Equipment was developed in VÚJE Trnava Inc. In case of interest in this equipment, or in the execution of PKV, KV tests using this equipment, please contact the addresses.

VÚJE Trnava Slovak Republic
Ing. Stanislav Štanc, CSc., Ing. Juraj Šipka, Ing. Peter Vanco
Tel. 00421 33 599 1184 (1333,1330), Fax. 00421 33 599 1184
e-mail: stanc@vuje.sk, sipka@vuje.sk, vancop@vuje.sk

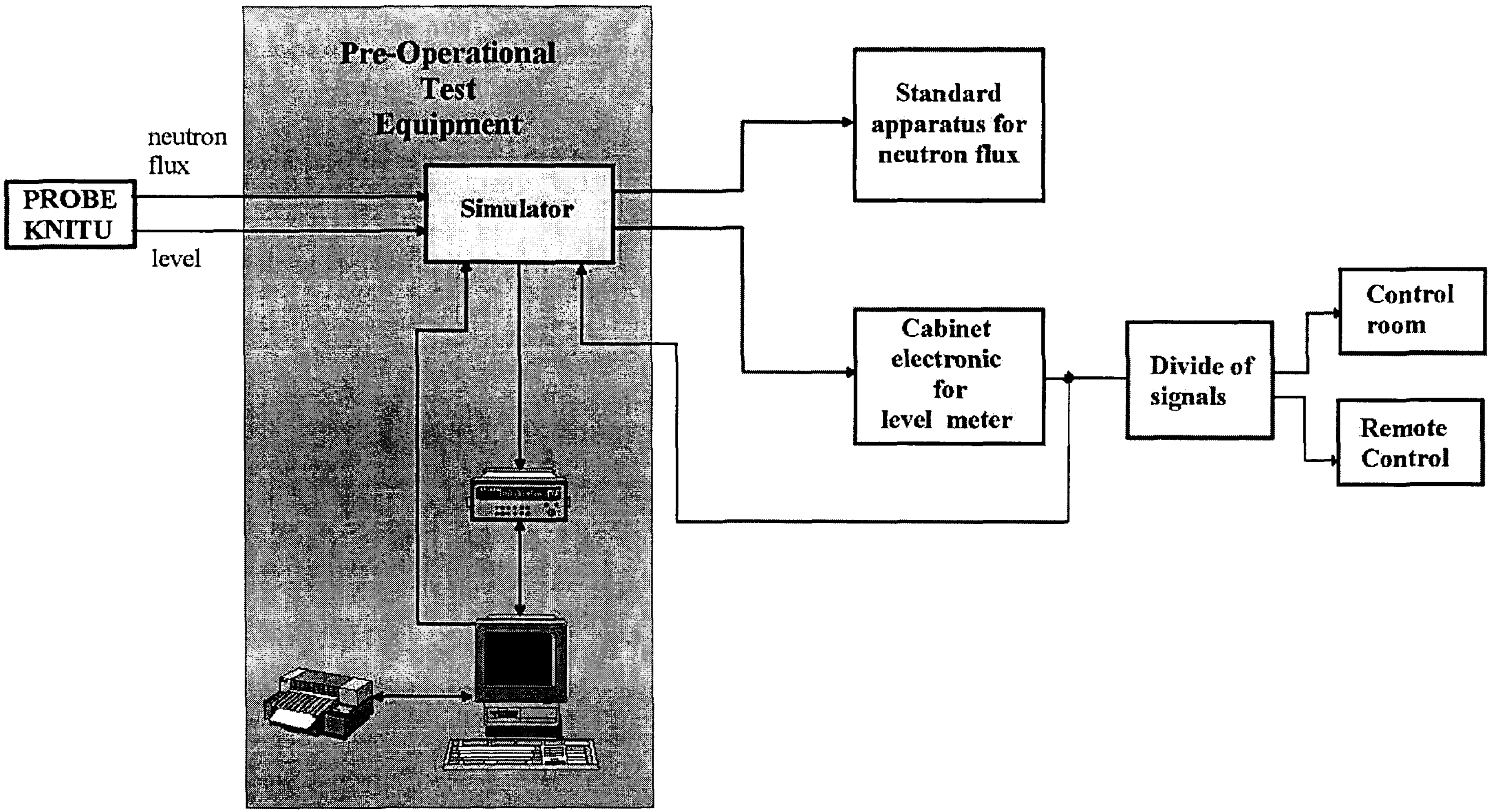


Fig. 3 Pre-operational testing equipment – principal diagram

VÚJE Trnava, a.s., inžinierska, projektová a výskumná organizácia **vüje**

Izolačný odpor emitorov DPZ a fónových žíl proti kostre a navzájom

Predmet skúšok: Sonda KNITU 11 99012502

Miesto konania: EBO,reaktorová sála
Dátum konania: 13.5.2000
Použité prístroje: Meracia ústredňa HP34970A, v.č. US37010046
Notebook DELL Latitude CPi, v.č. ZBVQY
Simulátor stavov hladinomera v TNR, v.č. 001

Skúšaný parameter	Kritérium správnosti	Skúšobný postup
Izolačný odpor emitorov DPZ a fónových žíl proti kostre a navzájom	Riz > 5 Gohm pri teplote okolia Riz > 100 Mohm pri meraní s HP34970A	Použitím programového balíka na meranie izolačného odporu a meracej ústredne so simulačným zariadením zmerať izolačný odpor emitorov DPZ a fónových žíl proti kostre a navzájom

Záver zo skúšok: Vyhovuje

Skúšky vykonali: Ing. Juraj Šipka
Ing. Radovan Mráz
Ing. Marek Slanina
Kontroloval: Ing. Stanislav Badiar
Schválil: Ing. Stanislav Štanc CSc.

Strana 1 / 2 ID: 000082

Fig. 4 Sample of automatically processed testing report

VÚJE Trnava, a.s., inžinierska, projektová a výskumná organizácia

vúje

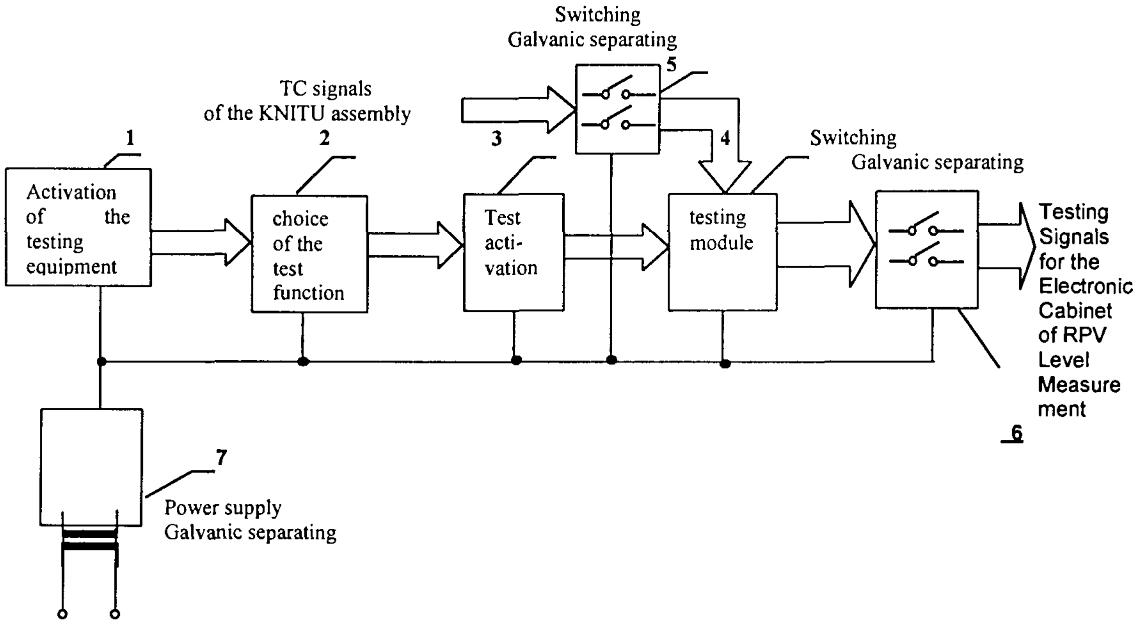
Izolačné odpory DPZ [ohm]

	D1-e	D1-f	D2-e	D3-e	D4-e	D5-e	D6-e	D7-e
Kostra	>100M	>100M	>100M	>100M	>100M	>100M	>100M	>100M
D1-e	-	>100M	>100M	>100M	>100M	>100M	>100M	>100M
D1-f	-	-	>100M	>100M	>100M	>100M	>100M	>100M
D2-e	-	-	-	>100M	>100M	>100M	>100M	>100M
D3-e	-	-	-	-	>100M	>100M	>100M	>100M
D4-e	-	-	-	-	-	>100M	>100M	>100M
D5-e	-	-	-	-	-	-	>100M	>100M
D6-e	-	-	-	-	-	-	-	>100M

Strana 2 / 2

ID: 000082

Fig. 4 Sample of automatically processed testing report



220 V AC
(24 V DC)

Description of the Operational testing equipment

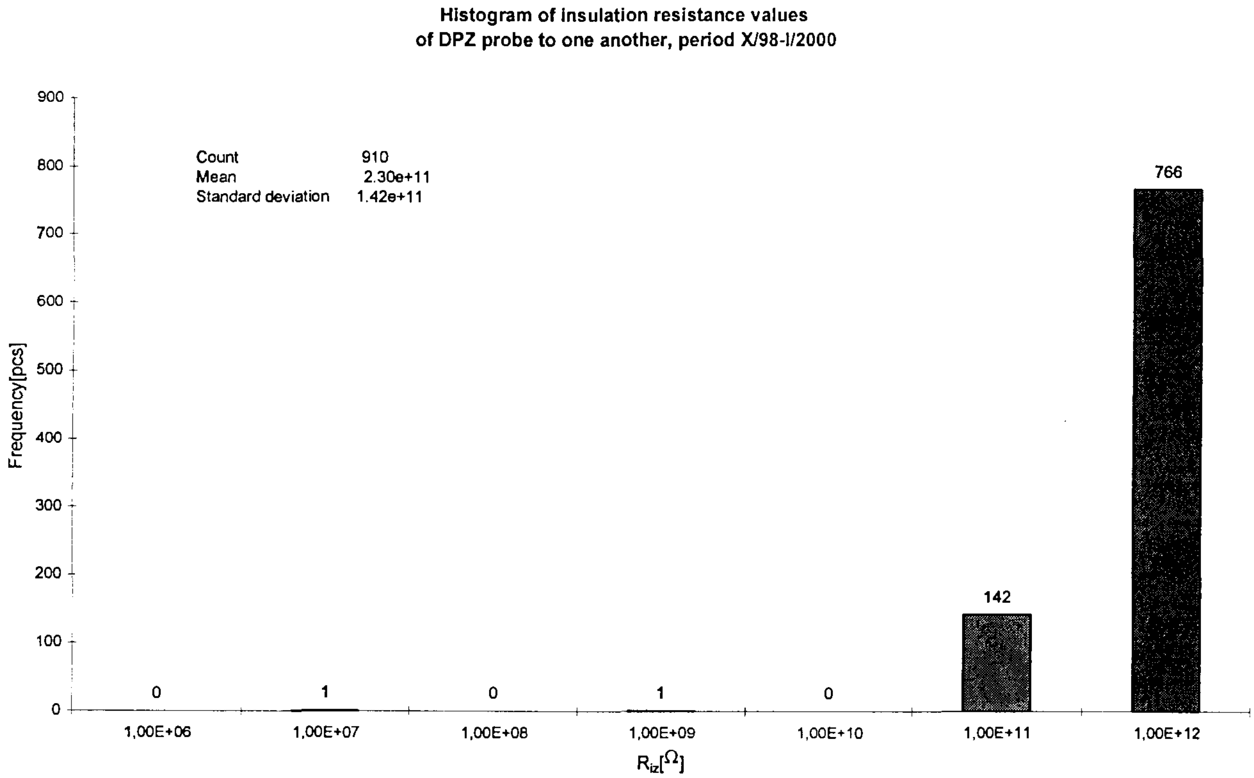
Supply voltage: 24 V DC or 230 V DC

Testing inputs:
- TC signal for Level 1 (up to 20 mV)
- TC signal for Level 2 (up to 20 mV)
- TC signal for Level 3 (up to 20 mV)
- reference TC1 signal (up to 20 mV)
- reference TC2 signal (up to 20 mV)

Testing outputs:
- Level 1 simulation (up to 20 mV)
- Level 2 simulation (up to 20 mV)
- Level 3 simulation (up to 20 mV)
- simulation of „electronic cabinet malfunction“ signal (switch contact)
- simulation of „heating current low“ signal (switch contact)
- simulation of „heating current overflow“ signal (switch contact)

Manipulating elements:
- activation of the equipment
- choice of testing function
- activation of testing function

Fig. 5 Block diagram of operational testing equipment



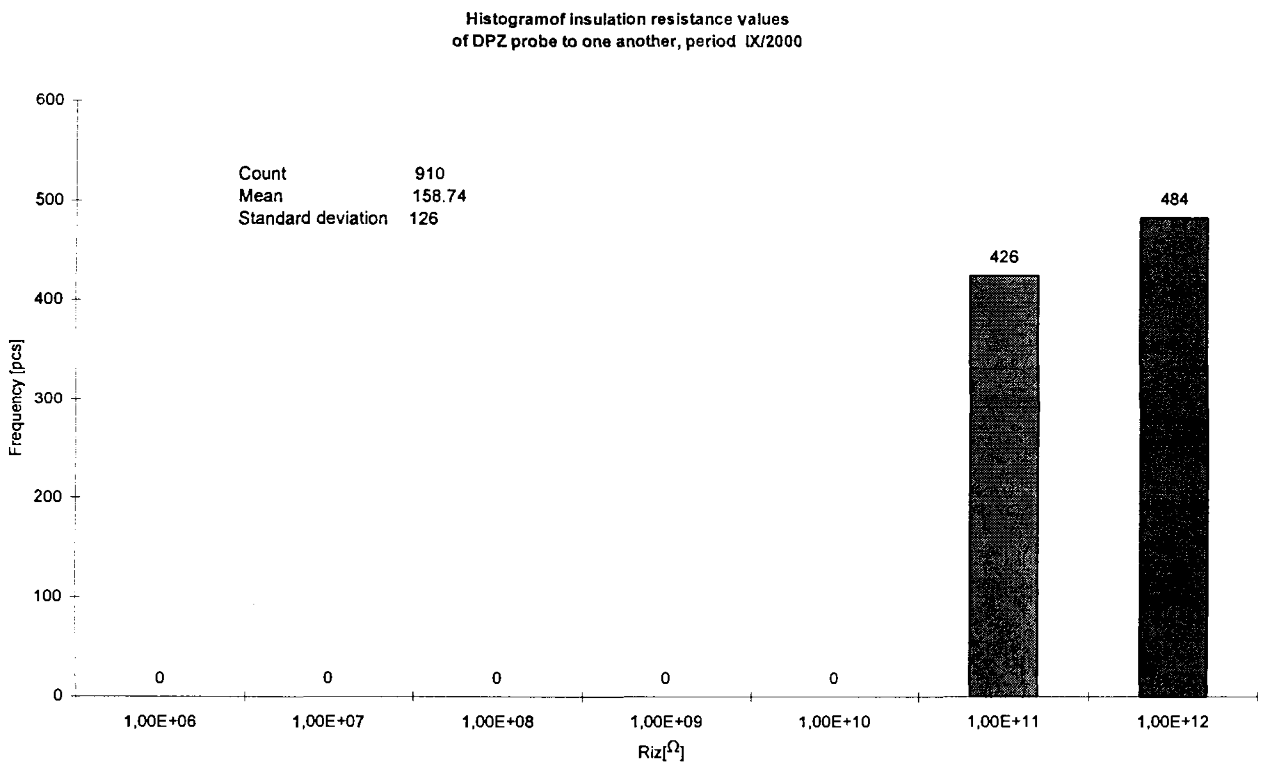


Fig. 6 Histograms of deviations of conversion features TC; KNITU 11 probe from data of calibrated resistance temperature sensor