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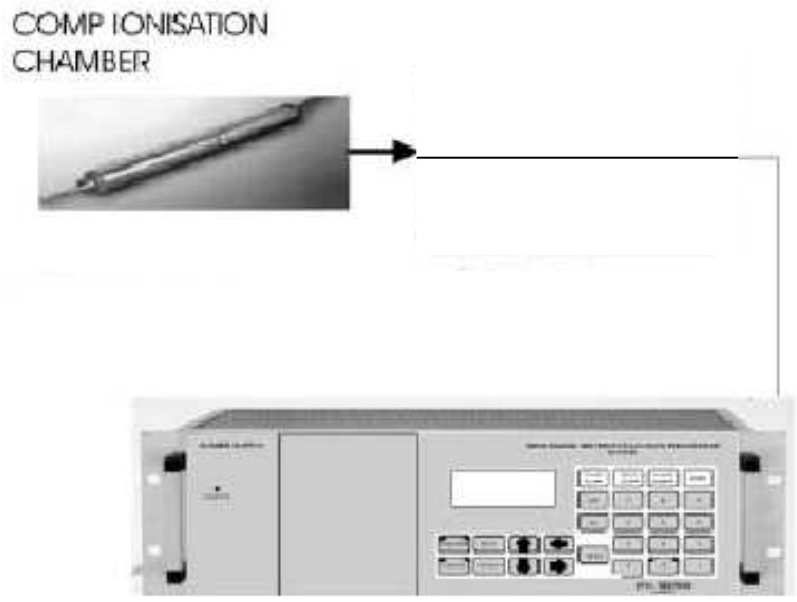
Current Range Neutron Flux Monitoring and Safety Assembly

NFA-09.10



Contents

1. Current Range Neutron Flux Monitoring and Safety Assembly NFA-09.10

Features:

- Detectors: fixed position fission chamber and compensated ionisation chamber
- Neutron flux and period time measurement
- Neutron flux range: 1 to 10^{11} nv
- Typical measuring ranges:
    - Current range: 10^4 to 10^{11} nv (compensated ionisation chamber type KNK-53)
- Period time range: -3 s ∞ +3 s
- Trip signals: power level, period time
- Self testing capability
- % Power, Current Range logarithmic power, multi-range linear power, period time outputs.

2. Operation

Components of the NFA-09.10 Current Range Neutron Flux Monitoring and Safety Assembly:

- Compensated ion chamber probe with max. 200m long cable.
- NFL-03.09 Picoammeter.
- NFA-05.06C Current Range Neutron Flux Data Processor (CR-NFDP).
- DCL-03 Keyboard & Display.

3. Detector

3.1. Compensated Ionisation Chamber Probe

The detector KNK-53M is a ^{10}B lined, gamma compensated ionisation chamber for detection of thermal neutrons in a flux range of 10^4 to $5*10^{10}$ nv. During out-of-core measurement neutrons are to be detected in the presence of a strong gamma field, and as a consequence the ionisation current caused by gamma radiation exceeds the current originating from neutrons. In a compensated ionisation chamber a second ionisation chamber detecting only gamma is placed as Cell. The signal from the gamma chamber (gamma sensitivity is $1,5*10^{-12}$ A/r/H) may be used to cancel the gamma contributions to the neutron chamber signal (neutron sensitivity $4*10^{-14}$ A/nv). The probe is design and constructed from materials that minimise the effects of activation.

4. Analog Module

4.1. Picoammeter Module NFL-03.09

- Measuring range: 10^{-11} to 10^{-3} A (in 8 ranges)
- Neutron flux measurement in intermediate and power ranges
- High voltage generators: included (positive and negative)
- Computer interfacing:
    - Multiline: analogue and digital signals Without intelligence.
    - RS 485 serial I/O
- Powered from single power supply

The Picoammeter Module NFL-03.09 receives the signal of compensated ion chamber probe.

The current from an ionization chamber, with the values of 10^{-11} to 10^{-3} A, is fed to the equipment through a coaxial cable. The module with 8 switchable ranges converts detector signal into a measurement current of 0/4…20 mA. The range switching is accomplished by automatic or manual manner, depending on the state of AUT/MAN signal. In manual state the range is controlled by RANGE UP or RANGE DOWN binary signals controlled electronic stepping-switch system. The TEST GEN. is controlled from TEST ON input. If this level is high, a 5 µA current is switched to the amplifier.
The positive and negative HV power supplies are built up of encapsulated circuits surrounded by current-loop driven isolated set-value controls and HV-monitoring isolation amplifiers. Both set-value control signals (HV+CNTR and HV-CNTR), and monitoring signals (HV+MON and HV-MON) are controlled by means of current loops.
The primary supply of power enters the board. Transient protection from the outside world is done by fuse diode. It saves the inputs of a four-member group of isolated DC-DC converters from damages.

5. Current Range- Neutron Flux Data Processor (CR-NFDP) NFA-05.06C

The signals from compensated ion chamber module are further processed in the Current Range Neutron Flux Data Processor (CR-NFDP).
Components of the CR-NFDP:

1. NFL-03.09 Picoammeter;
2. NFI-08.18 Picoammeter interface module
3. NFI-08.14 Main processor module;
4. DCL 03 keyboard & display board;
5. Low voltage power supply.

The modules are situated in a 19" rack. On the front panel the operator interface is accomplished via DCL 03 keyboard & display board. The power switch, SERVICE lock switch, mains connector and fuse are on the back panel. The CONTROL DESK and SAFETY connectors are on the main processor unit. An RS 485 connector and other organs that are important from the point of view of usage are placed on the back panel. In addition, there are still several terminals on the back panel, which are mainly important on servicing.
Analog and digital lines carry out the signal exchange between analog modules and CR-NFDP. For analog signal exchange 0/4…20 mA decoupled current loop signals are used because nearly interference frees transmission. For digital signal exchange potential free relay contacts ensures the decoupling. The frequency and serial interface signals are transmitted and decoupled according to RS485A standard.

The following values are calculated from the DC power signal:

1. Linear level from 10^3 to 10^{11} nv is measured in sixteen ranges. In this multirange function the equipment converts the DC power signal into 16 linear power ranges. This feature provides precise reading of linear power level over the 8 decade of reactor power. The multirange function is either auto range or slaved to an operator's switch.
2. On the logarithmic power output the power signal in logarithmic scale is presented. This function provides for the reading of eight-decade power magnitude (10^3 to 10^{11} nv) in a single range.
3. Period time calculation. The measure for the relative rate of change in neutron flux density is derived from the DC power signal. The measure for the relative rate of change in neutron flux density is derived from the limited Current Range power signal. If the neutron flux density increases exponentially, then $n = n_0 * e^{\frac{t}{T}}$ the rector period, T, is the reciprocal of the fractional change in the neutron population per unit time. $\frac{1}{T} = \frac{dn/n}{dt} = \frac{dn/dt}{n}$
   Where n is the neutron flux density and t is the time.
4. Limit value (trip) monitoring. The 1, 2, 3 signals of the measuring channels are supervised by the limit value monitor system. The module provides isolated digital output signals for the safety logic through SAFETY connector. ALARM or WARNING lamps on the front panel of DCL-03 lights if any of the alarm or warning situations have occurred. In the following the most important safety functions are listed:
   a. Power Alarm: if the power level exceeds the PWR120% value the alarm signalisation is activated;
   b. Power Warning: if the power level exceeds the PWR110% value or decreases under the PWR10% value the warning signalisation is activated;

c. Period Alarm: if the period time is less than the PER10s value the alarm signalisation is activated;
d. Period warning: if the period time is less than the PER20s value the warning signalisation is activated.

The 1-3 signals are led also to REMOTE connector as isolated 0/4…20 mA outputs.
The A/D converter receives current and range signals and of NFL-03.09 module.
Digital outputs control the test generator, the range of the DC amplifiers and the operating mode.
Interface lines control and the output voltage of high voltage power supplies.
Watchdog unit supervises the proper operation of the whole digital processing hardware. An operating status signal (WORK) shows if the program goes to a wrong path or the self-monitoring system shows malfunction situation. The WORK lamp shows the state of the watchdog unit.

NFI-08.14 Main processor module.
An internal communication line ensures data exchange to interface modules and control panel.
The following values are calculated from the Current Range signal:

1. Power level from 10^4 to 10^{11} nv is measured in sixteen ranges. In this multirange function the equipment converts the limited Current Range power signal into 16 linear power ranges. The multirange function is either auto range or slaved to an operator's switch.
2. Period time calculation. The measure for the relative rate of change in neutron flux density is derived from the extended Current Range power signal.
3. Limit value (trip) monitoring. The signals of the measuring channels are supervised by the limit value monitor system. The level excess monitoring (trip) operates on the base of the 1.to 3 signals. The module provides isolated digital output signals for the safety logic through SAFETY connector. ALARM or WARNING lamps on the front panel of DCL-02 lights if any of the alarm or warning situations have occurred. In the following the most important safety functions are listed:
    - Power Alarm: if the power level exceeds the PCR120% value the alarm signalisation is activated;
    - Power Warning: if the power level exceeds the PCR110% value or decreases under the PCR10% value the warning signalisation is activated;
    - Period Alarm: if the period time is less than the PER10s value the alarm signalisation is activated;
    - Period Warning: if the period time is less than the PER20s value the warning signalisation is activated.

The 1.to 4 signals are led to REMOTE connector as isolated 0/4.to 20 mA outputs.
Watch-dog unit supervises the proper operation of the whole digital processing hardware. The WORK lamp shows the state of the watchdog unit.
The unit shall be provided with a data acquisition module. The DAS module shall acquire the analog data & digital data from each analog modules related to power& power rate (period time, reactivity) readings, individual alarms, EHT failure, Battery low, EHT voltage, alarm settings etc. The power and power rate shall be displayed as trend graphs also.
The DAS shall record the data at regular interval in a local storage media. The interval shall vary from 1 ms to 1 min. It shall also record the alarm status including the instances of alarm generation and restoration to normal state. During the alarm condition, the recording interval shall be short so that data is not lost. The monitor shall retain data for at least the previous 24 hours at any time. In case of an alarm, the data preceding to the alarm, during the alarm and after the alarm shall be retained and not overwritten. The data in memory shall be provided through Ethernet port to a remote PC on demand. The protocol shall be based on Modbus. The recording intervals shall be as follows:

Preceding the accident	: 0.1 s.
During first 10 seconds after criticality has been detected	: 0.1 s
During the next 100 secs.	: 1 s.
During the next 1000 secs.	: 10 s.

The DAS module shall be provided with an Ethernet 10/100 Mbps port for interfacing with a remote IBM PC-compatible computer. The PC and the instrument shall operate in a host-slave configuration and the software protocol shall be Modbus/TCP or Modbus/RTU. The PC as the host shall give commands and send queries. The monitor shall carry out the various functions as per the required information in response to the queries.

The firmware of the instrument shall be able to send the instrument data like Instrument ID, Instrument type, alarm settings, alarm status, current reading, and diagnostic status of EHT etc. to the Host PC on demand. The firmware shall also send the history data for at least the last 24 hours on demand. Detailed list of the command and response for the Host-slave communication will be provided by the user.

Primary function of the module, in addition to the mentioned level excess monitoring, is to establish man-machine connection, and to produce accessibility of the measured data via a serial interface.
Operator interface is accomplished via a 4x20 character wide vacuum fluorescent display and a keyboard of 23 push buttons. In LOCAL mode by means of the keyboard one can control the operation of the whole channel, set measuring range, changing display picture, controlling test, power etc. In remote mode the trip reset and range control can be realised through REMOTE rear panel connectors.
By means of a key lock the operator can determine the operating mode. In OPER mode the equipment provides alarms (trips) when period and/or neutron flux level exceeds the set point value(s).

Functional capabilities are testing during reactor operation and during outages because the entire system is self-monitored. All adjustable parameters of the neutron monitoring assembly, like high voltage value, power factor, etc. are testing periodically. Failures or deviations from reselected values are indicated immediately.

6. Technical data

6.1. Compensated Ion Chamber Probe

Detector Type	KNK-53M
Measuring range	10^{3} to 5 x 10^{10} nv
Manufacturer	Russia
Detector/compensation voltage	+ 500 V/ - 500 V adjustable
Neutron sensitivity	4 x 10^{-14} A/nv
Gamma sensitivity	1,5 x 10^{-12} A/R/h
Length	472 mm
Diameter	70 mm
Operating temperature	- 40 to + 400 °C

6.2. NFL-03.09 Picoammeter

1. Picoamper meter

Isolated input	Isolation voltage: 500V max.
Offset voltage	5 mV max. at 25 C° 0,05 mV/ C° max.
Bias current	10^{-12} A max. at 25 C°
Input resistance	10 kΩ

Input ranges

Range [A]	Accuracy (RTM) [%]	Temperature coefficient [/C°]	Settling Time Filtered output [ms]	Settling Time Direct output [ms]
10^{-10}	±1	0,05 %	1000	< 5 ms
10^{-9}	±0,5	0,05 %	200	< 5 ms
10^{-8}	±0,3	0,03 %	80	< 5 ms
10^{-7}	±0,2	0,02 %	15	< 5 ms
10^{-6}	±0,2	0,02 %	7	< 5 ms
10^{-5}	±0,2	0,02 %	7	< 5 ms
10^{-4}	±0,2	0,02 %	6	< 5 ms
10^{-3}	±0,2	0,02 %	6	< 5 ms

Range control input	
-Number	3 (RANGE UP, RANGE DOCN, AUT/MAN)
- Levels	-33 to 8 V logic 0 13 to 72 V logic 1
- Isolation	500VDC, 230VAC(between input and internal ground)
Range overlapping failure	< 1 % (RTM)
- Dead time after switching range	10 ms
Analog output	
- Output range	0/4 to 20 mA
- Accuracy	± 1 % (T=25°C, related to end value)
- Voltage test	500 V AC (between output and housing)
- Nonlinearity	< 2 x 10^{-3} (related to end value)
- Temperature coefficient	Max. 10^{-4} / K
Output select input	
- Levels	-33 to 8 V logic 0 (direct output) 13 to 72 V logic 1 (filtered output)
- Isolation	500VDC, 230VAC(between input and internal ground)
- Dead time after selecting output	20 ms

2. High voltage power supply

High voltage setting range (detector)	0 to + 500 V / max. 1 mA
High voltage setting range (Gamma compensation)	0 to - 500 V / max. 1 mA
Ripple	Max. 100 mV_{pp}
Power supply effect	Max. 10^{-4} / V
Temperature effect	Max. 2 x 10^{-4} / K
Load effect	Max. 10^{-4} / 0.3 mA
HV settling	Through 0/4 to 20 mA current loop
HV monitoring	Through 0/4 to 20 mA current loop

3. Communication

Interface	Isolated RS485A
Rate	57.6 kbaud
Protocol	ANSI-0
Length	Max. 100 m..
Address setting	2 micro switch

4 Further Data

External power

- Nominal value	24 V DC
- Deviation	18 to 33 VDC
- Ripple	Max. 3.6 V_{pp} (on + 24 V)
- Power consumption	15 W

Monitoring output of ext. power

- Range	0/4 to 20 mA
- Conversion factor	10 mA / 24 V
- Loading resistance	Max. 500 Ω

Operating conditions

-Ambient temperature	10 to + 55 °C
-Relative humidity	Max. 90 %

6.3. Neutron Flux Data Processor

1.Analog Inputs

- Signals	<u>Signals from NFL-03.09 Picoammeter</u> Current Signal Current Range Signal 24 V Power Supply Monitor
- Range	0/4 to 20 mA
- Resistance	75 Ω
-Isolation	500VDC, 230VAC
- Accuracy	± 1 % (T=25°C)

2. Digital Outputs

-Signals	Test-on Range-up Range-down Aut/Man
-Characteristics	Isolated relay contact pairs Contact rate: 50 V/100 mA Isolation: 300 V

5. Remote connector

5.1 Digital Inputs

- Functions	RANGE UP: range up control RANGE DOWN: range down control AUT/MAN: range control mode RESET: TRIP reset OPERATION MODE: automatic, manual, pulsed, square wave
- Characteristics	Opt isolated Voltage / current: 5 V/20 mA Isolation voltage: 300 V dc

5.2 Analog outputs

- Functions	PEROUT: period time analog signal LIN POWER: multirange analog signal LIN POWERRANGE: range signalisation LOG. POWER: logarithmical analog signal
- Characteristics	Isolation: 300 V dc Current range: 4…20 mA Load resistance: max 500 Ω Accuracy: ± 1 %

6.4. DCL-03 Keyboard & Display

1.	**Display** Displayed values	4x20 characters VFD DC channel range & current level Period time Reactivity Power(W) High voltage levels: HV+, HV- Thresholds of trip monitoring stages Trip signals: • Period time alarm • Period time Warning • Power high alarm • Power high Warning • Power low Warning Operating status: measuring, test Range control mode: automatic, manual. Channel control mode: remote, local.
2.	**Keyboard**	23 push buttons • Numeric characters: 0…9, ±, .,exp • ENTER • Clear enter (CE) • Select (→, ←) • Increase (↑) • Decrease (↓) • Display select (PAGE UP, PAGE DOWN) • REMOTE/LOCAL • WORK/TEST
3.	**Indicator lamps**	• POWER ALARM, • PERIOD ALARM, • POCER/PERIOD WARNING, • WORK
4.	**Switch**	LOCAL RESET

6.5. General

Mains	220 V +10 % - 15 %, 50 Hz, max. 100 VA.
Dimensions	Width: 19" (481 mm). Height: 3U (177mm). Depth: 440 mm.
Ambient temperature	10.to.40 °C
Relative humidity	max 90 %
Mass	10 kg

7. Block diagram