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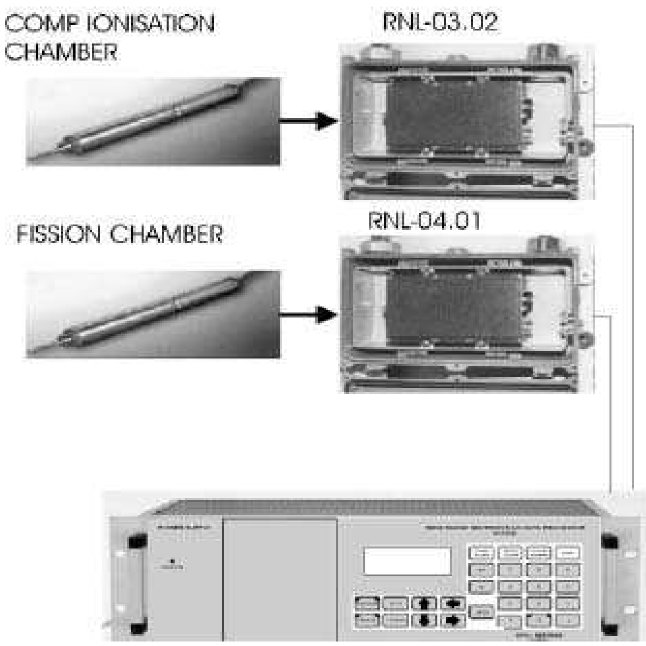
Wide Range Neutron Flux Monitoring and Safety Assembly

NFA-09.06



Contents

1. Wide Range Neutron Flux Monitoring and Safety Assembly NFA-09.06

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:
  - Pulse range: 1 to 10^6 nv (fission chamber type CFUL08)
  - AC range: 10^4 to $2*10^{10}$ nv (fission chamber type CFUL08)
  - 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, wide range logarithmic power, multi-range linear power, period time outputs.

2. Operation

Components of the NFA-09.06 Wide Range Neutron Flux Monitoring and Safety Assembly:

- Fission chamber probe with max. 25m long cable.
- Compensated ion chamber probe with max. 200m long cable.
- RNL-03.02 Compensated Ion Chamber Analog Module.
- RNL-04.01 Fission Chamber Analog Module
- Max. 200 m cables to interconnect the analog modules and processing compartment.
- NFA-05.06W Wide Range Neutron Flux Data Processor (WR-NFDP).
- DCL-02 Keyboard & Display.

3. Detectors

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 well. 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.

3.2. Fission Chamber Probe

The detector CFUL 08 is a fission chamber (recommended for out-of-core applications) for detection of thermal neutrons in a flux range of 1 to $2*10^{10}$ nv. The same detector probe is used for the pulse (sensitivity 1 pps/nv), and variance (sensitivity $4*10^{-26}$ A^2/Hz/nv) measurement. The probe incorporates integral inorganic cable of triaxial design to provide long life and freedom from electrical problems. Due to the high amplification and wide bandwidth of the preamplifier, it is necessary to use super-screened coax cables to connect the detector to analog module.

The signal transmission path from detector to the preamplifier is the most sensitive part of the entire instrument chain. Optimum screening is achieved by sheathing the mineral insulating detector cable in an additional low resistance copper screen. An electrically conducting connection is established between this screen and the fission chamber guide tube by means of contact spring. The connector end of the detector inorganic cable terminates in a tightly sealed metallic connector housing. The transition from the mineral insulated detector cable to a flexible plastic cable takes place within this connector housing. A hermetically sealed corrugated tube with triple copper braiding surrounds the coaxial super screen cable (3 x copper braiding, 2 x Mu. metal) and an FRNCX sheathe (flame resistant, halogen free, radiation resistant).

The detector signal cables are generally allocated to that group of cables which carries voltages less than 60 V. These cables must be physically separated by a distance of 600 mm from cables that carry voltages greater than 60 V. The signal cables must not intersect or be laid parallel to cables carrying voltages of greater than 500 V or cables belonging to phase control drive.

4. Analog Modules

4.1. Compensated Ionisation Chamber Analogue Module RNL-03.02

- 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 Compensated Ionisation Chamber Analogue Module RNL-03.02 receives the signal of compensated ion chamber probe.
The module is located in a double-shielded box near to the detector (max. 25-m) but out of the reactor vessel. It is built in massive brass housing to protect from electro-magnetic interference waves and cross coupling. This unit is installed isolated into additional die-cast aluminium housing. This insulated installation provides an additional protective screen. Maximum 200-m long cable ensures the electrical connection between the analogue module and CR-NFDP.

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. A linear DC amplifier with 8 switch able 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 connected to RS 485 serial I/O lines.
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. The unit also contains an isolation amplifier-current loop function to get the primary power monitoring signal (MON POWER S) output.

4.2. Fission Chamber Analogue Module RNL-04.01

The Fission Chamber Analog Module RNL-04.01 is located in a double-shielded box near to the detector (max. 25 m) but out of the reactor vessel. It is built in massive brass housing to protect from electro-magnetic interference waves and cross coupling. This unit is installed isolated into additional die-cast aluminium housing. This insulated installation provides an additional protective screen. A max. 200-m long cable ensures the electrical connection between the analog module and WR-NFDP.

The signal of the fission chamber gets to the input of the. It amplifies the measuring signal obtained from fission chamber and splits it into pulse and AC components. These signals are separately amplified in the pulse and AC1 amplifiers. The function of the preamplifier with two remote controllable test generators (TG0) can be checked from the WR-NFDP. This test generator causes the injection of test signals in addition to the measurement signals. The WR-NFDP evaluates the injected test signals as real signals. The AC1 amplifier has a divider (AC-signal division by 1 or 100 controlled by 2^3 signal) that is used to build together with the programmable divider the 16 linear fractions. The signal from the AC1 amplifier is conducted through an eight-step signal attenuator (0…7*5 dB) with measuring range commutation switch to the AC2 main amplifier. The measuring range control should be performed through 3 binary code lines (2^2, 2^1, 2^0). Each linear AC measuring range fractions covers 2 decades of the neutron flux density. The step from one to the next range corresponds to a change in signal amplification of 5 dB. The input of the step divider can be switched over to the output of TG2 test generator by remote controlled binary signal (0,5 V/25 kHz). The amplitude of TG2 test generator can be adjusted by potentiometer.

The correlator performs the squaring and smoothing of the alternating signal. Output signal of correlator is led through the isolated driver to the AC SIGNAL OUTPUT connector via WR-NFDP. The AC range overlaps at its lower end with the pulse range more than one decade.

The pulse signal is processed in an amplifier with amplitude discrimination. The amplitude discriminator converts the incoming detector pulses into standard pulses, if the threshold voltage of the discriminator exceeded. The adjustable discriminator suppresses background signals induced in the cable, electronic noise, and α radiation. This pulse signal will be processed by software of the WR-NFDP in the range of 1 pps to 10^6 pps. The pulse frequency pre divider serves to purpose of minimising the statistical double pulse and dead time error. The ÷16 FREQU DIVIDER controls the divider. Threshold level can be controlled from DISCR LEVEL CONTR current-loop input, and can be monitoring from MON DISCR LEVEL current loop output. The input of the integral discriminator can be switched over to the output of TG1 test generator by remote controlled binary signal (TEST ON TG1). The two possible test frequency of TG1 test generator can be selected by binary signal (TG1 1,563/500 kHz).

The high voltage stage generates the adjustable HV (0 to 800 V) required for the fission chamber. The HV power supply is built up of encapsulated circuit surrounded by current-loop driven isolated set-value controls and HV-monitoring isolation amplifiers. Set-value control signal from HV CNTR is current-loop input, monitoring signal from HV MON leave the board in the form of current loop output.

The 24 V DC power supply is provided from Wide Range Neutron Flux Monitoring Assembly via copper screened copper cable. It enters the board through transient protection fuse diode. After these, a common-mode filter and a polarity-protection diode The unit also contains an isolation amplifier-current loop function to get the primary power monitoring signal output.

5. Wide Range- Neutron Flux Data Processor (WR-NFDP) NFA-05.06

The signals from fission chamber analog module and from compensated ion chamber module are further processed in the Wide Range Neutron Flux Data Processor (WR-NFDP) NFA-05.06.
Components of the NFA-05.06 WR-NFDP:

1. RNL-03.02 module interface;
2. RNL-04.01 module interface;
3. NFL-05.06 main processor module;
4. Low voltage power supply;
5. DCL 02 keyboard & display board.

The modules are situated in a 19" rack. On the front panel the operator interface is accomplished via DCL 02 keyboard & display board. The power switch, SERVICE lock switch, mains connector and fuse are on the back panel. FISSION CHAMBER ANALOG MODULE, COMPENSATED IONISATION CHAMBER ANALOG MODULE, with corresponded SAFETY and CONTROL DESK connectors are situated on the interface units. The third 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 WR-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.

RNL-04.01 module interface
The pulse (WRM PULSE SIGNAL) and AC conditioned detector signals are led to the RNL-04.01 module interface. The ac signal is led by the way of 0/4…20 mA decoupled current loop signal and of digital range information. Software controlled counter and AD converters receive the conditioned detector signals. The pulse and ac signals are combined to form a continuous limited wide range power signal using an overlapping algorithm. An overlap between the pulse and the ac current ranges of more than one decade is provided. A sliding transition from the pulse signal to the ac current signal is guaranteed by overlapping algorithm. A fault alarm is generated if there is a failure in overlap.

The following values are calculated from the limited wide range power signal:

1. Linear level from 10^{-1} to 10^{9} nv is measured in sixteen ranges. In this multirange function the equipment converts the limited wide range power signal into 16 linear power range. This feature provides more precise reading of linear power level over the entire range of reactor power. The multirange function is either auto range or slaved to an operator’s switch. Automatic range selection is performed in the RNL-04.01 module interface. This function is scoped to accurate measurement of power in source and intermediate ranges.
2. Period time calculation. The measure for the relative rate of change in neutron flux density is derived from the limited wide range power signal. If the neutron flux density increases exponentially, then $n = n_0 * e^{\frac{t}{T}}$ the rector period, τ, 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.

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, 2 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:
    a. Power Alarm: if the power level exceeds the PWR120% value the alarm signalisation is activated;
    b. Period Warning: if the period time is less than the PER20s value the warning signalisation is activated;
    c. Power Warning: if the power level exceeds the PWR110% value or decreases under the PWR10% value the warning signalisation is activated;
    d. Period Alarm: if the period time is less than the PER10s value the alarm signalisation is activated.

The 1-2 signals are led to REMOTE connector as isolated 0/4…20 mA outputs.
The A/D converter receives AC current and range signals, output signal of discriminator threshold level, analogue module power supply signal and the divided signals of the two high voltage generator outputs of RNL-04.01 module.
Digital outputs control the TG0…TG3 test generators, the range of the AC amplifiers and the pulse frequency divider.
Analogue outputs control the output voltage of high voltage power supplies and the discriminator threshold level.
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.

RNL-03.02 module interface

The DC conditioned detector signals (CURRENT, RANGE) are led to the RNL-03.02 module interface. The signals are led by the way of 0/4…20 mA decoupled current loop. Software controlled AD converters receive the conditioned detector signals.

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 wide 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-02 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 power supply signal of RNL-03.02 module.
Digital outputs control the 5 µA test generator, the range of the DC amplifiers and the operating mode.
Serial interface controls and watches 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.

NFL-05.06 main processor module.
An internal communication line ensures data exchange to interface modules and control panel.
The extended wide range signal is calculated from limited wide range power signal and the DC power signals. An overlap between limited wide range power signal and the DC power signal of more than one decade is provided. A sliding transition is guaranteed by overlapping algorithm. A fault alarm is generated if there is a failure in overlap. The following values are calculated from the extended wide range signal:
The following values are calculated from the extended wide range power signal:

1. Power level from 10^{-1} to 10^{11} nv is measured in sixteen ranges. In this multirange function the equipment converts the limited wide range power signal into 16 linear power range. 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 wide 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 PWR120% value the alarm signalisation is activated;
   - Power Warning: if the power level exceeds the PWR110% value or decreases under the PWR10% 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.
4. Reactivity computing: see next chapter.

The 1.to 4 signals are led to REMOTE connector as isolated 0/4.to 20 mA outputs.
Watchdog 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, 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).

The NFA-05.06 type WRNFDP is designated for automatic testing and calibration. After switching on TEST mode the computer executes one test cycle automatically by remote controlled test generators. The automatic test cycle includes the following steps:

1. Activation of TG0 test generator causes the injection of 15,63 kHz and 500 kHz test signal in addition to fission chamber signal. The processor system evaluates the injected test signal as real one. This makes it possible to test the function of the entire pulse and AC chain including the cables and connectors up to the trip alarm and annunciator.
2. Activation of TG1 test generator causes the injection of 1,563 kHz and 500 kHz test signal into the input of integral discriminator. The processor system evaluates the injected test signal in order to check the operability of pulse channel.
3. Activation of TG2 test generator causes the injection of 0,5 V/25 kHz test signal to the input of AC2 amplifier. The processor system evaluates the injected test signal in order to check the operability of AC channel.
4. Activation of TG test generator in RNL-03.02 unit causes the injection of 5 µA test signal in addition to ion chamber signal. The processor system evaluates the injected test signal as real one. This makes it possible to test the function of the entire DC chain including the cables and connectors up to the trip alarm and annunciator.

During testing cycle the power level outputs are automatic calibrated. The power trip outputs are checked also automatically. Detection of unacceptable situation causes "electronic fault" alarm.

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 discriminator threshold, high voltage value, power factor, etc. are testing periodically. Failures or deviations from reselected values are indicated immediately.

6. Reactivity Computing

The reactivity meter method for measuring a reactivity worth of control rod is easy and simple, and the full curve showing the relation of reactivity to rod position can be obtained in a few minutes. Furthermore, from the point of view of reactor safety, the reactivity meter should be applicable as a tool in reactor instrumentation.
Changing its reactivity by moving control rods, by modifying the boron acid concentration, etc, controls the reactor. The change in the reactivity brought about in this way is measured by the time variations of the neutron.
Instead of reactivity it has been a general practice the measurement of the reactor period, that is, the time derivative of the logarithmic power. It might be considered a rough measure of reactivity provided that the reactor is near critical and the transient phenomena due to delayed neutrons have already decayed. In order to eliminate this ambiguity reactivity meters are generally used.

6.1. Theoretical Principles

The condition of a nuclear reactor is monitored - among others - by measuring the neutron flux. This parameter permits the calculation of the reactor's most important time dependent parameter, the reactivity. Continuous information on its value is highly useful.
The multiplication factor k can be assimilated to the term "reactivity" (ρ):

$$\rho = \frac{k-1}{k}$$

Fundamentally ρ is a non-dimensional number.

Several measures of reactivity:
1 pcm = 10^{-5}
1 % = 10^{-2}
1 \$ = β
Where β is the delayed neutron fraction in the fission process.

The measurement of reactivity can be only made in an indirect way. It must be deduced from the evaluation of the neutron density.
The time dependent behavior of neutron density in a thermal reactor can be described by the reactor kinetic equations assuming no space dependency.
A mathematical model of a reactor is given by the point kinetic equation system, which employs the following assumptions:
1/ The reactor is treated in a point-like manner, i.e. homogeneous spatial distribution of the neutron flux is assumed.
2/ In addition to the prompt neutrons from nuclear fission, the influence of the delayed neutrons appearing later is also taken into consideration.
3/ Delayed neutrons are divided into a finite number of groups of different decay constants (most frequently one or six per isotope).

4/ The combined effect of two or more isotopes (e.g. 235U and 238U) in the fission process can also be traced by means of the point kinetic equation system.
The point kinetic equation system is formulated as follows:

$$\frac{dn}{dt} = \frac{\rho \bullet n}{l^*} - \sum_{i,j} \frac{dC_{ij}}{dt} + S$$

$$\frac{dC_{ij}}{dt} = \beta_{ij} \bullet \frac{n}{l^*} \bullet \alpha_j - \lambda_{ij} \bullet C_{ij}$$

$$\alpha_j = \frac{f_j \bullet \nu_j}{\sum_j f_j \bullet \nu_j}$$

Where:
n - neutron density
ρ - absolute value of the reactivity;
l* - mean lifetime between neutron generation and collision
C_{ij}- concentration of the precursors of i-th delayed neutron group deriving from a j-type fuel element,
S - neutron density from an external neutron source,
β_{ij}- fraction of i-th delayed neutron group from j-type fuel element (related to all generated neutrons from j-type fuel element) ,
λ_{ij}- decay constant of the precursor of i-th delayed neutron group from j-type fuel element,
f_j- percentage of fissions in a j-type fuel element (related to all fissions) ,
v_j- number of neutrons emitted by a single fission of an atom in the j-type fuel element.

6.2. Description of Operation

After calculating the actual power level of the reactor, subtracting it from the previous power levels the instrument computes the reactivity output signal with the special algorithm. The computed reactivity value appears on the display in digital form.
The reactor physical parameters (β_i, Λ_i, C_i, l) can be set through keyboard.

7. Technical data

7.1. Compensated Ion Chamber Probe

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

7.2. Fission chamber

Detector Type	CFUL08
Manufacturer	Photonis
Detector HV	400 to 800 V
Neutron sensitivity	1 pps/nv (pulse) $4*10^{-26}$ A^{2}/Hz/nv (AC)
Measuring ranges	1 to 10^{6} nv (pulse range) 10^{4} to 10^{10} nv (AC range)
Operating temperature	Max. + 250 °C
Cable length.	12 m (integral cable)+ max.25 m multiscreen extension
Length	472 mm
Diameter	70 m

RNL-03.02 Compensated Ion Chamber Analog Module

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 DOWN, 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 Test Generator

Input test current	5 μA
Test control input	
- Levels	-33 to 8 V logic 0 (no test)
	13 to 72 V logic 1 (test)
- Isolation	500VDC, 230VAC(between input and internal ground)
External detector-current-test input	
-Conversation factor	5.5 x 10^{-5} A/10 V
-Input resistance	181.818 kΩ

3. 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 RS485 serial interface
HV monitoring	Through RS485 serial interface

4. Communication

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

5 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 %

7.3. RNL-04.01 Fission Chamber Analog Module

1. Preamplifier	
Input resistance	200 Ohm
Input noise	< 200 nA_{eff}
Transfer impedance	0,25 V/µA ±2%
Rise time	< 100 ns
2. Pulse Amplifier	
GAIN	1 V/µA ±2%
Rise time	< 100 ns
3. AC1 Amplifier	
Transfer impedance to detector input	11 V/µA ±1 % (higher sensitivity version) 0,11 V/µA±1 % (lower sensitivity version)
Frequency bandwidth	5,2 kHz to 104 kHz ± 1 %, ± 1 kHz
Input current range	0 to 60 µA
Commutation factor	1:100 ± 0,1 % (2^3 range selector off)
Temperature influence on gain factor	0,1 %/10 K
Temperature influence on bandwidth	0,1 %/10 K
4. TG0 Test Generator	
Test frequency	15,63 kHz ± 0,1 % (Test-on 15,63 kHz active) 500 kHz ± 0,1 % (Test-on 500 kHz active)
Control voltages for test activation	
- Levels	-33 to 8 V logic 0 (no test) 13 to 72 V logic 1 (test active)
- Isolation	500VDC, 230VAC
- Dead time after switching test	10 ms

5. Divider & mean amplifier (AC2)

Temperature influence to total gain < 0,1 % / 10 K

2^2	2^1	2^0	GAIN ± 1 %
Off	Off	Off	40
Off	Off	On	22,5
Off	On	Off	12,6
Off	On	On	7,11
On	Off	Off	4,0
On	Off	On	2,25
On	On	Off	1,26
On	On	On	0,711

2^0…2^2 range control inputs (Resulting total gain at different signal attenuation)

- Levels	-33 to 8 V logic 0	(off)
	13 to 72 V logic 1	(on)
-Isolation	500VDC, 230VAC	
-Dead time after switching range	< 10 ms	

6. Mean squaring stage and isolated drivers

Amplification	1 to 3 adjustable
Temperature influence to total gain	< 0,1 % / 10 K
Output signal time constant	200, 400, 600, 800,ms selectable
Analogue 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)
- Surge voltage test	1 kV ; 1.2/50 µs (betw. Out. and logic gnd)
- Nonlinearity	< 2 x 10^{-3} (related to end value)
- Temperature coefficient	Max. 10^{-4} / K

7. TG2 Test Generator

Test signal	0,1 to 0,5 V_{eff} / 25 kHz adjustable
0,5 V/25 kHz TEST control input	
- Levels	-33 to 8 V logic 0 (no test) 13 to 72 V logic 1 (test)
-Isolation	500VDC, 230VAC
-Dead time after switching range	10 ms

8. Discriminator & Line Driver

Integral discriminator	
-Input resistance	50 Ω
-Input frequency	Max. 5 MHz
-Threshold voltage stability	1 mV/ 10 K (at the input of discriminator)
DISCR LEVEL CONTROL input	
- Range	0/4 to 20 mA
- Conversion factor	+ 5 V / 20 mA
- Resistance	75 Ω
- Accuracy	± 1 % (T=25°C)
DISCR LEVEL MONITOR output	
-Range	0/4 to 20 mA
- Conversion factor	+ 5 V / 20 mA
-Isolation	500VDC, 230VAC
- Loading resistance	Max. 500 Ω
- Accuracy	± 1 % (T=25°C)
Predivider	
-Frequency dividing factor	16
÷16 FREQU. DIVIDER input	
- Levels	-33 to 8 V logic 0 (no predividing) 13 to 72 V logic 1 (predividing)
-Isolation	500VDC, 230VAC
-Dead time after switching range	10 ms
Frequency output	
- Specified frequency range	1 pps to 5 Mpps
- Logic levels	RS 485A
-Pulse duration	≥ 40 ns

9. TG1 Test Generator

Test frequency

TEST ON	TG1 A	TG1 B	Test freq.
Off	X	X	No test
On	Off	Off	500 kHz
On	On	Off	125 kHz
On	Off	On	1953,1 Hz
On	On	On	488,3 Hz

Control voltages for test activation	- Levels	-33 to 8 V logic 0 (no test) 13 to 72 V logic 1 (test)
	-Isolation	500VDC, 230VAC
	-Dead time after switching range	10 ms

10. High Voltage Power Supply

High voltage	
-Setting range	0 to + 800 V / max. 3 mA
-Ripple	Max. 100 mV_{pp}
-Power supply effect	Max. 10^{-4} / V
-Temperature effect	Max. 2 x 10^{-4} / K
-Isolation	500VDC, 230VAC
-Load effect	Max. 10^{-4} / 0.3 mA
HV CONTROL input	
- Range	0/4 to 20 mA
- Conversion factor	+ 1000 V / 20 mA
- Resistance	75 Ω
-Isolation	500VDC, 230VAC
- Accuracy	± 1 % (T=25°C)
MON. DET. HV output	
-Range	0/4 to 20 mA
- Conversion factor	+ 1000 V / 20 mA
- Loading resistance	max. 500 Ω
- Accuracy	± 1 % (T=25°C)
-Isolation	500VDC, 230VAC

11. Further Data

External power	
-Nominal value	24 V DC
- Deviation	18 to 33 VDC
- Ripple	Max. 3.6 V_{pp} (on + 24 V)
- Permissible over voltage	1 s / 10 ms + 35 V / + 45 V
- Power consumption	Max. 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 temperature	0 to + 60 °C
Relative humidity	Max. 100 %
Dimensions	w:160 mm, h:95 mm, d: 295mm
Ambient temperature	+10...+55 °C

7.4. Neutron Flux Data Processor

1.Analog Inputs		
	- Signals	<u>RNL-03.02 Ion Chamber Module Interface</u> Current Signal Current Range Signal 24 V Power Supply Monitor
		<u>RNL-04.01 Fission Chamber Module Interface</u> AC Signal 24 V Power Supply Monitor Detector HV+ Monitor Discriminator Level Monitor
	- Range	0/4 to 20 mA
	- Resistance	75 Ω
	-Isolation	500VDC, 230VAC
	- Accuracy	± 1 % (T=25°C)
2. Analog Outputs		
	- Signals	<u>RNL-04.01 Fission Chamber Module Interface</u> Detector HV+ Control Discriminator Level Control
	-Range	0/4 to 20 mA
	- Loading resistance	Max. 500 Ω
	- Accuracy	± 1 % (T=25°C)
	-Isolation	500VDC, 230VAC
3.	**Counter Inputs**	
	-Signals	<u>RNL-04.01 Fission Chamber Module Interface</u> Pulse signal
	-Levels	RS 485A
	-Isolation	500VDC, 230VAC
4.	**Digital Outputs**	
	-Signals	<u>RNL-03.02 Ion Chamber Module Interface</u> Test-on Range-up Range-down Aut/Man
		<u>RNL-04.01 Fission Chamber Module Interface</u> Range Select 2^3 Range Select2^2 Range Select2^1 Range Select2^0 Test On TG1 TG1 15,63 kHz/500 kHz Test On TG0/15,63 kHz Test On TG0/500 kHz 0,5 V/25 kHz Test ÷16 Frequency Divider
	-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	Optoisolated Voltage / current: 5 V/20 mA Isolation voltage: 300 V dc
5.2	Analog outputs	
	- Functions	REACTIVITYOUT: reactivity analogue signal PEROUT: period time analog signal LIN POWER: multirange analog signal LIN POWER RANGE: range signalisation LOG. POWER: logarithmical analog signal
	- Characteristics	Isolation: 300 V dc Current range: 4…20 mA Load resistance: max 500 Ω Accuracy: ± 1 %

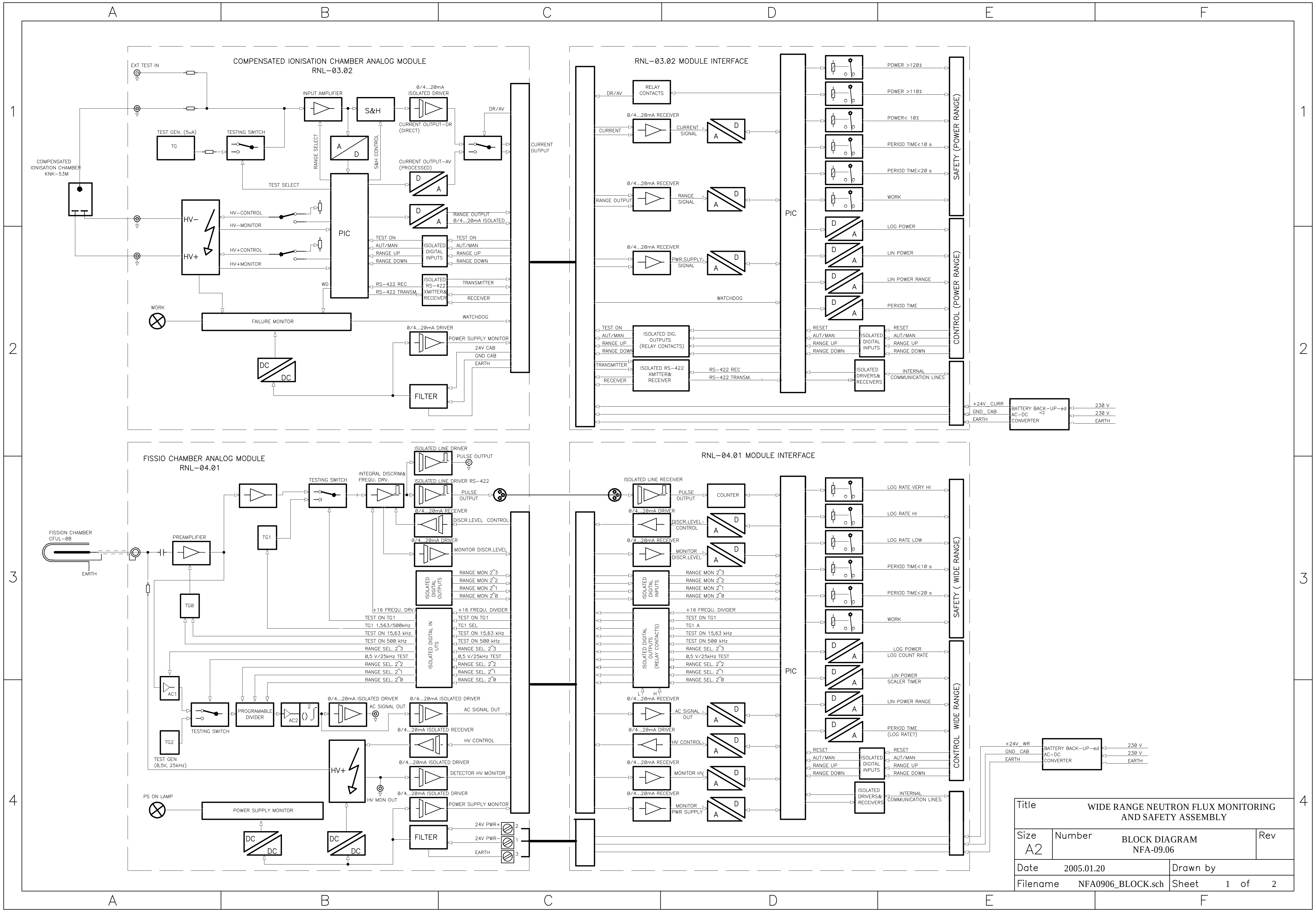
7.5. DCL-02 Keyboard & Display

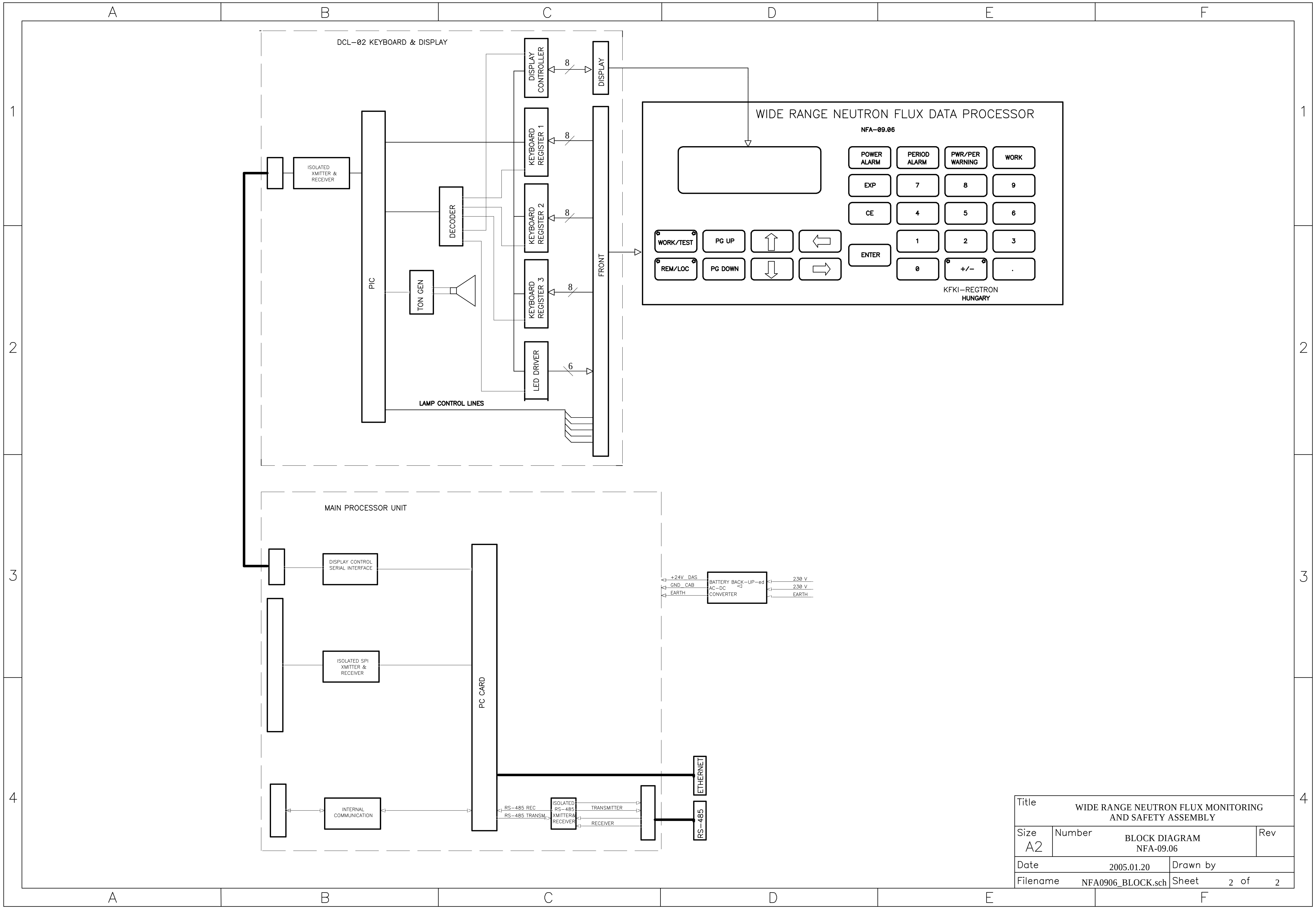
1.	**Display** Displayed values	4x20 characters VFD DC channel range & current level Period time Reactivity Power (W) High voltage levels: HV+, HV- Thresholds of trip monitoring stages Trip signals: • Period time alarm • Period time warning • Power high alarm • Power high warning • Power low warning 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, • POWER/PERIOD WARNING, • WORK
4.	**Switch**	LOCAL RESET

7.6. 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

8. Block diagram





DCL-02 KEYBOARD & DISPLAY
DISPLAY CONTROLLER
DISPLAY
KEYBOARD REGISTER 1
KEYBOARD REGISTER 2
KEYBOARD REGISTER 3
LED DRIVER
DECODER
PIC
TON GEN
FRONT
ISOLATED XMITTER & RECEIVER
LAMP CONTROL LINES
8
6
WIDE RANGE NEUTRON FLUX DATA PROCESSOR
NFA-09.06
POWER ALARM
PERIOD ALARM
PWR/PER WARNING
WORK
EXP
7
8
9
CE
4
5
6
WORK/TEST
PG UP
ENTER
1
2
3
REM/LOC
PG DOWN
0
+/-
.
KFKI-REGTRON
HUNGARY
MAIN PROCESSOR UNIT
DISPLAY CONTROL SERIAL INTERFACE
ISOLATED SPI XMITTER & RECEIVER
INTERNAL COMMUNICATION
PC CARD
RS-485 REC
RS-485 TRANSM
ISOLATED RS-485 XMITTER& RECEIVER
TRANSMITTER
RECEIVER
ETHERNET
RS-485
+24V DAS
GND CAB
EARTH
BATTERY BACK-UP-ed AC-DC CONVERTER
230 V
230 V
EARTH
A B C D E F
1 2 3 4
Title WIDE RANGE NEUTRON FLUX MONITORING AND SAFETY ASSEMBLY
Size A2
Number BLOCK DIAGRAM NFA-09.06
Rev
Date 2005.01.20
Drawn by
Filename NFA0906_BLOCK.sch
Sheet 2 of 2