EQUIPMENT FOR GEOPHYSICAL SURVEY OF WELLS
AT OIL AND GAS FIELDS AND ORE DEPOSITS
One of the areas of VNIIA activities is the development of neutron generators and based on them nuclear geophysical logging equipment for surveying wells of oil-and-gas fields and ore deposits.

Current world trends in the development of effective technologies of hydrocarbons production (such as involving nonconventional and hard to mine mineral reserves for development, drilling of slant and horizontal holes, drilling-out of sideholes from a parent hole, various effects on a bed for stimulation, and so on) require application of state-of-the art tools for geophysical survey of wells (WS) at all stages of their construction and the following field development.

Within the totality of WS techniques, nuclear-physical methods based on neutron and gamma radiation have unique information capabilities. These methods are capable of providing information about a well both in uncased wellbore while drilling and construction of the well, and in cased well while the field development.
VNIIA DEVELOPS AND PRODUCES:

- integrated impulse neutron-neutron logging equipment;
- spectrometric pulsed neutron lifetime gamma-ray logging equipment;
- self-contained equipment for logging while drilling of slant and horizontal holes;
- integrated system for survey of uncased wellbore of oil-and-gas wells;
- integrated system for direct determination of uranium in wells by the method of recording prompt U-235 fission neutrons;
- radiographic equipment for nondestructive testing of geophysical instruments;
- over 15 types of logging neutron generators.

DISTINGUISHING FEATURES OF VNIIA’S NUCLEAR-GEOPHYSICAL EQUIPMENT:

- high accuracy of parameter measurements;
- separation of information about bed and borehole;
- reduction of delay time due to integration of methods in a single integrated system;
- low cost in comparison with similar foreign prototypes.

VNIIA renders after-sales services on implementation, warranty and post-warranty repair, and provides support in operation of equipment supplied.

The supplies are carried out to research and production organizations of Russia, neighboring and far foreign countries.

Enterprises and organizations of the USA, China, Germany, Great Britain, Japan and other countries are among our clients.
ING-06

PULSED GAS-FILLED NEUTRON TUBE GENERATORS FOR LOGGING EQUIPMENT

ING-061
1. Tube module
2. Power supply and control module

ING-062

ING-063

1. Tube module
2. Power supply and control module
**GENERATOR FEATURES:**

Three basic models of ING-06 generator family with adjustable key parameters: radiation mode, neutron flux, operation frequency, and pulse duration.

Vibration-proof generator design is possible.

**APPLICATION:**

- AINK-73C-2 and AINK-89C-2 pulsed neutron gamma logging equipment;
- Neutron module for operation within logging-while-drilling (LWD) equipment configuration.

**TECHNICAL CHARACTERISTICS:**

<table>
<thead>
<tr>
<th></th>
<th>ING-061</th>
<th>ING-062</th>
<th>ING-063</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average neutron flux, neutron/s, at least</td>
<td>(1 \times 10^4)</td>
<td>(2 \times 10^4)</td>
<td>(2 \times 10^4)</td>
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<tr>
<td>Average neutron pulse width</td>
<td>(25-100) (\mu s)</td>
<td>(25-100) (\mu s),</td>
<td>(25) continuous mode</td>
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<td>Frequency, Hz</td>
<td>(400-10000) (*)</td>
<td>(400-10000) (\mu s),</td>
<td>(5000-10000) (\mu s) continuous mode</td>
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<td>Operating lifetime, hours, at least</td>
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<td>300</td>
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<tr>
<td>Power supply, V</td>
<td>200</td>
<td>200</td>
<td>200</td>
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<tr>
<td>Maximum power consumption, W</td>
<td>30</td>
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<td>30</td>
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<tr>
<td>Dimensions, mm:</td>
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<tr>
<td>diameter</td>
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<tr>
<td>total length</td>
<td>1220</td>
<td>950</td>
<td>930</td>
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<tr>
<td>Distance from the face to neutron tube target, mm</td>
<td>195</td>
<td>39</td>
<td>39</td>
</tr>
</tbody>
</table>

* By customer request.
ING-08

PULSED GAS-FILLED NEUTRON TUBE GENERATORS FOR LOGGING EQUIPMENT

1. Tube module
2. Power supply and control module
GENERATOR FEATURES:
Small-diameter generator with adjustable key parameters: radiation mode, neutron flux, operation frequency, and pulse duration.

Vibration-proof generator design that withstands mechanical load up to 30g is possible.

APPLICATION:
- AINK-43-600 pulsed neutron-neutron logging equipment;
- Small-diameter logging equipment for replacement of mass-production logging equipment with isotope sources.

TECHNICAL CHARACTERISTICS:
- Average neutron flux, neutron/s, at least: \( 1 \times 10^4 \)
- Average neutron pulse width
  \( \mu s \): \( 25-200 \), continuous flux *
- Frequency, Hz: \( 400-10000 \), continuous mode *
- Maximum operating temperature, °C: \( 120 \)
- Operating lifetime, hours, at least: \( 200 \)
- Power supply, V: \( +150 \)
- Maximum power consumption, W: \( 30 \)
- Dimensions, mm:
  - diameter: \( 36 \)
  - total length: \( 1355 \)
  - Distance from the face
to neutron tube target, mm: \( 160.5 \)

* By customer request.
ING-10

PULSED VACUUM NEUTRON TUBE GENERATORS FOR LOGGING EQUIPMENT

ING-10-20-120

BHT2-26 (BHT4-26) neutron tube

ING-10-20-150

BHT4-26 neutron tube

ING-10-20-175

BHT4-26 neutron tube

1. Tube module
2. Power supply and control module

Dimensions:
- BHT2-26 (BHT4-26) neutron tube: Ø34, 607.5mm
- BHT4-26 neutron tube: Ø34, 607.5mm
- Total length: 672.5mm
GENERATOR FEATURES:

Three basic models of ING-10 generator family for operation within wide range of temperature (up to +175 °C) and mechanical loads.

Vibration-proof generator design that withstands mechanical load up to 30g is possible.

APPLICATION:

- AINK-43-50 pulsed neutron-neutron logging equipment;
- AINK-60 pulsed neutron logging equipment for determination of uranium.

TECHNICAL CHARACTERISTICS:

<table>
<thead>
<tr>
<th></th>
<th>ING-10-20-120</th>
<th>ING-10-20-150</th>
<th>ING-10-20-175</th>
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</thead>
<tbody>
<tr>
<td>Average neutron flux, neutron/s, at least</td>
<td>1.5·10⁴</td>
<td>1.0·10⁴</td>
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<td>Average neutron pulse width</td>
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<tr>
<td>at half amplitude level, μs, not more than</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Frequency, Hz</td>
<td>1 - 20 *</td>
<td>1 - 20 *</td>
<td>1 - 20 *</td>
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<tr>
<td>Operating lifetime, h, at least:</td>
<td></td>
<td></td>
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<tr>
<td>at the environment temperature up to 100°C</td>
<td>150</td>
<td>100</td>
<td>100</td>
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<tr>
<td>at the maximum operating temperature</td>
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<td>40</td>
<td>40</td>
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<tr>
<td>Maximum operating temperature, °C</td>
<td>+120</td>
<td>+150</td>
<td>+175</td>
</tr>
<tr>
<td>Power supply, V</td>
<td>+150</td>
<td>+150</td>
<td>+150</td>
</tr>
<tr>
<td>Maximum power consumption, W</td>
<td>30</td>
<td>30</td>
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<tr>
<td>Dimensions, mm:</td>
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<td>diameter</td>
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<tr>
<td>total length</td>
<td>1300</td>
<td>1300</td>
<td>1300</td>
</tr>
</tbody>
</table>

* By customer request.
ING-11-20-150
PULSED VACUUM NEUTRON TUBE GENERATOR FOR LOGGING EQUIPMENT

1. Tube module
2. Power supply and control module
GENERATOR FEATURES:
A small-diameter generator for operation at ambient temperature up to +150 °C. It is designed for geophysical survey of oil-and-gas fields within small-diameter downhole tool configuration.

APPLICATION:
- AINK-34 pulsed neutron-neutron logging equipment;
- Small-diameter logging equipment designed to survey wells via annular space without withdrawal of submersible pump, and to survey wells with high pressure at the wellhead.

TECHNICAL CHARACTERISTICS:
- Average neutron flux, neutron/s, at least: ........................................................................................................... $5 \cdot 10^7$
- Average neutron pulse width
  at half amplitude level, μs, not more than: ........................................................................................................... 1
- Frequency, Hz: .................................................................................................................................................... 1 - 20 *
- Operating lifetime, h, at least:
  - at the environment temperature up to 100°C: ................................................................................................. 100
  - at the maximum operating temperature: .......................................................................................................... 40
- Maximum operating temperature, °C: .................................................................................................................... +150
- Power supply, V: .................................................................................................................................................... +150
- Maximum power consumption, W: ..................................................................................................................... 25
- Dimensions, mm:
  - diameter: .......................................................................................................................................................... 30
  - total length: ..................................................................................................................................................... 1700

* By customer request.
ING-12-50-100
PULSED VACUUM NEUTRON TUBE GENERATOR
FOR LOGGING EQUIPMENT

ING-12-50-100

1. Tube module
2. Power supply and control module
GENERATOR FEATURES:
An enhanced service life generator designed to be used within the configuration of Ø48 mm downhole tools for direct determination of uranium content by instantaneous fission neutron logging method.

APPLICATION:
- AINK-48 pulsed neutron logging equipment for determination of uranium using instantaneous fission neutron logging method.

TECHNICAL CHARACTERISTICS:
- Average neutron flux, neutron/s, at least: ................................................................. $2 \times 10^4$
- Average neutron pulse width
  at half amplitude level, $\mu$s, not more than ................................................................. 1
- Frequency, Hz .................................................................................................................. 1 - 20 *
- Operating lifetime, h, at least:
  - at the environment temperature up to 50°C ................................................................. 250
  - at the maximum operating temperature ........................................................................ 150
- Maximum operating temperature, °C ............................................................................... +100
- Power supply, V .............................................................................................................. +150
- Maximum power consumption, W .................................................................................. 40
- Dimensions, mm:
  - diameter ....................................................................................................................... 42
  - total length ............................................................................................................... 1200

* By customer request.
1. Downhole tool consisting of:
   - detection and digital telemetry unit;
   - neutron generator unit

2. PU-10 control and monitoring unit
The equipment is designed for surveying well sections at oil-and-gas fields using pulsed neutron-neutron logging method.
AIK-34 is used for oil-and-gas reservoir engineering control, well survey without stopping at high wellhead pressure, and well survey through annular space without submersible pump withdrawal.

EQUIPMENT FEATURES:
Capability to survey annular space due to small size of downhole tool.

INFORMATION CAPABILITIES:
As a result of logging data processing, information is obtained on macroscopic cross-section of thermal-neutron absorption for rock beds within the investigated section interval.

MEASUREMENT CONDITIONS:
- measurements are carried out in Ø48 mm boreholes at a temperature up to +150 °C and hydrostatic pressure up to 100 MPa;
- logging speed - 150 m/h;
- the equipment operates within the configuration of a computerized geophysical station with load-bearing single-conductor armored logging cable of up to 7000 m length.

TECHNICAL CHARACTERISTICS:
- Thermal neutron absorption macroscopic cross-section measurement range, cm⁻¹ .................................................. 7.4·10⁻³ - 30·10⁻¹
- Number of measuring probes ............................................................................................................. 2
- Model of neutron generator .......................................................................................................... ING-11-20-150
- Power consumption, W ................................................................................................................ 30
- DC supply voltage, V .................................................................................................................. +150
- Downhole tool dimensions, mm:
  - external diameter .................................................................................................................... 34
  - length ..................................................................................................................................... 2500
AINK-43-50

PULSED NEUTRON LOGGING EQUIPMENT

1. Detection and digital telemetry unit
2. Neutron generator unit
3. PU-10U control and monitoring unit
The equipment is designed for surveying well sections at oil-and-gas fields using impulse neutron-neutron logging method.
AINK-43-50 is used for oil-and-gas reservoir engineering control, survey of lithology in the vicinity of a borehole, determination of contacts in gas-water, oil-gas, oil-water and other systems as well as for estimation of porosity and oil-and-gas saturation of strata.

**EQUIPMENT FEATURES:**
- stable operation of vacuum neutron tube generator;
- normalization of counter readings by generator neutron flux value;
- improved resolution.

**INFORMATION CAPABILITIES:**
As a result of logging data processing the following characteristics of beds within the investigated profile interval are obtained:
- macroscopic cross-section of thermal-neutron absorption of rocks;
- hydrogen content of rocks in water-saturated porosity units.

**MEASUREMENT CONDITIONS:**
- measurements are carried out in boreholes of up to 300 mm diameter at up to +150 °C temperature and up to 100 MPa hydrostatic pressure;
- logging speed - 150 m/h;
- the equipment operates within the configuration of a computerized geophysical station with load-bearing single-conductor armored logging cable of up to 7000 m length.

**TECHNICAL CHARACTERISTICS:**
- Thermal neutron absorption macroscopic cross-section measurement range, cm⁻¹ ................................................................. 7.4·10⁻³ - 30·10⁻³
- Rock water-saturated porosity measurement range, % ................................................................. 1-36
- Number of measuring probes ........................................................................................................... 2
- Model of neutron generator ........................................................................................................... ING-10-20-120 or ING-10-20-150
- Power consumption, W .................................................................................................................. 40
- DC supply voltage, V .................................................................................................................... +150
- Downhole tool dimensions, mm:
  - external diameter .................................................................................................................. 43
  - length ...................................................................................................................................... 3320
AINK-43-600

PULSED NEUTRON LOGGING EQUIPMENT

1. Detection and digital telemetry unit
2. Neutron generator unit
3. PU-10U control and monitoring unit
The equipment is designed for surveying well sections at oil-and-gas fields using impulse neutron-neutron logging method.

A1NK-43-600 is used for oil-and-gas reservoir engineering control, survey of lithology in the vicinity of a borehole, determination of contacts in gas-water, oil-gas, oil-water and other systems, for quantitative determination of porosity factor, and in case of formation water salinity ≥50 g/dm³ - oil saturation and gas content.

**EQUIPMENT FEATURES:**
- increased lifetime of the neutron generator;
- improved stability of neutron flux;
- high accuracy of the parameters measurement.

**INFORMATION CAPABILITIES:**
As a result of logging data processing the following characteristics of beds are obtained with increased accuracy:
- macroscopic cross-section of thermal-neutron absorption of rocks;
- hydrogen content of rocks in water-saturated porosity units.

**MEASUREMENT CONDITIONS:**
- measurements are carried out in boreholes of up to 300 mm diameter at up to +120 °C temperature and up to 100 MPa hydrostatic pressure;
- logging speed - 200 m/h;
- the equipment operates within the configuration of a computerized geophysical station with load-bearing single-conductor armored logging cable of up to 7000 m length.

**TECHNICAL CHARACTERISTICS:**
- Thermal neutron absorption macroscopic cross-section measurement range, cm⁻¹ .................................................. 7.4·10⁻³ - 30·10⁻³
- Rock water-saturated porosity measurement range, % .......................................................... 1-36
- Number of measuring probes ................................................................................................. 2
- Model of neutron generator .................................................................................. ING-08
- Power consumption, W ........................................................................................................... 40
- DC supply voltage, V ............................................................................................................ +150
- Downhole tool dimensions, mm:
  - external diameter ................................................................................................................. 43
  - length ................................................................................................................................. 2840
AINK-73C-2 highly informative software-and-hardware complex for multiparametric radioactive logging is designed for determination of rock composition and current oil saturation of reservoirs independently of formation water salinity based on measurements in cased wells of not less than 90 mm inner diameter, including deviated wells with maximum inclination angle of up to 75°.

AINK-73C-2 SHC allows investigations to be carried out by dual probe pulsed neutron gamma logging (PNGL-S) or C/O logging and natural gamma-ray spectrometry logging (GL-S) methods.

INFORMATION CAPABILITIES:
As a result of logging data processing the following characteristics of beds are obtained:

- concentrations of the main rock-forming and fluid-forming elements - C, O, Ca, Si, H, Cl, Fe, Mg, and others;
- mineral composition of bed;
- hydrogen content (porosity);
- macroscopic capture cross-section or lifetime of thermal neutrons;
- oil saturation factor;
- integral natural gamma activity;
- concentrations of natural radioelements - U (Ra), Th, K.

METROLOGICAL SOFTWARE:
Metrological software is developed using physical and mainly mathematical simulation, and includes libraries of standard spectra that are used when processing measurement results.

The measurement result processing software enables to computerize the processing procedure itself, and, due to application of the method of measured spectra expansion into standard spectra, ensure high accuracy of interpretation and geophysical parameters determination.

EQUIPMENT FEATURES:
- determination of the main parameters of beds in a single round-trip operation due to integration of PNGL-S, GL-S and Σ methods;
- investigation of side holes of oil-and-gas wells of not less than 90 mm inner diameter.
TECHNICAL CHARACTERISTICS:

- Natural radioelements determinable concentration range:
  - U(Ra), Th, ppm................................................................. 1 - 200
  - K, %........................................................................... more than 0.3
  - Thermal neutron absorption macroscopic cross-section measurement range, cm⁻¹ ...... 7·10⁻³ - 30·10⁻³
  - Porosity measurement range, %.............................................................. 5 - 40

- Detector type; detector dimensions, mm:
  - GL-S module.............................................................................. CsI(Na); Ø50 x 250
  - PNGL-S module........................................................................... LaBr₃; Ø25 x 25 and Ø50 x 60
  - Neutron generator model.................................................................... ING-063

- Maximum load of PNGL-S spectrometric channel, pulse/s.............................. up to 2·10⁶

- Number of amplitude spectra quantization levels (number of channels)............ 1024

- Number of time distribution quantization levels (number of channels)............. 256

- Energy resolution of spectrometric channels for 662 keV line, %:
  - close detector................................................................................... not more than 5
  - far detector...................................................................................... not more than 4

- Information rate, kbaud........................................................................ 80 - 160

- Maximum operating temperature, °C......................................................... +120

- Maximum hydrostatic pressure, MPa....................................................... 60

- DC supply voltage, V:
  - downhole tool.............................................................................. +150
  - neutron generator............................................................................ +200

- Power consumption, W.......................................................................... 40

- Downhole tool diameter, mm................................................................. 73

- GL-S module length, mm.................................................................. 1348

- PNGL-S module length, mm................................................................. 2507

- Total length of two-module downhole tool with cardan connector, mm.......... 4300
AINK-73C-2

1. GL-73S module
2. PNGL-73S-2 module
3. KS-73 cardan connector
4. Logging control and front-end processing of measurement results software
5. Metrological software

Csl(Na) crystal
Photomultiplier
LaBr, crystal
Photomultiplier
LaBr, crystal
Target
ING-063 neutron generator
AINK-89C-2

1. GL-89S module
2. PNGL-89S-2 module
3. Logging control and front-end processing of measurement results software
4. Metrological software

- CsI(Na) crystal
- Photomultiplier
- LaBr₃ crystal
- Connector

°90

1596

2073

Target
ING-062 neutron generator

3

4
AINK-89C-2 PULSED NEUTRON LOGGING EQUIPMENT

AINK-89C-2 highly informative software-and-hardware complex for multiparametric nuclear-geophysical logging is designed for determination of rock composition and current oil saturation of reservoirs independently of formation water salinity based on measurements in cased wells.

AINK-89C-2 SHC allows investigations to be carried out by dual probe impulse neutron gamma logging (PNGL-S) or C/O logging and natural gamma-ray spectrometry logging (GL-S) methods in vertical cased boreholes of not less than 126 mm inner diameter.

INFORMATION CAPABILITIES:

As a result of logging data processing the following characteristics of beds are obtained:

- concentrations of the main rock-forming and fluid-forming elements (C, O, Ca, Si, H, Cl, Fe, Mg, and others);
- mineral composition of bed;
- hydrogen content (porosity);
- macroscopic capture cross-section or lifetime of thermal neutrons;
- oil saturation factor;
- integral natural gamma activity;
- concentrations of natural radioelements - U (Ra), Th, K.

METROLOGICAL SOFTWARE:

Metrological software is developed using physical and mainly mathematical simulation, and includes libraries of standard spectra that are used when processing measurement results.

The measurement result processing software enables to computerize the processing procedure itself, and, due to application of the method of measured spectra expansion into standard spectra, ensure high accuracy of interpretation and geophysical parameters determination.

EQUIPMENT FEATURES:

- capability to carry out logging of the uncased borehole of up to 230 mm diameter;
- investigation of cased oil-and-gas wells of not less than 126 mm inner diameter.
TECHNICAL CHARACTERISTICS:

- Natural radioelements determinable concentration range:
  - U(Ra), Th, ppm........... 1 - 200
  - K, %........................................... more than 0.3
- Thermal neutron absorption macroscopic cross-section measurement range, cm$^{-1}$ .... 7·10$^{-3}$ - 30·10$^{-3}$
- Porosity measurement range, %........................................... 5 - 40
- Detector type; detector dimensions, mm:
  - GL-S module................................................................. CsI(Na); ∅50 x 250
  - PNGL-S module.......................................................... LaBr$_3$; ∅25 x 25 and ∅50 x 60
  - Neutron generator model.................................................. ING-062
- Maximum load of PNGL-S spectrometric channel, pulse/s........................................... up to 2·10$^4$
- Number of amplitude spectra quantization levels (number of channels).................................. 1024
- Number of time distribution quantization levels (number of channels)................................. 256
- Energy resolution of GL-S for 662 keV line, %.................................................. not more than 11
- Energy resolution of PNGL-S spectrometric channels for 662 keV line, %:
  - close detector.......................................................... not more than 5
  - far detector.............................................................. not more than 4
- Information rate, kbaud...................................................... 80 - 160
- Maximum operating temperature, °C.................................................. +120
- Maximum hydrostatic pressure, MPa........................................... 60
- DC supply voltage, V......................................................... +150±10
- Power consumption, W......................................................... 40
- Downhole tool diameter, mm.................................................. 90
- Downhole tool diameter in the boric protection area, mm........................................... 96
- GL-S module length, mm..................................................... 1530
- PNGL-S module length, mm.................................................. 2730
- Total length of two-module downhole tool, mm.................................................. 4183
AINK-48 EQUIPMENT FOR URANIUM PULSED NEUTRON LOGGING

The equipment is designed to determine uranium content by means of prompt $^{235}$U fission neutron method in boreholes of deposits developed by in-situ leaching method. Allows carrying out a set of methods of gamma logging and prompt fission neutron logging, determining radioactive equilibrium coefficient, and splitting lithological profile during a single round-trip operation.

AINK-48 allows works to be carried out practically in all types of wells at deposits developed by in-situ leaching method.

1. Downhole tool consisting of:
   - neutron generator unit;
   - prompt fission neutron detection unit;
   - gamma detection unit;
   - generator neutron flux monitoring unit;
   - digital telemetry unit

2. PU-10 control and monitoring unit

3. Logging control and front-end processing of measurement results software
EQUIPMENT FEATURES:
- additional probe for thermal neutron detection;
- increased neutron generator operation life;
- capable of being used in the areas of in-situ leaching filters.

MEASUREMENT CONDITIONS:
- measurements are carried out in cased and uncased boreholes of 60 to 200 mm diameter up to 1000 m deep at up to +70 °C temperature and up to 30 MPa hydrostatic pressure;
- logging speed is up to 60 m/hour;
- the equipment operates within the configuration of a computerized geophysical station with up to 1000 m long load-bearing single-conductor armored logging cable.

INFORMATION CAPABILITIES:
Pulsed neutron logging equipment allows fulfilling:
- pulsed neutron logging with prompt fission neutron detection;
- gamma logging.
During logging the downhole tool measures:
- time distribution of prompt neutrons of $^{239}$U isotope fission;
- natural radioactivity gammas.
Logging data processing results in obtaining of:
- borehole distribution of U content;
- linear U reserve through the borehole;
- radioactive equilibrium coefficient.

TECHNICAL CHARACTERISTICS:
- Operating temperature, °C.................................................................+80
- Hydrostatic pressure, MPa...............................................................20
- Minimum determinable uranium content measurement, %..........................0.003
- Number of measuring probes..............................................................3
- Neutron generator model..................................................................ING-12
- Neutron generator operating lifetime, h..................................................250
- Power consumption, W........................................................................40
- DC supply voltage, V..........................................................................+150
- Downhole tool dimensions, mm:
  - external diameter............................................................................49
  - length..............................................................................................2910
- Logging speed, m/h............................................................................60
- Load-bearing single-conductor armored logging cable length, m.................1000
1. Downhole tool consisting of:
   - neutron generator unit;
   - prompt fission neutron detection unit;
   - gamma detection unit;
   - generator neutron flux monitoring unit;
   - digital telemetry unit
2. PU-10 control and monitoring unit
3. Calibration and sensitivity control unit
4. Logging control and front-end processing of measurement results software
The equipment is designed for direct determination of uranium content in natural deposit while exploration and operation of deposits in cased and uncased boreholes by means of prompt fission neutron method. Gamma logging is carried out concurrently.

**EQUIPMENT FEATURES:**
- capability to obtain prompt estimates of ore interval parameters at the stage of U deposit exploration;
- capability to carry out gamma logging at higher lifting speeds.

**MEASUREMENT CONDITIONS:**
- measurements are carried out in cased and uncased boreholes of 80 to 200 mm diameter up to 1000 m deep at up to +70 °C temperature and up to 30 MPa hydrostatic pressure;
- logging speed is up to 60 m/hour;
- the equipment operates within the configuration of a computerized geophysical station with up to 7000 m long load-bearing single-conductor armored logging cable.

**INFORMATION CAPABILITIES:**
Pulsed neutron logging equipment allows fulfilling:
- pulsed neutron logging with prompt fission neutron detection;
- gamma logging.
During logging the downhole tool measures:
- time distribution of prompt neutrons of $^{235}$U isotope fission;
- natural radioactivity gammas.
Logging data processing results in obtaining of:
- borehole distribution of U content;
- linear U reserve through the borehole;
- radioactive equilibrium coefficient.

**TECHNICAL CHARACTERISTICS:**
- Uranium content measurement range, % ........................................................................... 0.005 - 0.5
- Number of measuring probes ................................................................................................. 2
- Neutron generator model ........................................................................................................... ING-10-20-120
- Power consumption, W ........................................................................................................... 40
- DC supply voltage, V ............................................................................................................... +150
- Downhole tool diameter, mm .................................................................................................. 60
- Downhole tool total length, mm .............................................................................................. 3200
- Downhole tool weight, kg ....................................................................................................... 25
KMIS-75
INTEGRATED TOOL SET FOR UNCASED WELLBORE SURVEY

Integrated tool set is intended for determination of porosity, shaliness, in-place permeability and oil- and-gas saturation of beds in vertical and slant holes.

EQUIPMENT FEATURES:
• integration of modules allows fulfilling final logging of a borehole during two or three round-trip operations.
TECHNICAL CHARACTERISTICS:

- Data transmission: Manchester-2 (up to 100 kb/s)
- Logging speed (measured in wide range), m/h: 300-1000
- Maximum power consumption, W: 30
- Operating pressure, MPa: 100
- Operating temperature, °C: 150
- Modules diameter, mm: 75

All downhole tools are implemented based on a unified digital telemetering system and are capable of operating both individually and within assemblies.
KMIS-75

1. ГК+ЛМ module
   Gamma logging - locator of couplings
   **Fulfilled tasks:** correlation of borehole sections and lithological variations.
   **Application area:** measurement of rocks natural gamma radiation exposure rate in up to 7000 m deep boreholes with maximum temperature of up to 175 °C and up to 120 MPa pressure, as well as location of couplings.

2. 2ИК module
   Dual induction logging
   **Fulfilled tasks:** evaluation of oil-saturated reservoirs.
   **Application area:** measurement of apparent specific conductivity of rocks using two induction logging probes of large (ИК-6) and medium radii of investigation. It is recommended to be used in low-resistance terrigenous sections with raising penetration in boreholes drilled using fresh water-based drilling fluids of over 0.2 Ohm-m resistance. Surveyed wells are of 100 to 400 mm diameter.

3. КП module
   Hole caliper - profiler
   **Fulfilled tasks:** measurement of borehole diameter.
   **Application area:** measurement by independent lever arms of two diameters in mutually perpendicular planes (wellbore profilometry), and of medium diameter (caliper measurement) in holes drilled for oil and gas. Surveyed wells are of 100 to 600 mm diameter.

4. БК-МБК module
   Lateral logging - micrologging
   **Fulfilled tasks:** selection of reservoirs in oil-and-gas well sections.
   **Application area:** measurement of apparent resistivity of rocks using two microprobes (MCP) and a lateral logging device (LLD), and diameter measurement in boreholes drilled for oil and gas. Surveyed wells are of 100 to 360 mm diameter, drilling mud resistance is from 0.05 to 5.0 Ohm-m.

5. 2БК module
   Dual lateral logging
   **Fulfilled tasks:** estimation of bed resistivity values.
   **Application area:** measurement of rocks apparent resistivity by four lateral logging devices of different radius of investigation carried out using a five-electrode probe tool with "volumetric" electrodes; and provision of galvanic channel for measurement of spontaneous polarization potentials in boreholes drilled for oil and gas.
6 ИНКЛ module
Inclinometer

**Fulfilled tasks:** determination of borehole direction.

**Application area:** measurement of inclination angle and azimuth angle in wells drilled for oil and gas.

7 НГК module
Neutron gamma logging

**Fulfilled tasks:** determination of gas-bearing strata, gas-liquid and water-oil contacts.

**Application area:** measurement of exposure rate of secondary gamma radiation of rocks in boreholes drilled for oil and gas.

8 ГГКп module
Density gamma-gamma logging

**Fulfilled tasks:** correlation of borehole sections and lithological variations.

**Application area:** measurement of volume density and photoelectric absorption index of rocks in boreholes drilled for oil and gas. Surveyed wells are of 100 to 340 mm diameter.

9 2НК module
Dual neutron logging

**Fulfilled tasks:** determination of gas-bearing strata, gas-liquid and water-oil contacts.

**Application area:** measurement of water-saturated porosity of rocks in boreholes drilled for oil and gas.

10 4АК module
Acoustic logging

**Fulfilled tasks:** determination of porosity factor and elastic modulus of rocks in uncased boreholes, and evaluation of casing string cementing quality.

**Application area:** measurement of characteristics of wave packets from **R1** and **R2** receivers generated by **E** emitter at 23 kHz emission frequency and propagating in casing string, cement stone, and rocks in cementing acoustic logging mode; measurement of interval times, amplitudes and effective attenuation coefficients of refracted longitudinal, transverse and Lamb elastic waves in rocks from **R3** and **R4** receivers generated by **E** emitter at 17 kHz emission frequency in acoustic logging mode, in boreholes drilled for oil and gas and filled with washing fluid.
SMIS-120-B  EQUIPMENT FOR LOGGING WHILE DRILLING

The equipment is intended for determination of porosity, shaliness, permeability and oil-and-gas saturation of beds, including record of information while well drilling.

EQUIPMENT FEATURES:

- transmission of information about drilling tool position and geological parameters of a bed via hydroimpulsive channel to the surface allows hole making to be carried out remaining within the bed boundaries.
TECHNICAL CHARACTERISTICS:

- Type of downhole telemetric system: hydraulic channel with positive pulse
- Determined elements: Fe, Si, Mg, Ca, Al, Cl, O, C, S, Gd, H, Na
- Maximum power consumption, W: 50
- Resistivity, Ohm·m: 1 - 200
- Gamma activity, μR/h: (0 - 250) ± 15%
- Operating temperature, °C: 120
- Maximum module diameter, mm: 172

**Modules are shown in representative scale**

**1. ВИКПБ-120-Б**
High-frequency induction logging while drilling

**Fulfilled tasks:**
section layering, including thin-layer one, with high spatial resolution; estimate of water-oil and gas-water contacts location.

**2. ИНГК-С-120-Б**
Pulsed neutron gamma-ray spectrometric logging

**Fulfilled tasks:**
determination of mineral model of a bed, its “neutron” porosity and density.

**3. МС-120-Б**
Connecting module

**Fulfilled tasks:**
data transmission via a single conductor.

**4. МПИ-120-Б**
Power supply and measuring module

**Fulfilled tasks:**
correlation of well sections and lithological measurements; determination of well direction.

**5. МП-120-Б**
Power supply module

**Fulfilled tasks:**
power supply of a tool from lithium batteries.

**6. МУП-120-Б**
Pulsator control module

**Fulfilled tasks:**
pulsator control.

**7. МПГ-120-Б**
Pulsator-generator module

**Fulfilled tasks:**
data transmission via hydraulic channel.
SMIS-102-A AUTONOMOUS DRILL PIPE LOGGING EQUIPMENT

The equipment is intended for determination of porosity, shaliness, permeability and oil-and-gas saturation of beds in horizontal and directional wells.

EQUIPMENT FEATURES:
- final well logging is carried out by means of moving autonomous downhole system on drilling tool without logging cable.
**TECHNICAL CHARACTERISTICS:**

- Data transmission: time-stamped storage in flesh memory
- Maximum power consumption, W: 35
- Logging speed, m/h:
  - general: 360
  - detailed: 70
- Operating temperature, °C: 20
- Diameter of modules, mm: 102

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**INCL-102-A**

Module

**Fulfilled tasks:**
Determination of wellbore spatial coordinates.

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**ВЭМКЗ-102-A**

Module
High-frequency electromagnetic logging

**Fulfilled tasks:**
Section layering; estimate of water-oil and gas-water contacts location.

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**БК-102-A**

Module
Lateral logging

**Fulfilled tasks:**
Selection of reservoirs; evaluation of oil-and-gas saturation character.

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**ИНГК-С-102-A**

Module
Pulsed neutron gamma-ray spectrometric logging

**Fulfilled tasks:**
Determination of mineral model of a bed.

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**МПП-102-A**

Module
Memory and power supply module

**Fulfilled tasks:**
Tool power supply from lithium batteries; data record into memory.

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**МРГК-102-A**

Module
Resistivity meter and gamma channel module

**Fulfilled tasks:**
Determination of ρ, values; lithological layering of section.
The system is developed for X-ray nondestructive monitoring of the state of downhole tools and equipment in order to detect their mechanical damages (cracks, chipping of the tool thread connections, wire breaks, and so on).

**EQUIPMENT FEATURES:**
- X-ray image recording is implemented to digital flat panel monitor;
- X-ray images are processed using specialized software.

**TECHNICAL CHARACTERISTICS:**
- Maximum X-ray energy, keV: 400
- Maximum penetrability, mm Fe: 60
- Resolution, μm: 100
- Contrast sensitivity (for X-raying 50 mm Fe), %: 1
- Diameter of monitored objects, mm, not more than: 152
- Time of X-ray image obtaining, min, not more than: 15
- Power consumption, W, not more than: 1000

1. X-ray devices RAPAN 300/150 ZA and RAPAN 400/200 ZA
2. Power panel
3. Remote control panel
4. Monitored downhole tool
5. Digital flat panel X-ray monitor Цифровижен 300/100
6. Protective container
7. Workstation for processing and interpreting X-ray images, equipped with specialized software НОРД

- A set of equipment and consumables for X-ray radiography; auxiliary components; cable set.