MEASURING APPARATUS FOR MONITORING RADIOACTIVE NOBLE GAS DISCHARGE IN NUCLEAR POWER PLANTS

By

S. Dési

Nuclear Training Reactor of the Technical University Budapest

Received April 9, 1981

Presented by Dir. Dr. Gy. Csom

Objective

Continuous and reliable monitoring of radioactive substances emitted into the environment is of primary importance in the operation of nuclear power plants. Practice indicated that the effective level of radioactive emission is very low. Considering the huge air circulation in the stack, the extremely low concentration of radioactive substances in the discharged air will require high-sensitivity instruments. The calculation of dose rates acting on the population and the request for a definite identification of the values measured in environment control makes it necessary to perform measurements selective as far as possible (determination of isotope composition).

The inlet gas entering the stack of the nuclear power plant is composed of the air exhausted by the ventilation systems of the reactor plant and the accessory building for handling and storing wastes, and of the air of the gas-purifying system.

The main components of the gaseous radioactive waste in the air leaving the power plant through the stack are

— radioactive noble gases,
— radioactive aerosols (alpha-, beta- and gamma-emitters),
— radioactive iodine and
— tritium.

Within the mixture of nuclides, the concentration of radioactive noble gases surpasses the concentrations for other isotopes by orders of magnitude. Due to the dilution by the vast amounts of air, the radioactive concentration is below the maximum admissible concentration by several orders of magnitude. No reliable data are at our disposal on the factual isotopic composition emitted by the blocks type VVER-440 in operation. In the followings an apparatus will be outlined which is intended to measure the amount of radioactive noble gases emitted by nuclear power plants. The prototype of this apparatus will be set up at the 1st and 2nd block of the Nuclear Power Plant in Paks, Hungary.

The location and construction of the apparatus

The measuring apparatus will be located at two sites: the detector unit in the lower space of the stack and the data processing and evaluating units in the dosimetric control room. The general arrangement plan is shown in Fig. 1.

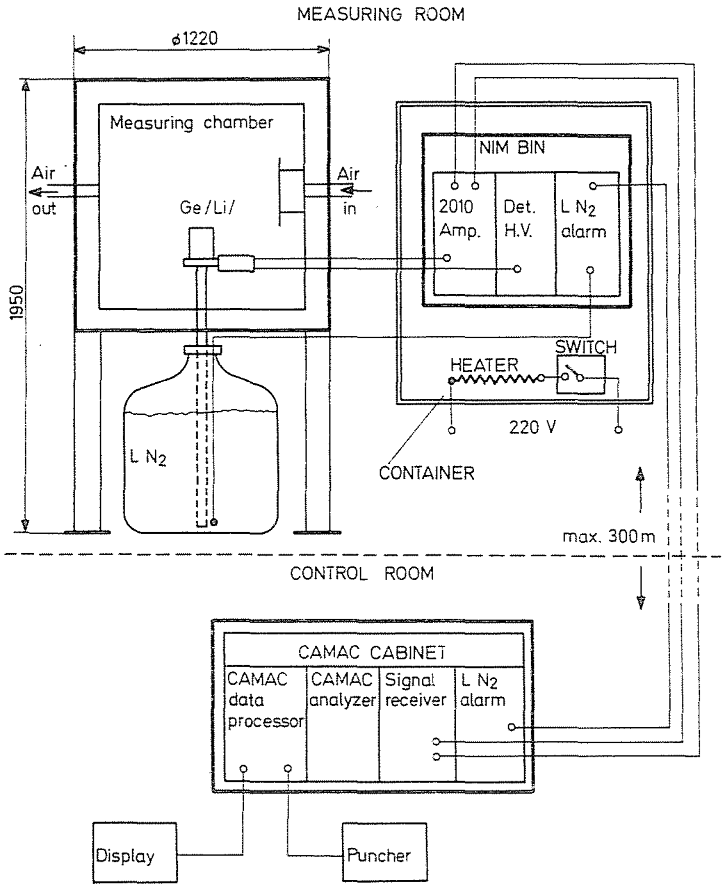

Fig. 1. Schematic layout of the measuring apparatus

The emitted noble gases will be measured in a low-background measuring chamber, using a germanium semiconductor detector cooled with liquid nitrogen and analogue signal processing units. The concentration of four radioactive noble gas nuclides: ^{85m}Kr, ^{88}Kr, ^{133}Xe and ^{135}Xe will be measured by gamma spectroscopy. The minimum activity measured is 540 Bq/m^3 during a measuring period of maximum 3000 s. At these conditions of minimum measurable activity and maximum measuring period the task can be performed in an about 0.85 m^3 low-background measuring chamber using a semiconductor detector with a detection efficiency of around 10% rel. Due to the relatively low gamma energy of the noble gas nuclides to be determined (minimum 81 keV, maximum 305 keV), the low-background measuring chamber made of iron and having a wall thickness of 80 mm will be able to reduce the effect of the emission of the measured noble gas nuclides outside the chamber to a negligible value (below 0.1%), and will also keep the eventual external background radiation with higher energies at a satisfactorily low level. The measuring chamber is connected to the ventilation system through a sampling iodine and aerosols. After the measurement the air sample is returned to the ventilation system.

The iron measuring chamber is cube-shaped, with internal edge lengths of 930 mm and 80 mm wall thickness.

Uniform gas circulation within the chamber is ensured by suitably positioned baffle plates. The chamber has an openable door to allow the decontamination of the internal surfaces, when needed. It should be mentioned that decontamination will be required only rarely if the filters operate satisfactorily, since the noble gases to be measured cannot become enriched in the measuring space, and other radioactive impurities (primarily in the form of iodine and aerosols) will be efficiently removed by the filters. Other impurities eventually finding entrance into the chamber will not interfere with the measurement of the noble gas nuclides in question, owing to the energy-selectivity of the measuring apparatus. In addition, their half-life is generally short enough to prevent their enrichment in the measuring space.

The semiconductor detector is introduced into the measuring chamber from the bottom. Since the detector requires permanent cooling with liquid nitrogen, the liquid nitrogen tank is equipped with a nitrogen alarm which gives a signal in the dosimetric control room, should the level of the nitrogen fall below a pre-set level.

Signal-processing electronics

The high-stability signal-forming amplifier serving to process the signals coming from the semiconductor detector is located in the measuring room. The requirement of primary importance is temporal stability of amplification. For this purpose we applied a spectroscopic amplifier type 2010, system Nuclear Instrument Module (N.I.M.) (manufacture: Canberra Corp., U.S.A.). The amplifier is installed in a N.I.M.-system power supply cabinet. Since the amplifier operates at temperatures between 0 and +50 °C, ambient temperature below this range must be ensured. For this purpose the power supply cabinet containing the amplifier is placed in a heatable container. Heating is controlled by a thermostat.

For data transmission — at a distance of maximum 300 m — between the analogue signal processing unit and the CAMAC system performing the computations, two alternatives exist.

One alternative consists in analyzing the signals with a multichannel analyzer located in the measuring room. The coded information in digital form is then transmitted through a serial data-interface unit by a data-transmitting MODEM unit to the MODEM receiver located in the dosimetric control room, where it is transmitted to the microprocessor carrying out the computations through a second serial data-interface unit. In this alternative, a ROM memory controlling the measuring cycle and an ICC (Intelligent Cabinet Control) unit are also required in the measuring room, both installed in a CAMAC cabinet.

The rate of data transfer in this alternative is controlled by the MODEM units: since, however, the types at disposal are only capable of transmitting 200 bits per second, the transmission rate of the whole system is slowed down substantially.

The second alternative consists in transmitting the analogue signals from the measuring room to the control room. This mode of signal transmission does not reduce the speed of data storage and processing and is also much less expensive than the transmission of digital signals. The main difficulty in this case is the elimination of external electrical interferences. For this purpose we developed a special system providing for the interference-free transmission of analogue signals by two independent means. The essence of the system is shown in the block diagram Fig. 2.

The shaped signals arriving from the main amplifier enter a line adapter which is coupled to the signal-transmitting cable by the wave resistance of the

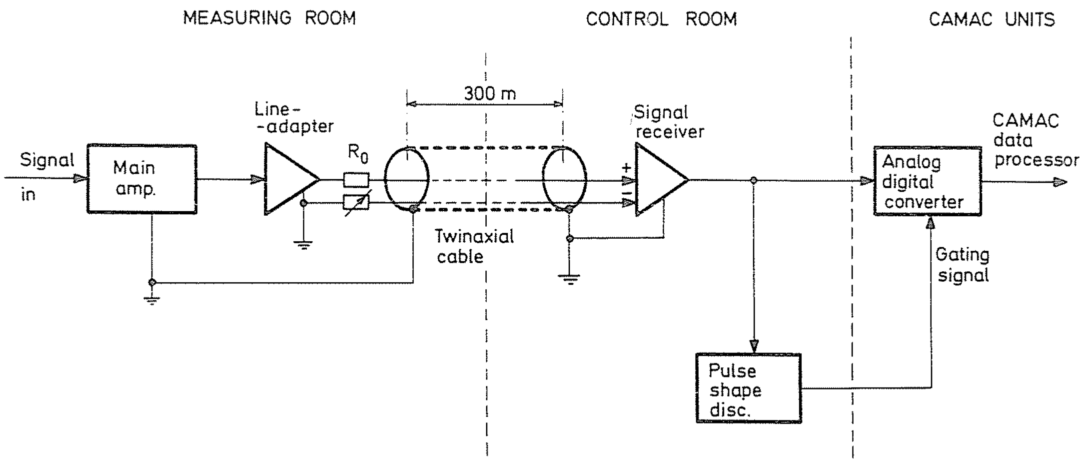

Fig. 2. The electrical block diagram of the measuring apparatus

cable. This is a twinaxial-type cable, that is, the two internal conductors are completely symmetrical. One of the conductors transmits the detector signals and together with them, noise frequencies eventually induced by external sources to one of the inputs of the signal receiver located in the dosimetric control room. The other conductor connects the signal-earthing point of the line adapter with the other (phase-inverting) input of the signal receiver. In this conductor, only the noise signals induced by external sources will be transmitted. If the cable is properly adapted, the magnitude of the noise signals arriving in the two conductors to the signal-receiving amplifier is identical. Since, however, they will be amplified with opposite signs, the noise-originated pulses will extinguish one another, and only the useful signal will appear in the output of the amplifier. By this means, the external noises can be reduced by a factor of 50 to 200, depending on the quality of the electrical components applied.

To achieve further reduction of the interfering effects of external electrical noises, we applied a second method. This is based on the fact that the wave-shapes of the noises differ from the wave-shape of the useful signal: the latter is defined by the signal-shaping amplifier, while the wave-shapes of the noises are irregular.

Both the noises and the useful signal are led into signal-shape discriminators. These produce gate signals permitting the operation of the analogue-to-digital converter only if the shape of the signal arriving to the discriminator agrees with the wave-shape of the original signal coming from the nuclear detector and shaped by the main amplifier. This is performed in the following manner: the discriminator monitors the time intervals between the start and a given (so-called zero-transition) phase of the signals entering the main amplifier, and gives the permission signal to the analyzer only for the time values corresponding to those characterizing the useful signal.

This system ensures completely noise-free transmission. Therefore it will be utilized in our measuring apparatus. The units located in the dosimetric control will be accomodated in one of the drawers of the CAMAC cabinet (cf. Fig. 1.), while the units in the measuring room will be placed in the main amplifier drawer of the N.I.M. cabinet. The system, on the one hand, is much less expensive than digital transmission, and on the other hand, allows fast data processing.

Automated energy calibration by radioisotopes

The high resolving power of the Ge(Li) detector to be used in the measuring apparatus requires the continuous energy calibration of the measuring system, even though high-stability electronic components are applied. For this purpose two low-activity radioactive sources are accommodated in the measuring room, one of them emitting around the lower limit, the other around the upper limit of the gamma energy range to be measured. Continuous monitoring of the photopeaks generated in the detector by these two calibrating sources allows that the data-processing unit establishes the calibration relationship between the position of the calibrating peaks and the corresponding channels and subsequently, for each measuring cycle, will select the channels corresponding to the gamma emission of the four noble gas nuclides to be determined, will compute the pulse counts below the individual photopeaks and finally, from these data, the specific activities of the noble gas nuclides.

Data processing

The data yielded by the detector and the analogue electronic units are processed by CAMAC system units manufactured in the Central Research Institute of Physics in Budapest. The major funcional parts are

— 4 K resolving power, programmed multichannel analyzer,
— microprocessor programmed to process the gamma spectra,
— interface unit for data output,
— display unit,
— tape puncher for recording the results,
— power supply units.

The radioactive noble gas nuclide concentrations computed by the data processing unit are recorded on punched tapes.

The data collecting and processing time is normally 60 minutes. However, if the permitted level should be exceeded, the apparatus switches over automatically — by the program set — to a data collecting time of 6 minutes.

The colour display located in the dosimetric control room shows the total spectrum measured, that is, not only the spectra of the four noble gas nuclides to be determined, but those of all other radioactive impurities in the air emitted by the stack of the nuclear power plant. If desired, the measured total spectrum can be recorded on the punched tape.

Summary

An apparatus serving to measure radioactive noble gases emitted through the ventilation stacks of nuclear power plants is described.

The apparatus uses a semiconductor detector accommodated in a low-background measuring chamber. The data measured are processed with a CAMAC type multichannel analyzer and a microprocessor. Both sampling and measuring are fully automated. The results are shown on a colour display and recorded on punched tape.

Dr. Sándor Dési H-1521 Budapest