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The Importance of On-line Monitoring Systems within the Environmental Monitoring Program of the Karlsruhe Nuclear Research Center

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Abstract

In case of normal operation of the nuclear facilities of the Karlsruhe Nuclear Research Center the annual radiation burden remains below the dose limit values admitted for the population living in the environment (30 mrem/a whole body, 90 mrem/a thyroid, 180 mrem/a bone). Observance of these low dose limits cannot be monitored by on-line environmental monitoring for the simple reason that the requirement on the measuring sensitivity cannot be fulfilled. In case of measurements of the radioactivity concentrations the detection limits required cannot be attained without enrichment procedures. In case of dose rate measurements it must be noted that only the local dose rate can be measured as a real measuring quantity in the environment. However, the necessary reference quantity for evidencing observance of the limit value of whole body dose, caused by activity releases with the exhaust air or liquid effluents, would call for difference measurements which cannot be carried out with the accuracy required for this purpose for the simple reason that the natural local dose is subject to variations. Therefore, the two on-line monitoring systems used in KfK environmental monitoring should be taken as measures of accident precaution and they are restricted to measurement of gamma local dose rates and of the (β+γ)-radiation levels. One of the systems serves to monitor the KfK operational area, the second serves to monitor the surrounding communities up to a radius of 8 km. By use of two different types of detectors the first system covers a range of measurement of 10 μrem/h to 1000 rem/h. By the second system only increases in the radiation level can be detected. It allows to record accidents in which countermeasures must be taken very urgently.

The two monitoring systems are described which have been operated and partly been developed at the KfK. The possibilities and limits of using them for environmental monitoring are discussed.

Die Bedeutung von on-line-Überwachungssystemen innerhalb des Programms zur Überwachung der Umgebung des Kernforschungszentrums Karlsruhe

Zusammenfassung

Bei bestimmungsgemäßem Betrieb der kerntechnischen Anlagen des KfK bleibt die jährliche Strahlenbelastung unter den für die Bevölkerung in der Umgebung zugelassenen Dosishöchstwerten, d.h. z.B. 30 mrem/a Ganzkörperdosis, 90 mrem/a Schilddrüsendosis, 180 mrem/a Knochendosis. Die Einhaltung so niedrig angesetzter Dosisgrenzwerte ist allein wegen der entsprechenden Meßempfindlichkeitsanforderung durch On-line-Überwachungssysteme in der Umgebung nicht überwachbar. Bei Messungen der Radioaktivitätskonzentrationen sind die erforderlichen Nachweisgrenzen nicht ohne Anreicherungsverfahren im Labor erreichbar. Bei Dosisleistungsmessungen ist zu beachten, daß in der Umgebung als reale Meßgröße nur die Ortsdosisleistung gemessen werden kann. Die erforderliche Bezugsgröße zum Nachweis der Einhaltung des Grenzwertes von 30 mrem/a Ganzkörperdosis, verursacht durch Aktivitätsableitungen mit Abluft oder Abwasser, würde jedoch Differenzmessungen notwendig machen, die allein wegen der gegebenen örtlichen Schwankungen der natürlichen Ortsdosis nicht mit der für diesen Zweck erforderlichen Genauigkeit durchführbar sind.

Die beiden On-line Überwachungssysteme der Umgebungsüberwachung des KfK sind deshalb als Maßnahmen der Störfallvorsorge zu begreifen und beschränken sich auf die Messung von Gamma-Ortsdosisleistungen und des (β+γ)- Strahlungspegels. Das eine System dient der Überwachung des betrieblichen Überwachungsbereiches des KfK, das zweite der Überwachung der umliegenden Ortschaften im Umkreis bis zu 8 km Entfernung. Das erste System erfaßt durch Einsatz zweier unterschiedlicher Detektoren einen Meßbereich von 10 μrem/h bis 1000 rem/h. Mit dem zweiten System können Erhöhungen des Strahlungspegels nachgewiesen werden. Hiermit sind Störfälle erfaßbar, bei denen Gegenmaßnahmen besonders vordringlich sind.

Die beiden am KfK in Betrieb befindlichen Überwachungssysteme, die teilweise am KfK entwickelt wurden, werden beschrieben. Möglichkeiten und Grenzen ihrer Nutzung für die Zwecke der Umgebungsüberwachung werden diskutiert.

1. Introduction

The importance of on-line systems for environmental monitoring of the Karlsruhe Nuclear Research Center (KfK) lies primarily in the quick availability of measured values allowing to estimate the external radiation burden during incidents and accidents. Therefore, the two on-line monitoring systems of KfK environmental monitoring should be understood in the first line as measures of precaution against incidents; they are restricted to measurements of the local γ-dose rates and of the (β+γ)-radiation level, respectively. One system serves to survey the 'monitored plant area'[1] of the KfK, the other to survey the communities in the neighborhood within a radius of up to 8 km.

The on-line system for the 'monitored plant area', i.e. the approximately 2 km^2 area within the fence (see Figs. 1 and 2) also serves the purpose of indicating and recording irregularities in operation of the individual nuclear facilities below the level characterizing an incident[2] and the resulting elevated dose rates (e.g. by elevated short-term emissions or transportations of radioactive materials). In this way, the attention of staff in the Environmental Monitoring Control Room is drawn to these events at an early time and, consequently, they can contact the responsible operators of the respective facilities which might be the origin.

The attribution with a high accuracy of elevated dose rates occurring within the 'monitored plant area' to the individual emitters requires that information about the respective meteorological data and emissions are available. Therefore, in the Environmental Monitoring Control Room

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[1] According to Ref.[1] a 'monitored plant area' is a plant area not belonging to the restricted access area and created by the use of ionizing radiation in which persons, in the case of permanent stays, receive more than 1/10 of the limits specified in Appendix X, Column 2, in any one calendar year.

[2] According to Ref.[1] an incident is an occurrence which requires the shutdown of the plant or the interruption of the work due to safety related reasons and for which the plant has been designed or for which protective measures have been provided for the work concerned.

meteorological data (wind velocity, wind direction, etc.) and the rates of emissions from the most important KfK-emitters (see Fig. 2) are also indicated and recorded on-line. For the rest of facilities a control lamp panel serves to indicate in parallel exhaust air alarms when the emission limit values set are axceeded.

For a better estimate of the benefit postulated here from the on-line monitoring system for measurement of the local γ-dose rate within the 'monitored plant area' it seems to be appropriate to present first a short survey of the KfK emitters and the activities they release.

Monitoring of liquid effluents from the KfK [2, 3] has been developed such that accidental discharges of radioactive liquid effluents can be ruled out. Therefore, it is not necessary to perform on-line monitoring of liquid effluents in the vicinity of the KfK. Moreover, such monitoring would not be meaningful because sufficiently sensitive on-line monitoring methods are not available by which some radionuclides of particular importance in the KfK liquid effluents, e.g. tritium, could be detected.

2. Releases from the Karlsruhe Nuclear Research Center into the Atmosphere

The release of radioactive substances into the atmosphere under normal operating conditions and in case of incidents is preplanned in exhaust air plans [4 - 7] which are applicable to a period of twelve months each and have been agreed upon with the licensing authorities. These exhaust air plans list for the individual emitters of the Nuclear Research Center the maximum admissible annual, monthly and weekly values broken down by radionuclides and radionuclide groups, respectively. The radionuclide groups were introduced taking into account the aspects of radiotoxicity and measurement technology. The exhaust air plan valid at present applies to 24 nuclear facilities, e.g. several reactors and research institutes, the various facilities of a decontamination service (among them an incineration facility for burnable solid and liquid radioactive wastes), a cyclotron, and a reprocessing plant rated for an annual throughput of 40 tons of spent fuel. Some of them have several exhaust air systems with separate outlets and different heights of emission. Accordingly, the radioactive emissions are very diverse in nature: Besides radioactive gases, especially noble gases, tritiated water vapor and radio-iodine isotopes, α- and β-emitting aerosols are released.

Table 1 presents a survey of releases during the last five years. According to this table, the prevailing radionuclides released have been argon-41 (practically only from the FR-2 research reactor whose decommissioning has been already decided), krypton-85 (mainly from the WAK reprocessing plant) and tritium (from the heavy-water moderated reactors MZFR and FR-2 and from the FERAB incineration facility). The table contains a summary of the iodine releases, expressed as iodine-131 equivalent. The measured releases of α-emitters are low and have so far remained within the order of few mCi.

The releases of β-emitting aerosols by the Nuclear Research Center as a whole have been of the order of some tenths Ci per annum during recent years. In the 'Radioactive Gases' column the releases of gaseous nuclides or mixtures of such nuclides have been summed up. They include fission noble gases and short-lived nuclides which occur e.g. during cyclotron operation and which are not relevant for the radiation burden to the environment [7].

Table 2 is a compilation of the calculated maximum local doses in mrem outside the Nuclear Research Center which are caused by the radioactive substances emitted in 1979. These local doses relate to uninhabited areas. The doses calculated for the nearest communities are in the most adverse case lower by one order of magnitude than the maximum values indicated [7].

3. Provisions and Dose Limit Values for Environmental Monitoring as Contained in the Radiation Protection Ordinance

The basic requirements of organization and practical implementation of environmental monitoring of nuclear facilities can be derived from those sections of the Radiation Protection Ordinance [1] which relate to the 'protection of the general public and the environment against the hazards of ionizing radiation' and to the definition of 'radiological protection areas'. The provisions formulated in these sections imply a classification by location of different monitored areas for which the different dose limit values have been fixed.

Within the 'monitored plant area', i.e. within the fence surrounding the plant but outside the controlled areas, the whole body dose for persons not occupationally exposed must not exceed 500 mrem/a (Sec. 51). To evidence observance of these limit values, measurements of the local dose and local dose rate, respectively, must be performed on the premises of the nuclear facility, if required. Moreover, there is an obligation to notify if - as a result of high local dose rates - 'the accumulated whole body dose of a non-occupationally exposed person in respect of any one year may reach 500 mrem in 40 hours per week assuming 50 weeks per year' (Sec. 61).

In the 'monitored off-plant area'[3] the whole body dose generally must not exceed 150 mrem/a for a person (Sec. 44). This limit value includes the dose contributions to be expected according to Sec. 45 from the emissions of radioactive materials with the exhaust air and the liquid effluents. The 'monitored off-plant area' directly adjoins the 'monitored plant area' or a controlled area. Regarding the 'monitored off-plant area' access is neither limited with respect to the duration of stay nor to an authorized group of persons. Since permanent stay of persons is admissible, this implies practically a limitation of the local dose. The inner limit of the 'monitored off-plant area' is practically set by the

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[3] According to Ref.[1] a 'monitored off-plant area' is an area immediately adjoining a restricted access area or a monitored plant area, in which persons, in the case of permanent stays, may receive more than 3/500 of the limits specified in Appendix X, Column 2 in any one calendar year.

fence of the nuclear facility. By contrast, the limitation of the external area must be qualified as an indistinct one. According to the definitions in Appendix I of the Radiation Protection Ordinance the size of the 'monitored off-plant area' coincides with an area in which persons, in the case of permanent stays, may receive more than 3/500 of the limits specified in Ref.[1]. This means for the whole body dose - and only this dose is referred to in Sec. 44 - that it may exceed 30 mrem/a, with the exposure to natural radiation obviously not taken into account.

In some particular cases the responsible authority may admit a whole body dose of 500 mrem/a for the monitored off-plant area if the objectives specified in Sec. 45 are not thereby affected. Since reference is expressively made to the objectives specified in Sec. 45 (limitation of the dose caused by the discharge of radioactive materials with the exhaust air and liquid effluents) this exceptional provision can be meant to relate only to direct irradiation sources.

The 'areas which are not radiological protection areas' are practically the national territory as a whole. Sec. 45 of the Radiation Protection Ordinance provides that the technical design and the operation of a nuclear facility must be conceived in such a way that the radiation exposure of man, caused by the radioactive materials released from the plant with the exhaust air or liquid effluents, shall be kept as low as possible. This radiation burden must not exceed the limits specified for different parts of the human body. When calculating the radiation exposure the 'most unfavorable points of impact and considering all relevant exposure pathways including food chains' must be taken as the basis. It is also important that the dose limit values are not understood to mean limit values per facility but relate to the site, which means that they have to be observed also if environmental impacts from several facilities are overlapping.

As appears from the calculated data in Table 2, the annual radiation burden remains below the admitted dose limit values for the population living in the environment of a nuclear facility, provided that the KfK facilities are operated according to specification; these limit values are e.g. 30 mrem/a of whole body dose, 90 mrem/a of thyroid dose, 180 mrem/a of bone dose. However, observance of such low dose limit values cannot be monitored by on-line monitoring systems in the environment, since the requirements on the sensivity of measurements cannot be fulfilled. When measuring the radioactivity concentrations, the required detection limits cannot be attained without enrichment techniques applied at the laboratory. It must be noted for dose rate measurements that only the local dose rate can be measured in the environment as a real measuring quantity. However, specification of the reference value required to evidence observance of the 30 mrem/a limit value of the whole body dose caused by activity releases with the exhaust air or liquid effluents would call for differential measurements which cannot be made with the accuracy required for this purpose, simply on account of the existing local variations of the local dose of natural radiation.

Consequently, the new 'Guideline on Emission and Environmental Monitoring of Nuclear Facilities' of November 1979 [8] practically does not impose on-line monitoring systems because they are not suited to help to attain the objective of monitoring as specified in Sec. 45 of the Radiation Protection Ordinance. The Guideline only calls for sensitive measurement and continuous recording of the local γ-dose rate in the two main sectors of diffusion.

More recent considerations concerning the installation of remote monitoring systems [9, 10] for nuclear power stations in the Federal Republic of Germany start from establishing an on-line monitoring system for incidents as a network of measuring stations allowing to record the radiation level and the local γ-dose rate, respectively, in the vicinity of nuclear power stations. This looming up requirement has been complied with for approximately 15 years already by the field stations equipped with counters and installed around the KfK (see Chapter 4.1).

The necessity and benefit of an on-line system for monitoring the local γ-dose rate cannot be derived from the Guideline on Environmental Monitoring of the vicinity of a nuclear facility but rather from the provisions of the Radiation Protection Ordinance on monitored plant and off-plant areas, which have been quoted at the beginning of this chapter. An on-line system offers a valuable supplement to the use of solid-state dosimeters.

4. The On-line Systems for Environmental Monitoring of the Karlsruhe Nuclear Research Center

The two on-line systems for direct measurement of radiation comprise eight GM-Counter stations and 31 measuring stations of a GM-Counter monitor system installed within the 'monitored plant area' [11, 12]. The major parts of both systems were already developed some years ago by the Health Physics Department (now: Safety Department) of the KfK.

4.1 GM-Counter Field Stations

Already five years before the completion of the first research reactor at Karlsruhe an extensive environmental monitoring program had been started. Several GM-counters with ratemeters and pen recorders had been installed in neighboring villages in order to observe the background level of natural radiation. Later-on, the Health Physics Department developed a monitoring system allowing interrogation of the remote GM-stations by telephone in order to have quick access to information in emergency situations. Data transfer was accomplished in the binary code by slow serial transmission of two audio frequencies. After 13 years of service this equipment was replaced by a commercial data transmission system which works fully automatically and conforms to the more recent regulations of the Deutsche Bundespost (Federal Postal Administration). The type of GM-counters used and the detector heads built at the KfK had proved to be very satisfactory and will be used also in the future. Large-area counting tubes are used to measure the (β+γ)-radiation level at seven fixed measuring stations located in the neighboring communities and at the Nuclear Research Center (see Fig. 1). The measured values of the (β+γ)-radiation level can be interrogated by telephone from the KfK central station. Information about the radiation level in a radius of 2 to 8 km would thus be available within a few minutes also in accident situations.

A Remote Radiation Monitor consists of a measuring head with a GM-counter, fixed atop of an eight meter high telescopic mast, the Data Collection and Transmission Unit, type RMK, and a modem with its associated telephone set (see Fig. 3).

The measuring head is a weatherproof cylindrical can containing a stabilized high voltage generator, a pulse shaper and a cable driver stage. An unshielded 3-wire cable serves for pulse transmission and 12 V dc supply.

The type BZ/120 A - GM-counter has a large surface and a thin aluminium wall, and it is therefore very sensitive to beta as well as to gamma radiation. Its specifications are given in Table 3. Because of their high sensitivity these counting tubes are particularly suited for use in the more distant environment.

The Data Collection and Transmission Unit, Type RMK, is a commercial equipment specially adapted to our needs. The pulses from the GM-tube are given into an eight-digit BCD-counter which acts as a store for the summed up pulses. In another six-digit BCD-counter, which is reset every minute, the momentary pulse rate is generated in cpm. This pulse rate is continuously recorded on a circular wax paper recorder via a digital-to-analog converter and a lin-log converter. The scale is from 10^2 to 10^5 cpm. Two BCD-LED-displays show the contents of the counters.

Data transmission is accomplished with the Data Transmission System, type DP 20 P, of the Deutsche Bundespost. In this system one digit is transmitted by a combination of two audio frequencies out of two groups of four different frequencies each. The transmission speed is 20 digits per second.

The Data Collection and Transmission Unit RMK is equipped with an appropriate code changer and a call control for recognizing an incoming call, for establishing the connection to the interrogating central unit (see Fig. 4) and for transmitting digit by digit the station identification number, the momentary pulse rate and the contents of the 8-digit store counter. The audio frequencies to be transmitted are generated in the modem (modulator-demodulator) which, like the telephone set, must be rented from the Deutsche Bundespost.

The main aspect in the selection of the locations for the measuring stations was to equip each community next to the KfK with one station. The detectors used are sufficiently sensitive to indicate still significant increases of the radiation level at the slopes of the azimuthal distribution, also in case of wind directions carrying the exhaust air plume of an emitter exactly in the direction amidst between two adjacent counter field stations.

Table 4 shows the annual mean values of the (β+γ) pulse rate as well as the ranges of variation of the results of phone inquiries. Phone inquiry of all counting tube stations has been performed automatically every six hours since a new data transmission system was introduced in late May 1979. The central station in the Environmental Monitoring Control Room controls the interrogations of the counting tube stations and records all incoming measuring values. Besides, the central station may interrogate at any time the individual counter stations, if need arises.

The monthly average values of 1979 furnished by seven field stations scatter between roughly 320 cpm and 560 cpm. By contrast, the annual average values are much closer to each other so that it seems to be justified to establish a total 1979 average for these stations. It amounts to 443 cpm.

The annual average value of 478 cpm for the station located on the KfK premises lies within the scattering band of measured values furnished by the field stations. Irradiations of dosimeters performed with different intensities and durations in the calibration hall only 140 m distant, did not yield in 1979 a significant increase in the annual average furnished by the KfK station.

4.2 Counter Monitor System for Monitoring the Local γ-Dose Rate within the KfK Plant Area

Until late 1967 an ionization chamber system comprising 14 measuring stations had been used to monitor the local γ-dose rate on the KfK premises. In this system the measured value was transferred as a very low direct current. The transmission of measured values to the Monitoring Control Room required a 7-wire special cable with an extremely high insulation resistance. Satisfactory operation had been possible up to one km of cable length only. Therefore, the ionization chamber system was replaced in early 1968 by a counting tube monitoring system which did no longer show the technical deficiencies mentioned. The new detector type was a BZ 120 counting tube equipped with an energy compensation filter so that above a quantum energy of 25 keV a dose rate can be indicated within a range from 10 µrem/h to 10 mrem/h which is independent of the energy. In this new system the measured value is transmitted from a low-impedance transmitter as a direct voltage of 0 to 3 V. The counting tube measuring head accommodating the detector contains a logarithmic ratemeter with a range of three decades. Most of these measuring stations are located at the boundaries of the Nuclear Research Center. A second detector (Valvo counting tube, type 18529, likewise equipped with an energy compensation filter) is installed at measuring points on the KfK premises which are of special interest in order to measure dose rates of 10 mrem/h to 10^3 rem/h. The specifications of this detector type are given in Table 5. The system is provided with an (optical and acoustic) alarm system capable of distinguishing between an operating failure and a true alarm.

The network of measuring stations in its present status of extension includes 31 measuring stations. Their locations within the 'monitored plant area' as well as the location of the most important KfK emitters have been represented in Fig. 2. 13 of these measuring stations allow γ-dose rates to be recorded up to 10^3 rem/h with a view to accident situations involving high radiation fields. 14 measuring stations cover the lower range of measurement from background up to 10 mrem/h, which makes them sensitive enough to indicate also the presence of slight increases in the dose rates, e.g., as a consequence of transports of radioactive waste. Four detectors at the boundary of the plant site of the reprocessing plant, unlike all the other measuring stations of the counter monitor system, are not equipped with energy compensation filters, which preserves the β-sensitivity of these counters for assessment of the ^{85}Kr-emissions from the reprocessing plant.

The indicators and recorders of all measuring stations referred to above are located in the Environmental Monitoring Control Room in the Building of the Safety Department. The readings of the measuring stations are transferred from the measuring stations by cables with an overall length of more than 30 km. Fig. 5 shows a block diagram of the Counting Tube Monitoring System. Fig. 6 is a sketch of the GM-heads for low and high dose rates belonging to this system.

The background of the local γ-dose rate at the KfK lies at the lower limit of measurement range of 10 μrem/h. Of the 14 low-dose rate measuring stations covering a measuring range of 10 μrem/h to 10 mrem/h one is located in the calibration hall of HS/D (Dosimetry Group of the Central Safety Department). The recordings of γ-dose rates at this measuring station correspond to the values obtained in routine irradiations performed in the calibration hall.

In 1979 the warning threshold set at 1 mrem/h was slightly exceeded at only one of the other 13 measuring stations. This was a measuring station within the MZFR area. The warning threshold was exceeded as a result of X-ray work performed on the MZFR operating site and lasted 8 hours in total. However, the maximum values recorded were still below 1.1 mrem/h.

At the 11 high-dose rate measuring stations of the counter monitor system with a measuring range of 10 mrem/h to 1000 rem/h a local dose rate above the lower limit of measurement range of these detectors was never recorded, not even for short durations.

There is no quantitative evaluation of recordings of the counter monitor system. The recording tapes (approx. 400 m per year) are filed after visual examination on every working day.

Two of the six measuring stations at the boundary of the reprocessing plant area are high-dose rate measuring stations. Dose rates within the range of measurement of these detectors have never occured. The scattering range of the ($\beta+\gamma$)-radiation level measured continuously at the other four measuring points ranged in 1979 from background (about $4 \cdot 10^{2}$ cpm) up to a maximum value of $1.8 \cdot 10^{5}$ cpm. At all four low level measuring stations the warning thresholds were exceeded in 1979. The causes were either X-ray work performed on the reprocessing plant area (e.g. to examine welding seams), ^{85}Kr-releases associated with the dissolution of fuel elements or direct radiation from transport vehicles carrying spent fuel elements.

Counting the cases where warning thresholds had been exceeded at the individual measuring stations and leaving aside the partly identical causes, 72 events in total are obtained (66 events in 1978).

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1979:	KfK 2951 B	(to be printed)

Nuclide	^{41}Ar	^{85}Kr	^{3}H	I	α	β	RG
1 9 7 5	95 730	43 464	1 574	0.20	$3\ 9 \cdot 10^{-3}$	0.43	1 475
1 9 7 6	82 871	85 660	1 179	$\leq 4.8 \cdot 10^{-2}$	$3.5 \cdot 10^{-3}$	0.3	1 309
1 9 7 7	78 774	114 800	1 767	$2.9 \cdot 10^{-2}$	$3.5 \cdot 10^{-3}$	0.6	767
1 9 7 8	65 069	33 596	2 212	$3.3 \cdot 10^{-2}$	$5.1 \cdot 10^{-3}$	0.2	920
1 9 7 9	70 531	50 560	1 488	$< 2.2 \cdot 10^{-2}$	$1.0 \cdot 10^{-3}$	0.2	1 421

Table 1: Releases from the Karlsruhe Nuclear Research Center into the atmosphere from 1975 to 1979, expressed in Ci/a [7].

The symbols mean: α = α gross activity
β = β gross activity
I = $^{131}I_{equivalent}$
RG = radioactive gases, except for ^{3}H and I
(e.g. ^{13}N, ^{16}O, ^{38}Cl, ^{41}Ar, fission noble gases).

Exposure Pathway	Submersion		Inhalation			Ingestion		
Part of Body/Organ	Whole Body	Skin	Lungs	Whole Body	Bones*	Whole Body	Bones*	Thyroid
Nuclide(s)	γ-emitters	β-emitters	$(\alpha+\beta)$-emitters	H-3, C-14, β-emitters	$(\alpha+\beta)$-emitters	C-14 and Sr-90	Sr-90	Iodine
Maximum dose outside the KfK	11.1	65.0	0.2	0.1	2.5	1.7	4.5	1.32

*The bone doses are dose commitments integrated over 50 years.

Table 2: Maximum local doses outside the Nuclear Research Center, in mrem, resulting from radioactive materials emitted in 1979 [7].

Technical Data:

Cathode (and walls):	0,2 mm aluminium
Mass coverage:	50 mg/cm^2
Counter gas:	argon with organic quenching additive

Operating Data:

Threshold voltage:	850 V
Operating voltage:	980 V
Plateau length:	> 250 V
Plateau slope:	< 3 %/100 V
Life:	10^9 counts
Temperature range:	- 30 °C to + 50 °C
Temperature coefficient:	ca. 0.1 V/°C
Background:	450 cpm in air
Measuring range:	Background to 150 000 cpm
Deadtime loss at 100 000 cpm:	ca. 20 %

Sensitivity for several nuclides in air		
Ar - 41	190	cps per 10^{-6} Ci/m^3
Kr - 85	45	cps per 10^{-6} Ci/m^3
J - 131	26	cps per 10^{-6} Ci/m^3
Xe - 135	55	cps per 10^{-6} Ci/m^3
Rn - 222 + daughters	460	cps per 10^{-6} Ci/m^3

Table 3: Specifications of the BZ/120 A - GM-Counter.

Locations of Measuring Stations	$(\beta+\gamma)$-Radiation Level in cpm		
	Annual Average	Minimum Value	Maximum Value
K F K	478	290	1084
LEOPOLDSHAFEN	444	294	1252
LINKENHEIM	440	250	1570
"FORSTHAUS" measuring cabin	407	273	1510
FRIEDRICHSTAL (9 months period of operation)	461	341	1462
BLANKENLOCH	498	339	1705
KARLSRUHE	411	303	1508
EGGENSTEIN	443	314	1473

Table 4: Results of measurements of the GM-Counter field stations in 1979 [7].

Technical Data:

Cathode:	28 % Cr, 72 % Fe
Mass coverage:	80 to 100 mg/cm^2
Counter gas:	He, Ne, halogen
Effective length:	8 mm
Capacitance:	0.7 pF

Operating Data:

Threshold voltage:	400 V
Operating voltage:	570 V
Plateau length	500 to 600 V
Plateau slope:	0.3 %/V
Life:	10^{10} counts
Temperature range:	- 40 °C to + 75 °C
Background (shielded with 50 mm lead and 3 mm Al):	1 cpm
Deadtime:	$\leq$ 11 µs

Count rate as function of dose rate

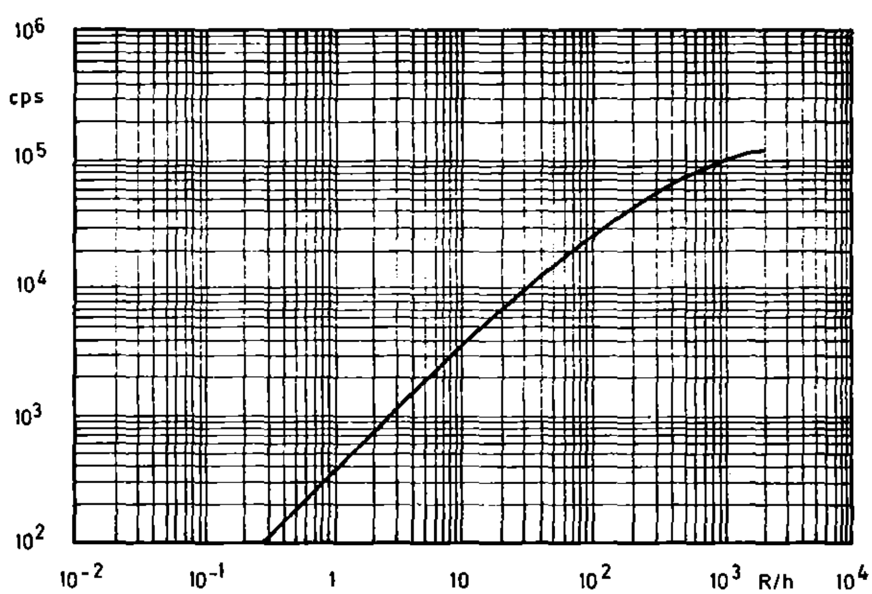

Table 5: Specifications of the GM-Counter Tube Type Valvo 18529.

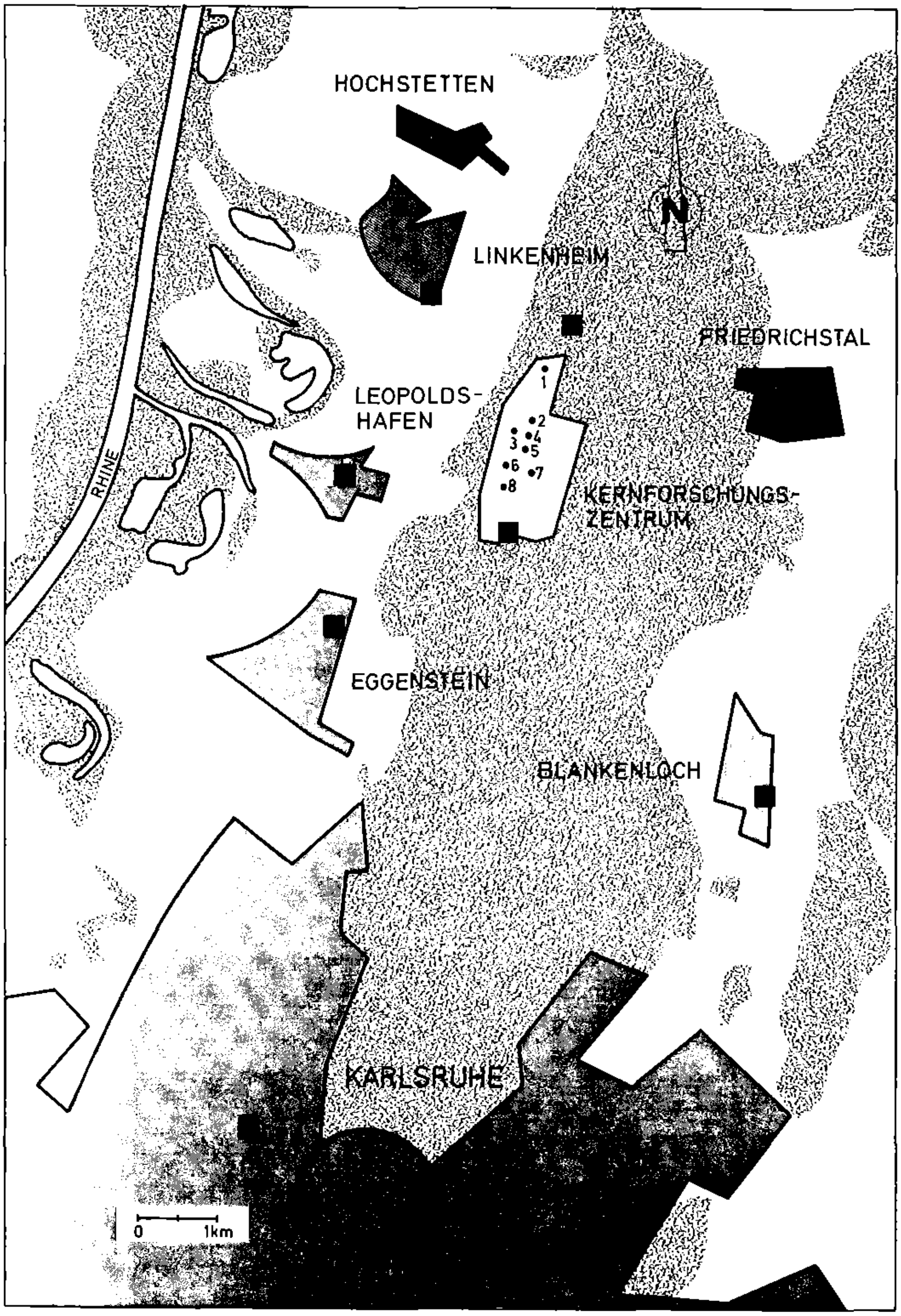

Fig. 1: Map of the measuring points for on-line environmental monitoring. The numerated points within the KfK plant area designate significant emitters of radioactive materials (1: Reprocessing Plant WAK; 2: Reactor MZFR (50 MW_{el}); 3: Compact sodium-cooled Reactor KNK (20 MW_{el}); 4: Institute for Hot Chemistry IHCh: 5: Hot Cells HZ; 6: Incineration Plant FERAB; 7: Research Reactor FR-2 (44 MW_{th}); 8: Cyclotron)

■ Counter Field Station, Forest

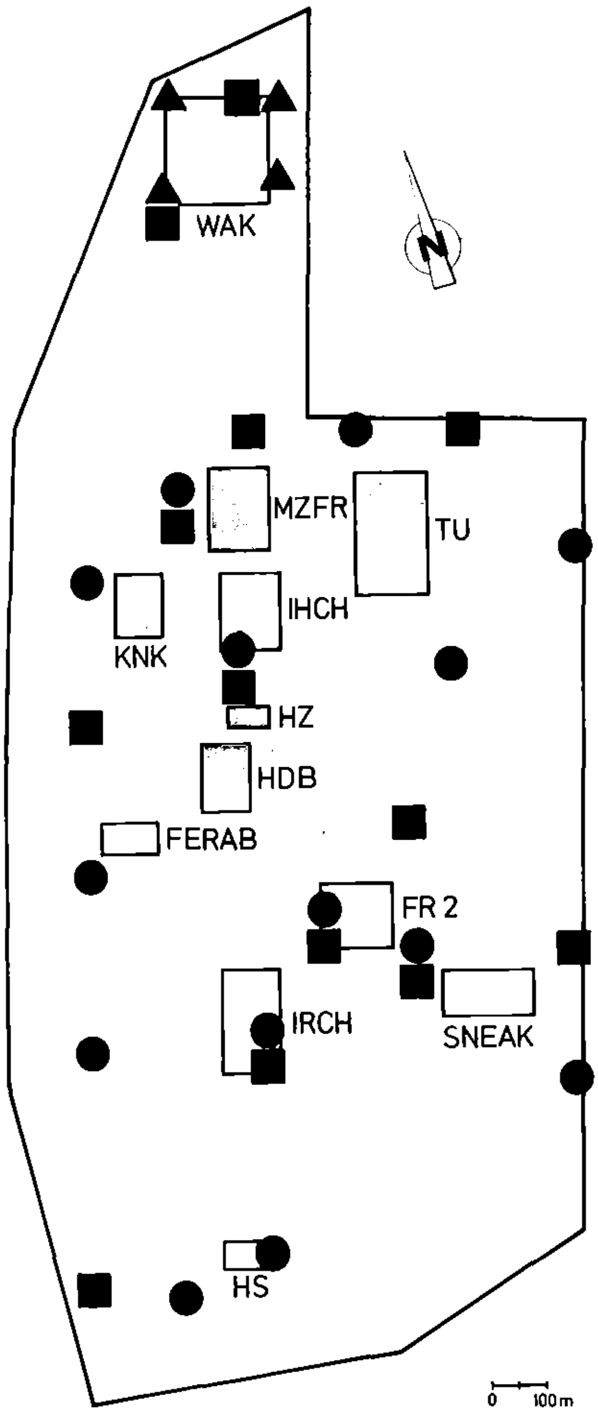

Fig. 2: Map of the measuring points of the Counter Monitor System for monitoring the KfK plant area.

● Low-dose rate measuring location } with energy compensation
■ High-dose rate measuring location } with energy compensation
▲ ($\beta+\gamma$)-low-dose measuring location

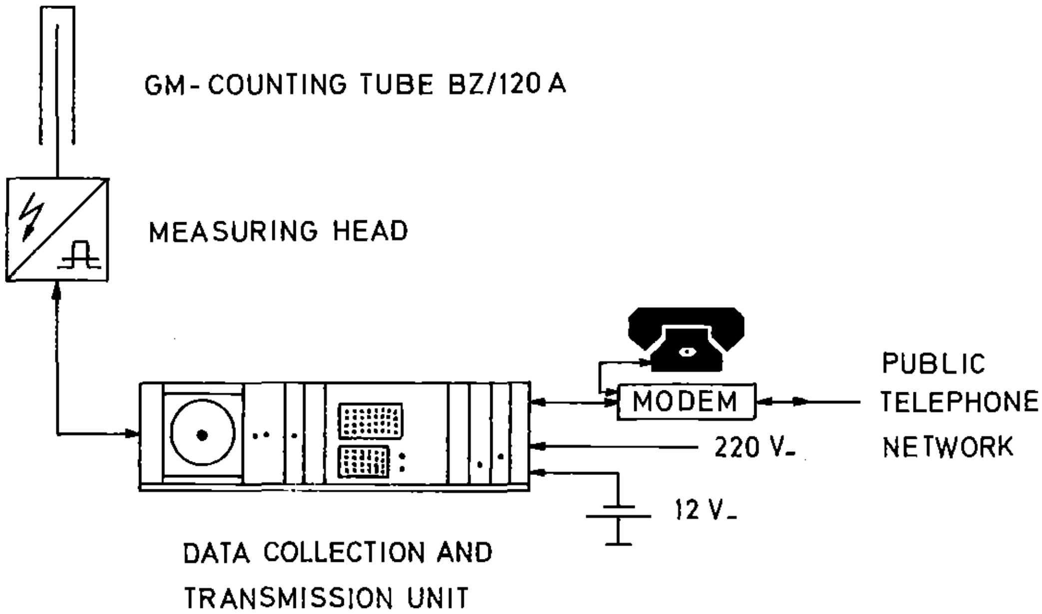

Fig. 3: Remote Radiation Monitor

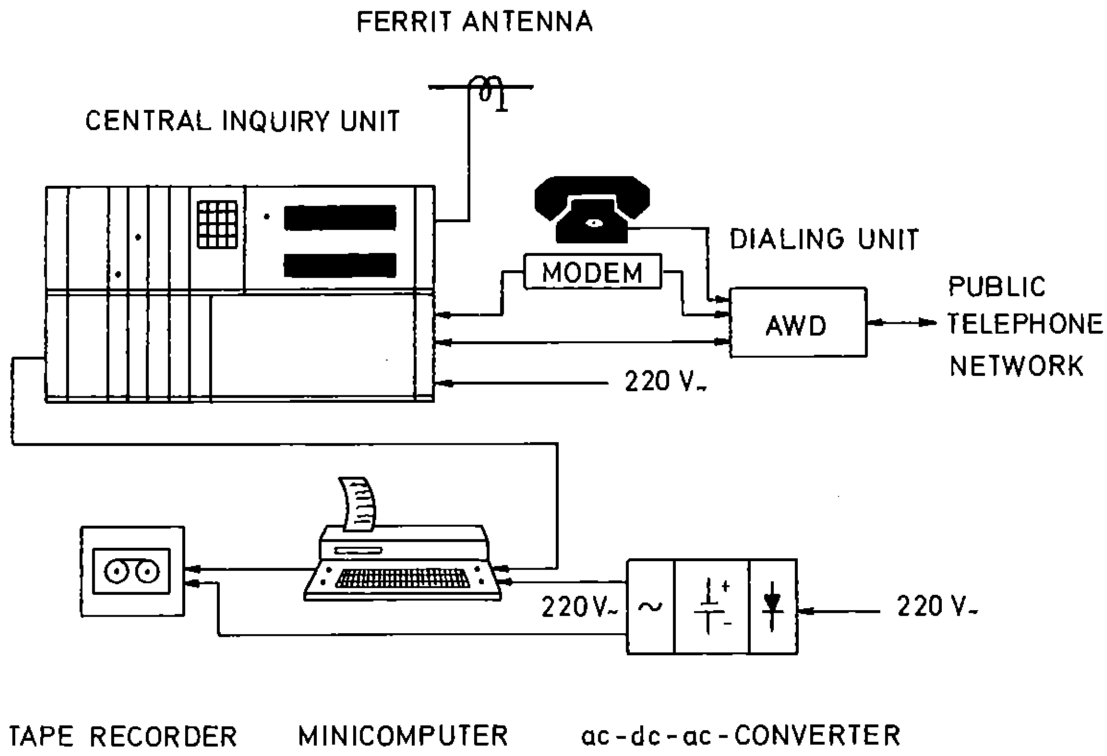

Fig. 4: Central Automatic Inquiry System

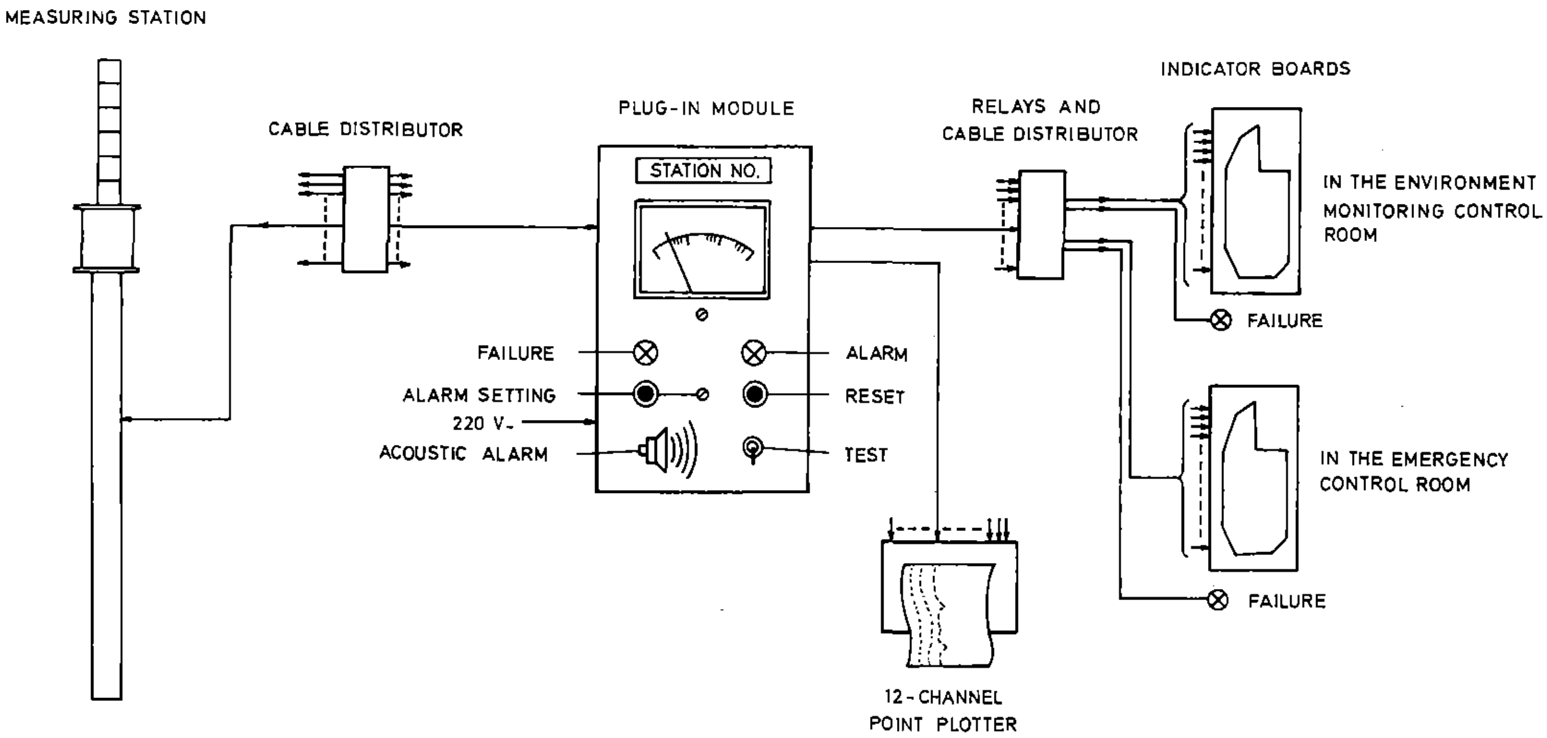

Fig. 5: Block Diagram of the GM-Counting Tube Monitoring System

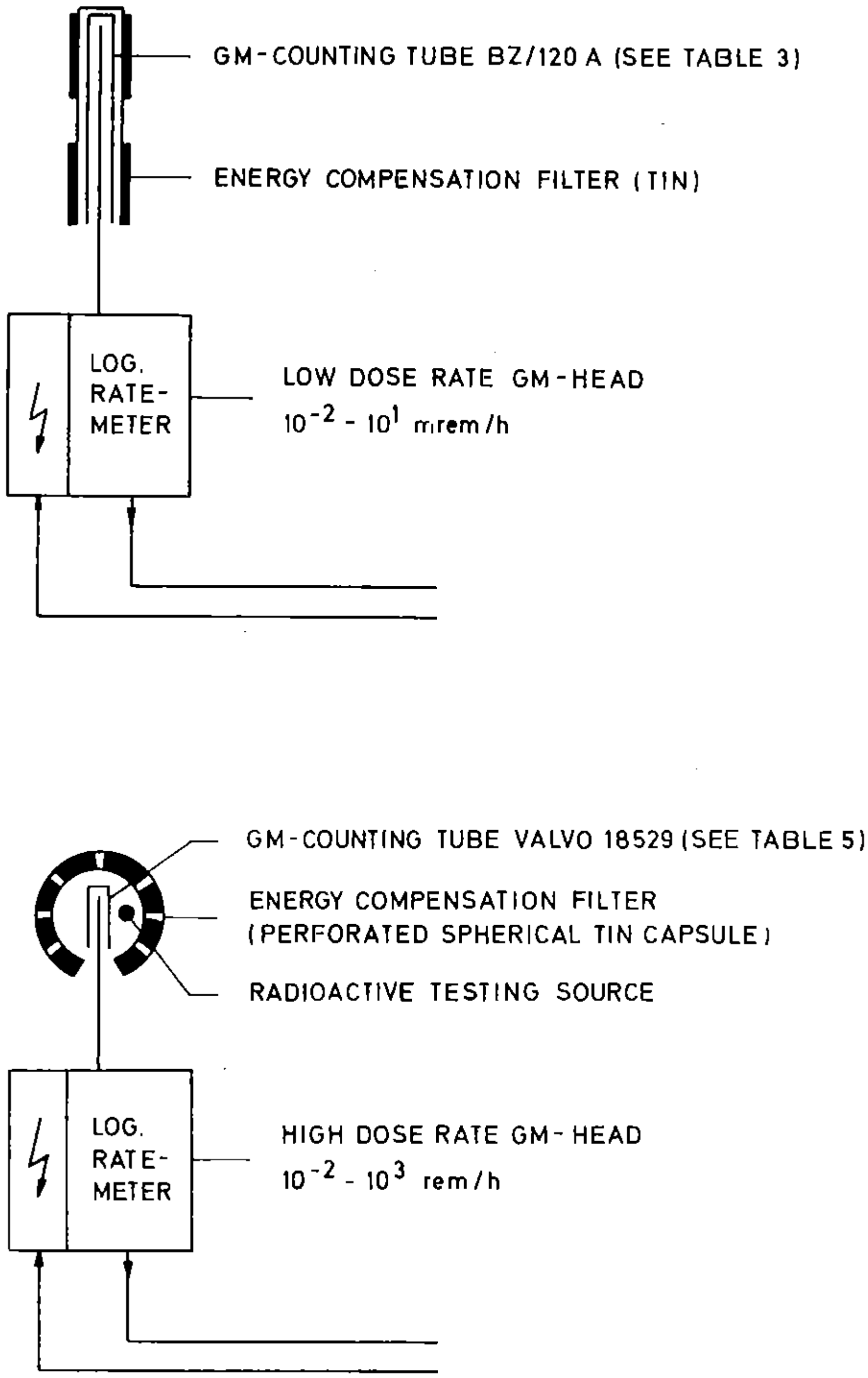

Fig. 6: Measuring stations for Low und High Dose Rates