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PARALLEL-PLATE MULTISECTION IONIZATION CHAMBERS FOR HIGH-PERFORMANCE REACTORS

D. P. Roux

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PARALLEL-PLATE MULTISECTION IONIZATION CHAMBERS FOR HIGH-PERFORMANCE REACTORS

D. P. Roux

APRIL 1966

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PARALLEL-PLATE MULTISECTION IONIZATION CHAMBERS FOR HIGH-PERFORMANCE REACTORS

D. P. Roux[1]

ABSTRACT

A new model of parallel-plate multisection ionization chambers was developed for reactor control applications in high-performance reactors. This chamber model has several improved performance features required by such reactors, and, in addition, the arrangement of the chamber allows the combination of different active sections in a single reactor penetration.

Each active section is comprised of parallel-plate electrodes, each 1.8 in. in diameter and 0.005 in. thick. The electrodes are coated with ^{10}B for use as neutron-sensitive chambers, with ^{235}U for use as fission chambers, or left uncoated for use as gamma-sensitive chambers. Also, a gamma-compensated neutron-sensitive chamber can be made by using boron-coated and uncoated electrodes (appropriately coated and connected).

A new electrode configuration is used to achieve an electrically adjustable gamma compensation. This compensation technique has the advantage over methods previously used, in that both the neutron- and gamma-section currents are well saturated at all polarizing voltages ordinarily used, and thus, electrical compensation is not obtained at the expense of saturation. Experimental results show the insensitivity of the gamma compensation to wide variations in intensity, energy, and geometry of the gamma background.

1. INTRODUCTION

A new model of parallel-plate multisection ionization chambers for reactor control was developed to meet the requirements of high-performance research and power reactors. The parallel-plate configuration was chosen to allow the combination of different electrically independent active sections in a single reactor penetration. Also, the use of parallel plates has led to a new electrode arrangement that achieves an electrically adjustable gamma compensation. The insensitivity of this configuration to wide variations in intensity, energy, and geometry of the gamma background permits control of the compensation within a few tenths of a percent. The stability of the compensation eliminates the need of frequent adjustments.

The penalty of a shutdown of a high-performance research or power reactor is so high that failure of an ionization chamber can hardly be tolerated. Accordingly, during the design of this chamber model, much emphasis was put on reliability performance. For underwater operation, the

[1]The author acknowledges the important contribution of J. C. Gundlach in the early stage of this project and thanks S. H. Hanauer for his many helpful suggestions and G. C. Guerrant and C. B. Stokes for their devoted assistance.

chamber and connecting cables are contained in a hermetically sealed and welded metallic housing assembly. Furthermore, the chamber and connecting cables are designed to operate a minimum of five years without failure by radiation damage.

2. CHAMBER DESIGN AND CONSTRUCTION

2.1 Sensitive Volume

The sensitive volume is comprised of titanium parallel-plate electrodes, each 0.005 in. thick, spaced 0.040 in. apart. The electrodes are of two shapes, as shown at the bottom of Fig. 1.

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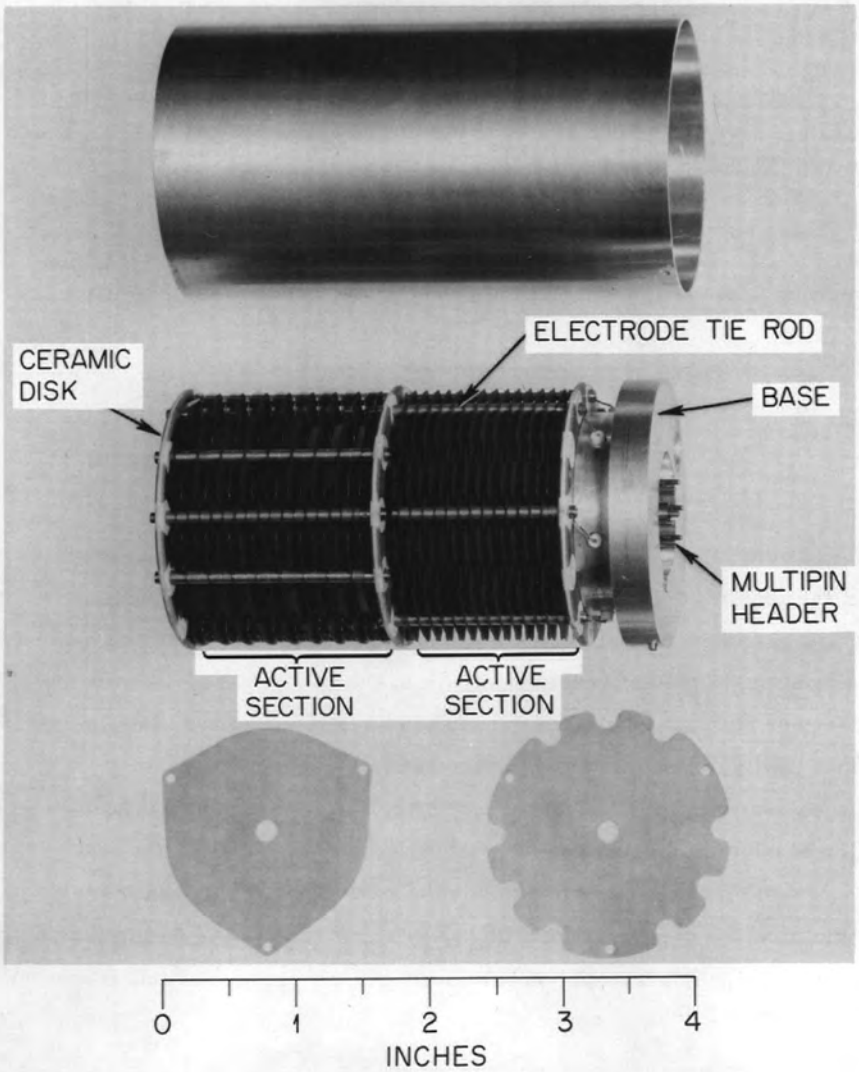

Fig. 1. Two-Active PCP III Section Sensitive Volume. The sensitive-volume can is shown at the top, and the two types of electrodes used in the assembly are shown at the bottom.

"Triangular" plates are used as signal electrodes, and "circular" plates are used as high-voltage electrodes. These electrodes are coated with ^{10}B for use as neutron-sensitive chambers, with ^{235}U for use as fission chambers, or are left uncoated for use as gamma-sensitive chambers. Also, a gamma-compensated neutron-sensitive chamber can be made by using boron-coated and uncoated electrodes, appropriately coated and connected (see Sect. 3.2). Electrically independent active sections are combined to assemble multipurpose radiation detectors as required for the different reactor applications.

Two models of ionization chambers were designed, PCP II and PCP III. The PCP III model, an improved version of the earlier PCP II model, retains the PCP II characteristics but is structurally more rugged and can be manufactured at a substantially lower cost. The PCP III model is described in the remaining portion of this section.

The middle part of Fig. 1 shows a typical sensitive volume comprised of two neutron-sensitive active sections. The active sections are separated and supported by alumina ceramic disks used to anchor the electrode tie rods. The electrical connections are fed through the aluminum base of the sensitive volume to a multipin header. The overall maximum electrical interaction between two adjacent sections is less than 1%. The interactions are caused primarily by the passage of lead connections from the front active section in close proximity to the rear section.

The sensitive volume is contained in an aluminum can, as shown at the top of Fig. 1. If required, the can may be welded to the sensitive-volume base so that the sensitive volume may be filled with its own gas filling, as is the case with the PCP II model. However, in a majority of the applications, the sensitive volume shares the same gas filling with the rest of the chamber-housing volume. Depending on the different active section combinations, the gas and its filling pressure are selected to obtain the best compromise.

2.2 Chamber Assembly

The chamber assembly (Fig. 2) consists of four main parts: a sensitive volume (described in Sect. 2.1), a core assembly, a cable assembly, and a nickel chamber housing. The core assembly provides a highly radiation-resistant, multicoaxial cable extension of 28 in. between the sensitive volume and the cable assembly and, after completion, is a plug-in unit to which the sensitive-volume multipin header and the cable assembly are plugged. An aluminum body, 2.2 in. in diameter and 27 in. long, in the core assembly surrounds a 0.75-in.-diam alumina multihole insulator. The multihole insulator is perforated by seven axial holes: four contain coaxial assemblies of nickel wires inserted in alumina insulator tubings which are coated with Aquadag on their outside surface, and three are for unshielded nickel-wire connections. A multicoaxial plug is mounted on the rear end of the aluminum body. From the multihole insulator to the multicoaxial plug, the insulation on the connecting wires is preirradiated polyethylene and the shields are copper braids.

The cable connecting the ionization chamber to electronic instruments consists of seven individual coaxial cables shielded and jacketed together and insulated with preirradiated polyethylene. This cable is connected to a multicoaxial, hermetic ceramic receptacle that mates to the plug of the core assembly. The cable and receptacle are inserted into a flexible annular metallic tube which is welded at the chamber end to a receptacle housing. The external shell of the receptacle is welded to the receptacle housing to provide a hermetic seal. The cable assembly is also sealed at its other end.

An external view of a PCP III ionization chamber assembly is shown in Fig. 3.

After a chamber has been completely assembled, the chamber housing is welded to the receptacle housing, and the degassing and gas filling operations are made through the exhaust tube mounted to the receptacle housing.

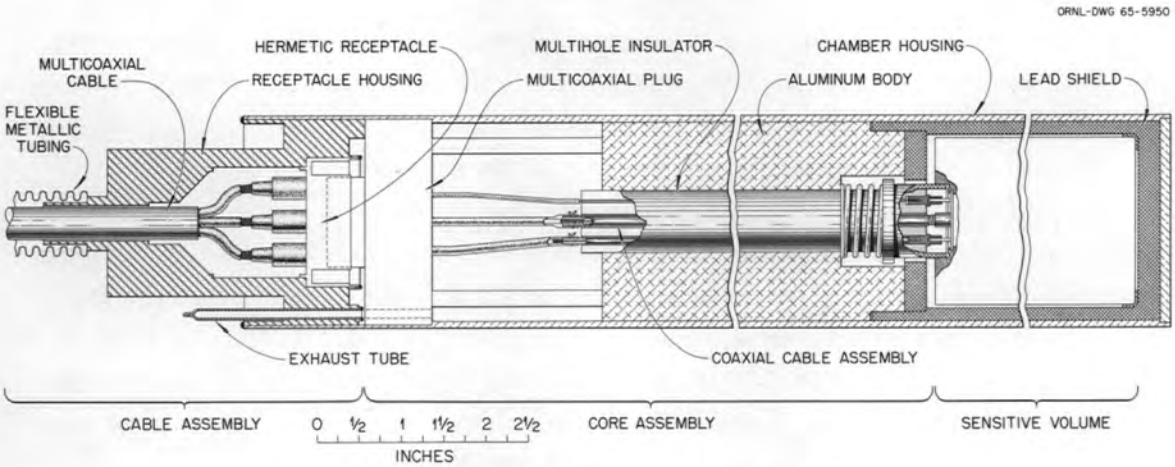

Fig. 2. PCP III Ionization Chamber Assembly.

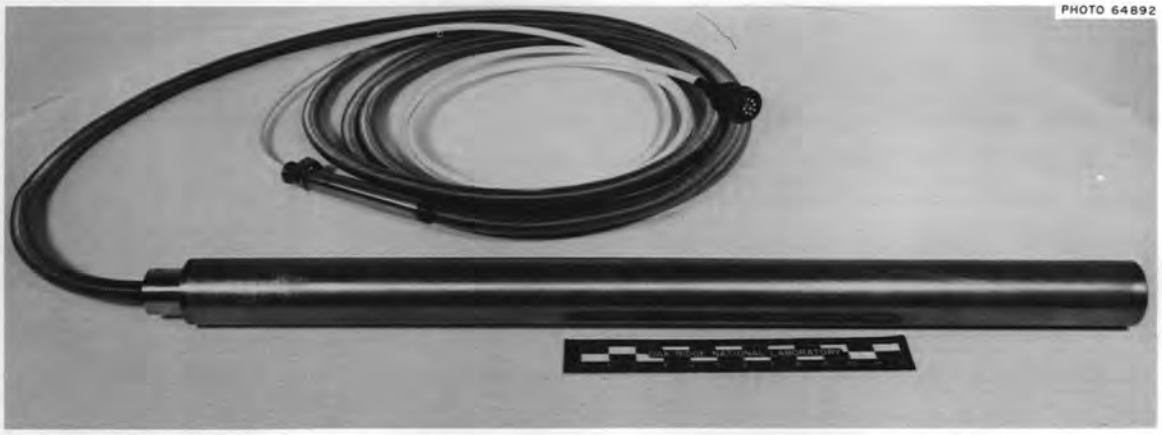

Fig. 3. External View of Ionization Chamber Assembly. The coiled waterproof and flexible metallic tubing, the multicoaxial cable, and multicoaxial connector are shown in the background.

A typical PCP III chamber assembly was subjected to accelerated irradiation in gamma-ray fluxes corresponding to five to ten years of normal operation in reactor installations. There was no noticeable damage to the cables or the seal, and there was no degradation in the performance of the ionization chamber.

3. IONIZATION CHAMBER PERFORMANCE

3.1 Boron-Coated Ionization Chambers

In the majority of applications of boron-coated neutron-sensitive ionization chambers, the current output range is limited by a lack of saturation at high currents and by the gamma radiation background. Thus, this chamber was designed for good saturation characteristics and optimization of neutron-to-gamma sensitivity ratio.

Good saturation characteristics, even at high current outputs, were obtained by selecting a close electrode spacing of 0.040 in. and a low gas-filling pressure. These two choices are required to minimize ion recombination. Typically, for a saturation current of 150 μa, the current collection is more than 99% complete at an applied voltage of 150 v. In this example, the boron-coated active section is filled with nitrogen at a pressure of 1.05 atm, and the current density is 0.5 $\mu a/cm^2$.

The neutron-to-gamma sensitivity ratio is optimized by selection of the sensitive-volume materials and the filling gas and pressure. Also, since in many reactor control applications, ionization chambers are located in light-water media, it is advantageous to use a short-length sensitive volume that has a relatively low sensitivity to neutrons and gamma rays. Because the relaxation length for thermal neutrons is much shorter than that for reactor-leakage gamma rays, for a given neutron-output current a low-sensitivity chamber must be located near to the core surface where the ratio of thermal-neutron to gamma-ray fluxes is higher. Table 1 illustrates this point. Both ionization chambers were assumed to have the same neutron-to-gamma sensitivity ratio, and both chambers were assumed to be located in a neutron flux such that the

Table 1. Gamma Current Outputs for Two Different Chambers Located in a Reactor Light-Water Shield

Chamber Type	Chamber Sensitivities		Swimming Pool: 1 Mw, H_2O Shield, 50-μa Neutron Current[a]	
	Neutron (amp/*nv*)	Gamma (amp-hr/r)	Gamma Flux[a] (r/hr)	Gamma Current (μa)
High-sensitivity	3×10^{-14}	1×10^{-11}	1×10^{6}	10
Low-sensitivity	3×10^{-15}	1×10^{-12}	2.7×10^{6}	2.7

[a]Data by the staff of the Bulk Shielding Facility, *Attenuation in Water of Radiation from the Bulk Shielding Reactor: Measurements of the Gamma-Ray Dose Rate, Fast-Neutron Dose Rate, and Thermal-Neutron Flux*, ORNL-2518 (July 8, 1958).

neutron-current output was 50 μa. In this example, the output gamma current of the low-sensitivity chamber is more than three times less than that of the high-sensitivity chamber.

For the reason previously discussed, the neutron sensitivities of the individual boron-coated active sections used in the different chamber configurations are between 3×10^{-15} and 6×10^{-15} amp/*nv*.

For activation consideration, the materials used in the sensitive volumes are titanium, aluminum, and high-purity alumina ceramic. To achieve low gamma-sensitivity performances, low-density materials are used, and the amount of material is kept to the minimum necessary for the ruggedness of the assembly. For this reason titanium is preferred to aluminum as electrode material. Also, the ^{10}B coating adheres better to titanium when applied as follows: a colloidal suspension of ^{10}B in mineral oil is sprayed on the electrodes; then the oil is baked out at 600°F.

Several tests were performed to measure the neutron and gamma sensitivities of the active sections as a function of gas filling pressure for five gases. The results are summarized in Table 2. An active section consisting of seven signal electrodes and eight high-voltage electrodes was used. The boron coating was 0.35 mg/cm^2. For each gas, the pressure was adjusted to obtain a neutron sensitivity of 6.0×10^{-15} amp/*nv*.

It is interesting to notice that the figures of merit in Table 2 vary little as a function of the atomic number Z. Hydrogen was not considered, because a pressure of approximately 13 atm would have been necessary to obtain a neutron sensitivity of 6×10^{-15} amp/*nv*. As a consequence, the increased thickness of the sensitive-volume can required to withstand such pressure would make the chamber more sensitive to the gamma radiation, and the net gain by using hydrogen would be canceled.

Nitrogen is the filling gas for boron-coated neutron-sensitive chambers, because it is the most stable gas recommended for close electrode spacings and it is a good compromise among different requirements.

Table 2. Ratio of Neutron to Gamma Sensitivities for Different Chamber Gas Fillings

Gas	Atomic Number, Z	Gas Pressure (atm)	Sensitivity		Figure of Merit[a]
			Neutron (amp/*nv*)	Gamma (amp-hr/r)	
			$\times 10^{-15}$	$\times 10^{-12}$	
He	2	4.80	6	1.25	1.15
N_2	14	1.10	6	1.45	1.0
Ar	18	0.76	6	1.57	0.90
Kr	36	0.53	6	2.4	0.60
Xe	54	0.34	6	2.6	0.55

[a]Ratio of neutron to gamma sensitivities, normalized to 1 for N_2.

The neutron-to-gamma sensitivity ratio for the nitrogen-filled chamber in Table 2 is higher than that of any commercially available boron-coated ionization chamber with a sensitivity between 5×10^{-14} and 2×10^{-15} amp/*nv*.

3.2 Gamma-Compensated Ionization Chambers

By using parallel plates we have developed a new electrode configuration (Fig. 4) that achieves an electrically adjustable gamma compensation. The surface area of the signal electrodes is less than that of the high-voltage electrodes. For equal positive and negative polarizing potentials, the zero-equipotential surface (Fig. 4*a*) is an extension of the signal electrode, and as a consequence, the electrical field lines are straight. For unequal polarizing potentials (Fig. 4*b*), the field lines are distorted; and the effective collection volumes, which are determined by the field lines drawn heavily in the figures, are changed accordingly. Since the saturation characteristics of the two situations are essentially the same, adjustment of compensation by this method does not affect the saturation.

The gamma-compensated active section contains 16 signal electrodes, 9 positive high-voltage electrodes, and 8 negative high-voltage electrodes (Fig. 5). To reduce the influence of geometrical effects on the gamma compensation, the length of the electrode stacking is nearly equal to the electrode diameters. For the same reason, the eight ion-chamber units indicated in Fig. 5 are symmetrical relative to the negative high-voltage electrodes. The active section is filled with nitrogen at 1.05 atm. Without gamma compensation, the chamber sensitivities are 6.0×10^{-15} amp/*nv* and 1.4×10^{-12} amp-hr/r.

Manufacturing tolerances are such that initially the gamma currents cancel within 1.5%. Figure 6 shows the gamma compensation as a function of electrode voltages. The slope of the curve corresponds to 1 to 3% compensation change per 100 v change in negative polarizing

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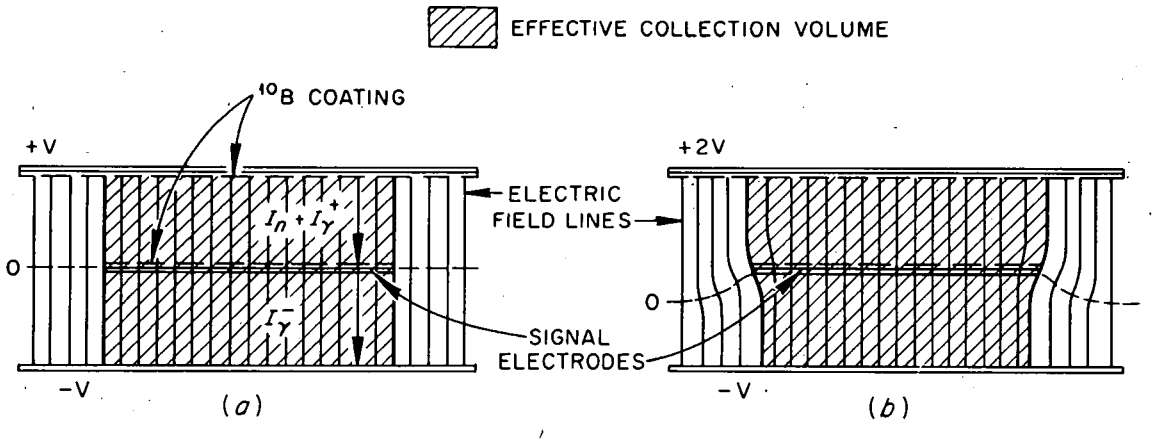

Fig. 4. Diagram of Adjustable Electrical Gamma Compensation. (*a*) Equal positive and negative polarizing potentials. (*b*) Unequal positive and negative polarizing potentials.

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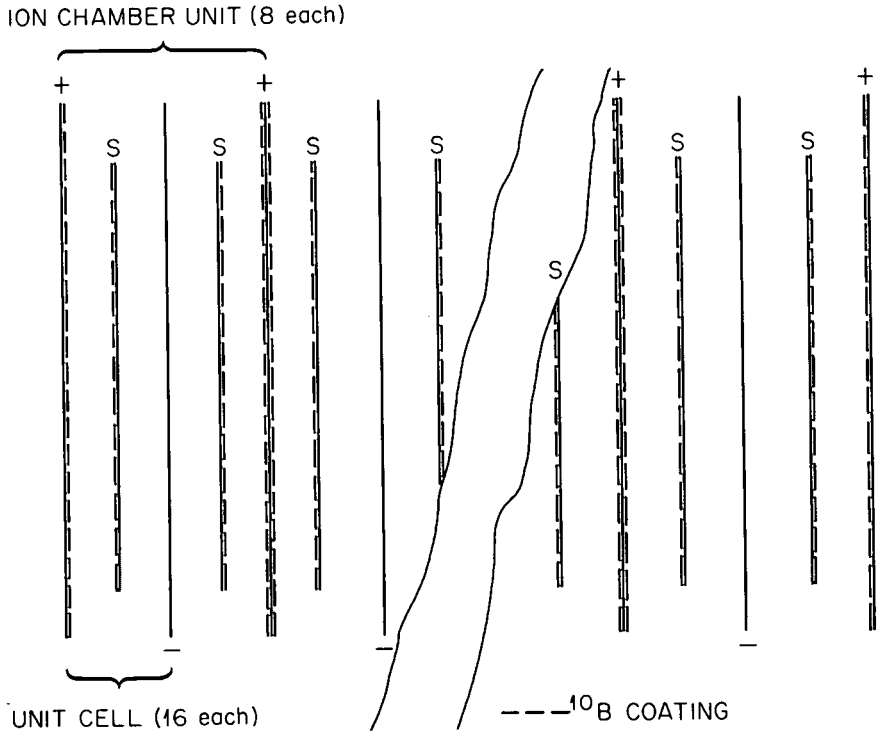

Fig. 5. Electrode Sequence of Gamma-Compensated Ionization Chamber.

Table 3. Gamma Compensation Obtained for Various Gamma Sources with Fixed Electrode Voltages (+300 v, −200 v)

Gamma Source Facility	Source Condition	Shield and Geometry	Deviation from Total Compensation[a] (%)
Hot cell, ^{60}Co	2000 curies	10 cm of air, source at front of chamber	+0.8
Hot cell, ^{60}Co	2000 curies	10 cm of air, source at side of chamber	+1.3
BSR,[b] fission products	10 min after reactor scram	20 cm of water	+0.9
BSR,[b] fission products	90 min after reactor scram	20 cm of water	+0.9
BSR,[b] fission products	1 week after reactor scram	20 cm of water	+0.6
BSR,[b] fission products	1 week after reactor scram	40 cm of water	+0.5

[a]The sign + means undercompensation; that is, $I_\gamma^+ > I_\gamma^-$.
[b]Bulk Shielding Reactor.

voltage, with the positive voltage equal to +300 v. These measurements were made in a hot cell with a ^{60}Co source.

Experimental results show that the gamma compensation is insensitive to wide variations in intensity, energy, and geometry of the gamma source. Typical gamma compensation results obtained with the same ionization chamber are given in Table 3.

The gamma compensation as a function of the chamber current was also measured in a hot cell with a ^{60}Co source. The experimental results are shown in Fig. 7, where the gamma compensation values for fixed electrode voltages (+300 v, −250 v) are plotted as a function of the chamber uncompensated current. Over a range of three decades of chamber uncompensated current, the deviation of the compensation stays within ±0.1%. This range of three decades, expressed as gamma flux, is from 2×10^6 to 2×10^3 r/hr.

The experience in reactor application indicates that this method of gamma compensation is stable. For a given reactor gamma-background condition, a variation of 0.4% in compensation was measured over a one-year period.

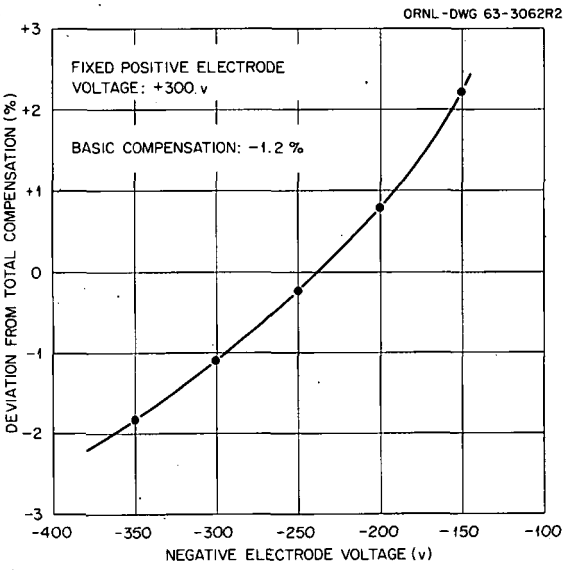

Fig. 6. Gamma Compensation as a Function of Electrode Voltages. Measurements were made in a hot cell with a ^{60}Co source.

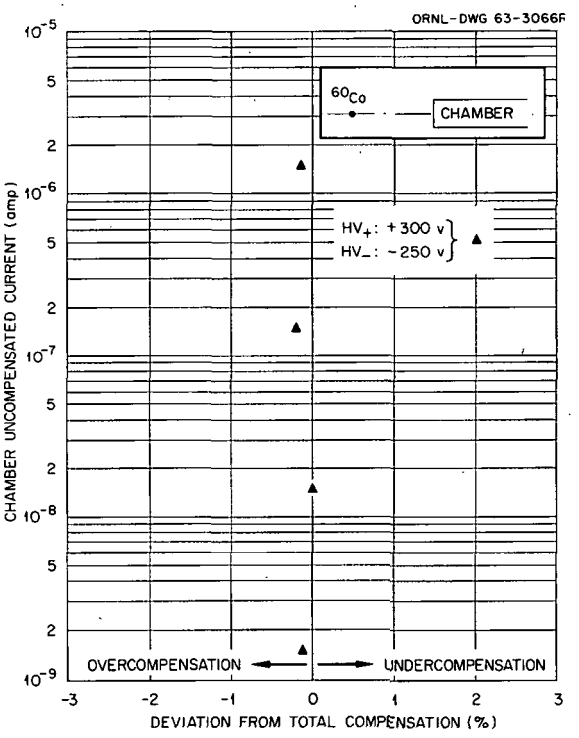

Fig. 7. Gamma Compensation as a Function of Chamber Current.

3.3 Fission Chambers

A fission chamber with a parallel-plate arrangement, described in Sect. 3.2, was built and tested. The active section consists of 15 signal electrodes and 16 high-voltage electrodes coated with 1.0 mg/cm^2 of >99% ^{235}U. The total coating surface is 1000 cm^2. The electrode spacing is 0.080 in., rather than the standard 0.040 in., to increase the gas volume required for the fission-fragment energy collection.

When used as a pulse fission chamber, the active section has a sensitivity of 0.55 count neutron^{-1} cm^{-2}. Figure 8 shows the neutron plateau and the alpha and gamma pileup characteristics of the detector filled with a mixture of 97% Ar and 3% CO_2 at a pressure of 3 atm. Discrimination against gamma pileup pulses in a flux of 3×10^5 r/hr can readily be achieved.

For application as an average-current ionization chamber, the active section was filled with a gas mixture of 99% Ar and 1% N_2 at 0.79 atm. The corresponding sensitivities are 7.2×10^{-14} amp/*nv* and 9×10^{-12} amp-hr/r; the alpha residual current is 1.1×10^{-10} amp. At a saturation current of 1×10^{-3} amp, the current collection is more than 95% complete at an applied voltage of 200 v.

In a fission chamber used as an average-current ionization chamber, the chamber current arises from two sources. The first source is ionization produced by the particles emitted at the time of the fission: the fission fragments and the prompt beta and gamma rays. The second

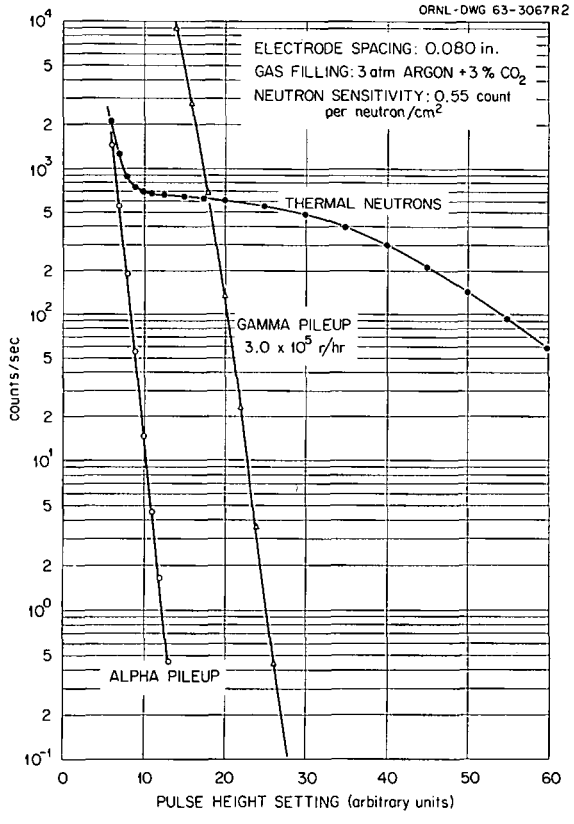

Fig. 8. Integral Curve of the Parallel-Plate Fission Chamber.

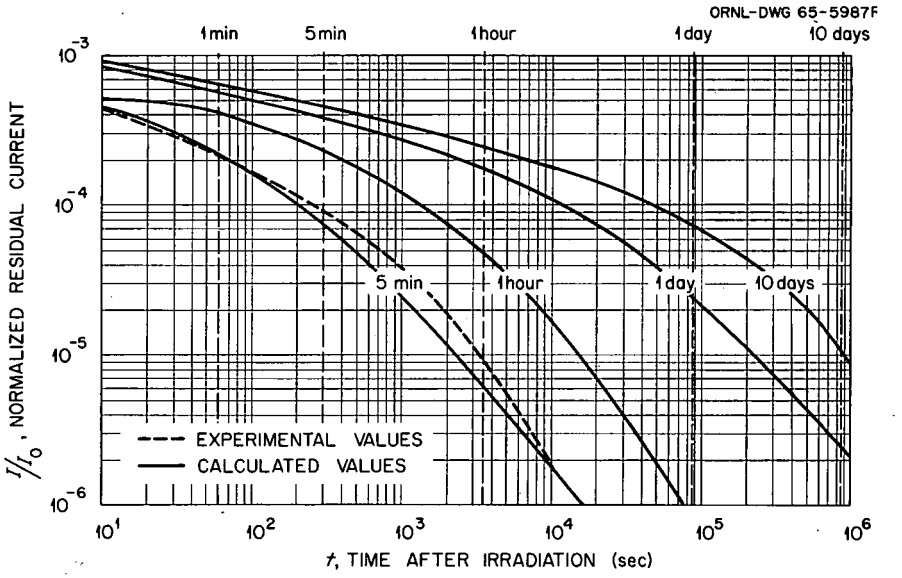

Fig. 9. Calculated and Experimental Fission-Chamber Residual Currents Due to Fission Product Activity as a Function of the Time After Irradiation. Parametric curves are for different irradiation times.

source, which is undesirable, is the ionization produced by the beta and gamma rays emitted by the radioactive fission products. This current, called residual current, is related to the "neutron history" of the chamber: thermal-neutron flux, chamber irradiation time, and time after irradiation.

To evaluate this residual current, an experiment was performed using the fission chamber previously described for application as an average-current ionization chamber. For this experiment, the chamber was irradiated for 5 min in a constant thermal-neutron flux between 10^3 and 10^4 higher than that for any other previous irradiation of this chamber, in order to override the effect of prior residual currents and the alpha current. The current I_0 was 1×10^{-3} amp. After the irradiation, the chamber was removed from the reactor flux, and the residual current I was recorded for 3 hr. Figure 9 shows the ratio of I to I_0 as a function of the time after irradiation. Figure 9 also shows a family of curves of I/I_0 for different times of irradiation, calculated using the empirical formula of Untermyer and Weills[2] for afterheat from beta and gamma rays of irradiated ^{235}U. Fitting of the calculated currents with the measured current was made at 10 sec after irradiation.

Considering the estimated accuracy of ±50% of the Untermyer and Weills formula, the experimental and calculated curves fit satisfactorily for an irradiation time of 5 min. From these curves, fission-chamber range limitations for average-current application can be determined for other configurations.

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[2]S. Untermyer and J. T. Weills, *Heat Generation in Irradiated Uranium*, ANL-4790 (Feb. 25, 1952).

3.4 Gamma-Sensitive Ionization Chambers

Although neutron flux is used universally as a parameter for reactor control and safety, the use of gamma radiation from the core can be advantageous, especially in a light-water shield, which attenuates neutrons much more strongly than gamma rays. In high-performance research reactors, the many beam holes and experiments can result in flooding, by mistake or accident, a part of the region between the core and the detector. Thus, safety gamma chambers are recommended, because in this type of accident, the gamma flux is much less reduced than the neutron flux and a better safety action against core meltdown is obtained.

On the other hand, gamma chambers have a well-known limitation: the radioactive decay of the fission products gives rise to a signal that is not proportional to the reactor power. Experiments were performed with a gamma chamber (to be described later in this section) to evaluate the fission product component of the chamber current. Results show that as little as 50 cm of light water is enough to absorb the low-energy fission product gamma rays; however, the high-energy fission product component cannot be significantly reduced by additional lead as a shield.

In the Oak Ridge Research Reactor (ORR), for a gamma chamber at 50 cm from the core surface, 13% of the total current at steady power was attributed to the fission product gamma rays. Other measurements show that 85% of the fission product gamma-component buildup occurs within 10 min after the fission. As a result, 10 min after a hypothetical step increase from zero to full reactor power, this gamma chamber would reach 98% of its total current at steady power [$0.87 + (0.85 \times 0.13) = 0.98$]. Also, 10 min after a scram of the ORR, after an operating period of two weeks, the measured residual current was 2%. This behavior is perfectly acceptable for safety applications at near reactor rated power, if one compares this error with errors of several hundred percent experienced when using a neutron-sensitive chamber located behind a flooded beam hole.

Different gamma-sensitive active sections were built and tested using the parallel-plate configuration. The two major factors which affect the sensitivity of a gamma chamber are the electrode material and the gas filling. For maximum output of gamma current, the electrodes should be thick and made of a high-density material. Nickel appears to be the most practical material if one considers density, activation cross section and radioactive life, and availability. Calculations and experiments have shown that optimized gamma sensitivity per unit of active-section volume is obtained with nickel electrodes 0.010 in. thick, spaced 0.040 in. apart. By

Table 4. Chamber Gamma Sensitivity as a Function of Different Filling Gases at a Pressure of 1.32 atm

	He	N_2	Ar	Kr	Xe
Gamma sensitivity, (amp-hr/r) $\times 10^{-11}$	0.25	1.23	1.87	3.8	6.9
Gas atomic number, Z	2	14	18	36	54
Gamma sensitivity/Z^a	1.42	1.0	1.18	1.20	1.45

[a]Normalized to 1 for N_2.

comparison, for a given filling gas and gas pressure, this configuration is twice as sensitive as 0.005-in.-thick titanium electrodes also spaced 0.040 in. apart.

Gamma sensitivities as a function of different filling gases are given in Table 4 for an active section consisting of 37 signal and 38 high-voltage nickel electrodes 0.010 in. thick each and spaced 0.040 in. apart. In each case the gas pressure is 1.32 atm. Experimentally, the chamber sensitivity was found to vary linearly with the gas pressure up to 5 atm. Also, the sensitivity is almost proportional to the gas atomic number Z.

4. CONCLUSIONS

To date, nine different models of ionization chambers were designed according to this concept and used in various reactor applications. One particular model is a combination of four individual active sections in the same sensitive volume. Two chamber models are commercially available.

More than 20 chambers have been fabricated and installed in different ORNL reactors.

5. APPENDIX

5.1 Description and Characteristics of Ionization Chambers Built and Tested

In Table 5 two models of ionization chambers are listed: PCP II and PCP III. The PCP III model, an improved version of the earlier PCP II model, retains the PCP II characteristics but is structurally more rugged and can be manufactured at a substantially lower cost.

The gamma and neutron sensitivities in Table 5 are for unperturbed homogeneous neutron and gamma fluxes. The accuracy is ±10%. For chamber application in light-water shieldings, the sensitivities are given on the drawings listed in Sect. 5.2.

5.2 Ionization Chamber Drawings and Procedures

In Table 6 the completed drawings and procedures for fabrication of PCP II ionization chambers, types 104, 105, 106, and 107, and PCP III chambers, types 106 and 109, are listed.

For the other three chamber types (PCP II types 101, 102, and 108), no completed drawings or procedures are available.

Table 5. Description and Characteristics of Ionization Chambers Built and Tested

PCP Model	Type	Section	Type of Section[a]	Gamma Sensitivity (amp-hr/r)	Neutron Sensitivity (amp/*nv*)	Neutron-Sensitive Deposit[b] (mg/cm^2)	Electrode		Gas Filling	
							Material	Thickness (in.)	Gas	Pressure (atm)
				$\times 10^{-12}$	$\times 10^{-15}$					
II	101	1	G	32			Nickel	0.010	N_2	4.0
		2	UN	2.4	5.0	0.25	Titanium	0.005	N_2	4.0
II	102[c]	1	FC	9	72	1.0	Titanium	0.005	99% Ar + 1% N_2	0.79
II	104	1a	UN	2.8	5.3	0.30	Titanium	0.005	N_2	1.32
		1b	UN	2.1	3.1	0.30	Titanium	0.005	N_2	1.32
		2	G	3.6			Titanium	0.005	N_2	1.32
		3	UN	1.4	4.8	0.30	Titanium	0.005	N_2	1.32
II	105	1	G	170			Nickel	0.010	Xe + 3% CO_2	3.0
II	106	1	UN	2.3	5.2	0.35	Nickel	0.005	N_2	1.05
		2	GCN	1.4[d]	4.7	0.35	Nickel	0.005	N_2	1.05
II	107	1	UN	3.2	6.5	0.35	Titanium	0.005	N_2	1.32
		2	UN	2.5	6.6	0.35	Titanium	0.005	N_2	1.32
II	108	1	GCN	1.4[d]	6.0	0.35	Titanium	0.005	N_2	1.05
III	106	1	UN	2.3	5.2	0.35	Titanium	0.005	N_2	1.05
		2	GCN	1.4[d]	4.8	0.35	Titanium	0.005	N_2	1.05
III	109	1a	UN	2.2	5.4	0.35	Titanium	0.005	N_2	1.32
		1b	UN	1.5	3.5	0.35	Titanium	0.005	N_2	1.32
		2	UN	2.0	6.8	0.35	Titanium	0.005	N_2	1.32

[a]Section types are designated as follows: G, gamma sensitive; UN, uncompensated neutron sensitive; FC, fission chamber; and GCN, gamma compensated neutron sensitive.

[b]Except for the PCP II type 102 chamber, all neutron-sensitive sections have a deposit of ^{10}B enriched to 92%. The PCP II type 102 chamber has a deposit of ^{235}U enriched to >99.8%.

[c]For fission counter application, the PCP II type 102 chamber is filled with a mixture of 97% Ar and 3% CO_2 at 3.0 atm. The sensitivity is 0.55 count $neutron^{-1}$ cm^{-2}. For fission chamber application, the residual alpha current is 1.1×10^{-10} amp.

[d]When uncompensated.

Table 6. Titles and Numbers of Drawings and Procedures for Fabrication of Ionization Chambers

Drawing and Procedure Titles	Drawing and Procedure Numbers					
	PCP II Chambers				PCP III Chambers	
	For Type 104	For Type 105	For Type 106	For Type 107	For Type 106	For Type 109
Main Drawings						
Characteristics, Dimensions, and External Wiring	Q-2618-104-1	Q-2618-105-1	Q-2618-106-1	Q-2618-107-1	Q-2633-106-1	Q-2633-109-1
Chamber Housing Assembly	Q-2618-104-2	Q-2618-105-2	Q-2618-106-2	Q-2618-107-2	Q-2633-106-2	Q-2633-109-2
Sensitive Volume Subassembly	Q-2618-104-3	Q-2618-105-3	Q-2618-106-3	Q-2618-107-3	Q-2633-106-3	Q-2633-109-3
Cabling Assembly	Q-2618-104-4	Q-2618-105-4	Q-2618-106-4	Q-2618-107-4	Q-2633-106-4	Q-2633-109-4
Chamber Assembly Detail Drawings						
Casing Subassembly	Q-2618-201	Q-2618-201	Q-2618-201	Q-2618-201	Q-2633-201	Q-2633-201
Shield Can and Plate	Q-2618-202	Q-2618-202	Q-2618-202	Q-2618-202	Q-2633-202	Q-2633-202
Plug Housing and Accessory	Q-2618-203	Q-2618-203	Q-2618-203	Q-2618-203	Q-2633-203	Q-2633-203
Insulator	Q-2618-204	Q-2618-204	Q-2618-204	Q-2618-204	Q-2633-204	Q-2633-204
Core	Q-2618-205	Q-2618-205	Q-2618-205	Q-2618-205	Q-2633-205	Q-2633-205
Miscellaneous	Q-2618-206	Q-2618-206	Q-2618-206	Q-2618-206	Q-2633-206	Q-2633-206
Sensitive Volume Subassembly Detail Drawings						
Base Subassembly	Q-2618-301	Q-2618-301	Q-2618-301	Q-2618-301	Q-2633-301	Q-2633-301
Can	Q-2618-302	Q-2618-302	Q-2618-302	Q-2618-302	Q-2633-302	Q-2633-302
Punched Electrodes and Grounding Tab	Q-2618-303	Q-2618-303	Q-2618-303	Q-2618-303	Q-2633-303	Q-2633-303
Insulator	Q-2618-304	Q-2618-304	Q-2618-304	Q-2618-304	Q-2633-304	Q-2633-304
Tie Rods, Spacers, and Signal Shield Tubing	Q-2618-305	Q-2618-305	Q-2618-305	Q-2618-305	Q-2633-305	Q-2633-305
Cabling Assembly Detail Drawings						
Housing Subassembly	Q-2618-401	Q-2618-401	Q-2618-401	Q-2618-401	Q-2633-401	Q-2633-401
Receptacle	Q-2618-402	Q-2618-402	Q-2618-402	Q-2618-402	Q-2633-402	Q-2633-402
Moisture-Proofing Capsule Subassemblies	Q-2618-403	Q-2618-403	Q-2618-403		Q-2633-403	
Corresponding Procedures:[a] Assembly and Testing Instructions						
For the Chamber Housing Assembly	P-2618-104-2	*b*	P-2618-106-2	P-2618-107-2	P-2633-106-2	P-2633-109-2
For the Sensitive Volume Assembly	*b*	*b*	P-2618-106-3	P-2618-107-3	P-2633-106-3	P-2633-109-3
For the Cabling Assembly and the Assembly of Cabling with the Ionization Chamber	P-2618-104-4	P-2618-105-4	P-2618-106-4	P-2618-107-4	P-2633-106-4	P-2633-109-4

Table 6 (continued)

Drawing and Procedure Titles	Drawing and Procedure Numbers					
	PCP II Chambers				PCP III Chambers	
	For Type 104	For Type 105	For Type 106	For Type 107	For Type 106	For Type 109
Special Procedures and Drawings						
Helium Leak Test Instructions	P-2618-1	P-2618-1	P-2618-1	P-2618-1	P-2633-1	P-2633-1
Electrodes: Punching, Etching, and Coating Instructions	P-2618-2	P-2618-2	P-2618-2	P-2618-2	P-2633-2	P-2633-2
Special Tools and Jigs					Q-2633-501	Q-2633-501
Ionization Chamber Test Geometry					Q-2633-502	Q-2633-502

[a]These procedures correspond to the main drawings; that is, P-2618-104-2 corresponds to drawing Q-2618-104-2, and P-2633-109-4 corresponds to Q-2633-109-4, for example.

[b]Not available.

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