using both the graphite rod and Tesla discharge techniques, were unsuccessful.

Although no direct measurements of the power supplied to the plasma by each generator have yet been made, approximate values were obtained by a load substitution method: the power dissipated in a dummy load, a graphite cylinder of the dimensions required to produce the same load conditions as the plasma itself, was determined by measuring the equilibrium temperature of the graphite load in a slow stream of nitrogen and assuming that the power supplied was equal to the rate of loss of heat by radiation (convection losses are comparatively small). This method has been shown by Reed[9] to give results which agree well with those obtained by using the conventional water-cooled calorimeter. The output from generator No. 2 was about 13 kW with generator No. 1 on (Fig. 2) and 10 kW with generator No. 1 switched off. Similar measurements on generator No. 1 indicated an output power of approximately 7 kW.

There appears to be no reason why still lower frequencies should not be used provided that: (*a*) suitable means of initiation are incorporated, either by the use of a high-frequency pilot plasma as in the present work or possibly by pressure reduction as apparently used by Dymshits; (*b*) the size of the plasma torch is increased.

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RADIOBIOLOGY

Measurement of Polonium-210 in Human Blood

POLONIUM-210 is a naturally occurring alpha-emitting isotope of the uranium series derived from decay of its long-lived parent, lead-210. Polonium-210 is present in most plants and foodstuffs, as well as in human tissues[1–3]. Body burdens of this isotope are usually determined by measuring its activity in tissue samples or urine[2,4,5]. Tissue samples other than teeth are not readily available during life, however, and 24 h urine collections may be difficult to obtain and process, yet are often necessary to quantify urinary excretion. We have found that polonium-210 can be easily detected in 10 ml. human blood samples by a simple radiochemical and counting technique. The measurement of polonium-210 concentration in blood may thus be a practical method of estimating body burdens of this isotope, as well as of its parent lead-210[3]. As tobacco smoke has been shown to contain trace amounts of polonium-210[6], we have related blood concentrations to smoking habits in a group of middle-aged men.

Ten ml. samples of fresh clotted blood were weighed and digested in 30 ml. of hot concentrated hydrochloric acid, placed in plating cells with 0·5 N hydrochloric acid and 50 mg ascorbic acid, and the polonium plated on to silver planchets[4,7]. The planchets were counted for 48–72 h in low background gas-flow proportional counters[7]. Polonium-210 concentrations as low as 0·3 pc./kg blood could be reliably measured by this method. Blood samples were obtained from 100 healthy men between the ages of 45 and 54 years, all of whom resided in one suburb of Boston. Detailed smoking histories were obtained from these men, and they were divided into four groups: current cigarette smokers, current pipe and/or cigar smokers only, past cigarette smokers (had been regular smokers until a year or more previously), and individuals who had never smoked.

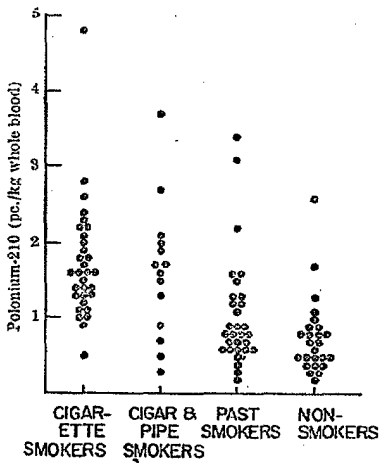

Fig. 1. Polonium-210 concentrations measured in 10 ml. blood samples from 100 healthy men 45–54 years of age

The results are presented in Fig. 1. The average polonium-210 concentration in smokers was 1·72 pc./kg blood, compared with 0·76 pc./kg in non-smokers. Although a significant difference existed between blood concentrations in cigarette smokers and non-smokers ($P < 0.001$), a two to three-fold variation among individuals was present in each group. Such variation has also been observed among polonium-210 concentrations in pulmonary tissues of different individuals[7]. In addition, we have examined other body tissues including liver, spleen, kidney, urinary bladder and bone obtained at autopsy from ten cigarette smokers and four non-smokers. Average concentrations were very similar to those recently reported by Hill[1], but up to a three-fold variation in concentrations in each organ was observed among individuals.

The variation in blood concentrations may in part result from dietary factors. As Hill has pointed out, polonium-210 concentrations differ widely in various foodstuffs; beef and lamb kidney and certain shell fish, for example, may contain relatively large amounts of the isotope[1]. In a preliminary study of possible dietary effects, several blood samples were drawn from an 85 kg subject before and after a meal containing about 100 pc. of polonium-210 (200 g of beef kidney). Blood polonium-210 concentrations were 0·98 pc./kg before the meal and rose to a maximum of 1·56 pc./kg 12 h after the meal, which suggests that a significant fraction of the isotope present in food is absorbed into the blood.

In separate experiments in four heavy cigarette smokers, blood samples were obtained before and at regular intervals after sudden complete cessation of smoking. Blood polonium-210 concentrations fell an average of 27 per cent during the first week after smoking was stopped, but thereafter changed very little during the next 4–8 weeks.

In addition to the polonium-210 normally inhaled and ingested by the general population, it has been estimated that cigarette smokers retain an excess of about 1·5 pc./day per twenty cigarettes, much of which may be cleared from the lungs in the mucous sheet and swallowed[6,7]. The present results indicate that such small differences in chronic environmental exposure to polonium-210 can be detected in 10-ml. blood samples from exposed individuals. The values reported here should serve as a baseline to evaluate concentrations found in blood of individuals possibly exposed to high environmental levels of polonium-210 or its parent isotopes. In preliminary experiments, detectable concentrations of radium were found in 10-ml. blood samples from two normal individuals. Analysis of small blood samples, therefore, may also prove useful in estimating body burdens of alpha-emitting isotopes other than polonium-210.

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Caesium-137 in Edible Freshwater Fish

KNOWLEDGE of radioactivity in fish is largely limited to determinations made of the strontium-90 occurring in certain ocean species and to some attempts at the evaluation of caesium-137 content (^{137}Cs) of the same or similar specimens. Häsänen and Miettinen[1] found concentrations of the order of nanocuries of caesium-137 per kilogram (nc./kg) in freshwater fish. These were taken from lakes in Finland during 1962 and 1963 in the course of an investigation into sources of caesium-137 other than caribou and reindeer meat in the Laplander's diet. This finding could have been predicted from the earlier work of Pendleton and Hanson[2], which demonstrated the rapid accumulation of caesium-137 by various aquatic forms through several trophic levels in a freshwater pond contaminated with caesium-137. Caesium-137 in these organisms was found to reach concentrations several orders of magnitude greater than those found in the surrounding water.

During the first 3 months of 1965, the concentrations of caesium-137 present in freshwater fish available commercially in the Chicago area were similar to those found earlier in Finland (Table 1). The fish (which were purchased at random in local food markets) were boned fillets (except for smelts) and ready to cook. Both the concentration of caesium-137 and of potassium-40 were determined by gamma-ray spectrometry in 1–2-kg samples of fresh fish using conventional low-background techniques. A number of varieties of ocean fish were also examined and showed appreciably lower concentrations of caesium-137 but similar potassium levels (Table 1). This inherent difference between salt and freshwater species as regards the content of caesium-137 had been previously noted by Häsänen and Miettinen[1].

The caesium-137 concentration present in fish depends primarily on three factors: (1) the concentration of the radionuclide in the water environment; (2) the accompanying level of potassium (ratio of caesium-137: potassium); (3) the position of the fish in question in the aquatic food chain (that is, the trophic level). Published values of caesium-137 in salt and freshwater are sparse. However, monthly measurements in Lake Huron showed average concentrations of 0·4 and 0·3 pc./l. during 1963 and 1964, respectively[3]. During this same interval the concentration in lakes and rivers in the vicinity of Chalk River, Ontario (presumably uncontaminated by reactor wastes), was three to four times greater than that in Lake Huron[3]. Surface waters of the Pacific Ocean sampled in mid-1963 indicated an average level of 0·6 pc. caesium-137/l. (ref. 4). Profiles of caesium-137 activity in ocean water have shown decreasing concentration with depth[5]. Judging by the limited data available, there did not appear to be appreciable differences between the concentration of caesium-137 in salt and freshwater. However, the possibility exists that closed lakes which do not possess large dilution capacity may contain higher levels of caesium-137 because they collect the run-off from large areas. Conversely, because of the large dilution effect possible in the oceans, the effective concentrations may be much lower than that observed in surface waters.

The potassium content of the oceans is ten to several hundred times greater than of freshwater. The value in the oceans, based on a large number of analyses, is fairly constant, and is given as 380 parts per million (p.p.m.)[6]. The few measurements taken in the Great Lakes show values of a few p.p.m., with smaller lakes and rivers in the area containing somewhat higher amounts[7]. Amounts in closed lakes in this region and further north are an order of magnitude higher, with values approaching marine concentration in some instances[7]. The concentrations of rubidium and stable caesium are several orders lower than that of potassium in both salt and freshwater and are almost insignificant[6,7].

The greater concentration of caesium-137 in freshwater fish, seen in Table 1, probably reflects, in the first place, the higher caesium-137 : potassium ratio present in freshwater[8]. The trophic level is also a factor—as shown by the higher caesium-137 concentration in carnivorous fish as opposed to plankton feeders and other non-carnivorous fish, in both salt and freshwater. The lower concentrations in lake perch and smelt may also result from younger age at capture as well as different feeding habits.

The question now arises as to what effect the presence of relatively high concentrations of caesium-137 in freshwater fish may have on the average intake by human beings

Table 1. CAESIUM-137 AND POTASSIUM IN SALT AND FRESHWATER FISH PURCHASED BETWEEN JANUARY AND APRIL 1965

Species*	Feeding habits	^{137}Cs (pc./kg wet weight)	Potassium (g/kg wet weight)	^{137}Cs pc./g K
		Freshwater fish		
Lake trout	Carnivorous†	2,210	2·49	887
,,	,,	3,374	3·50	1,107
,,	,,	2,923	2·90	1,008
Pike	,,	2,610	3·58	729
,,	,,	1,428	3·25	439
,,	,,	1,167	2·47	472
Whitefish	Plankton	1,316	3·57	369
,,	,,	328	3·51	93
,,	,,	265	3·65	73
Lake perch	,,	365	2·89	126
,,	,,	330	2·96	111
Smelts	,,	327	2·69	126
,,	,,	377	3·17	119
		Marine fish		
Flounder	Bottom feeder, molluscs, etc.	24	2·88	8·3
Halibut	Carnivorous	62	5·26	11·8
Ocean perch	Plankton, annelids	32	3·08	10·4
,, ,,	,, ,,	56	3·11	18·0
Ocean catfish	Carnivorous	43	4·04	10·6
Haddock	,,	66	4·02	16·4
Salmon	,,	71	3·51	20·2
Cod	,,	43	4·17	10·3
Red snapper	,,	12	1·76	6·8

* The common or commercial names of fish are used here instead of taxonomic names because of the difficulty in determining the latter with any precision with frozen, dressed fish.
† 'Carnivorous' is meant to imply feeding on fish and other animals smaller than the fish in question.