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RADIATION SAFETY*

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RADIATION SAFETY

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Since soon after the discovery of x-rays, attention has been given to radiation safety. However, the Manhattan Engineering District or A-bomb project gave a far broader scope and meaning to the problem of radiation safety and produced a new field, *Health Physics*. The last thirty-five years have continued to produce new problems to solve in radiation safety, and the health physicist has contributed to their solution.

What is the fundamental theme of radiation protection? It would be easy if we could say simply that it is to protect people from radiation, i.e., make them completely safe, especially if we could either turn off all sources of radiation or totally shield people from them. It is not simple because either implicitly or explicitly, the health physicist long ago realized that: (a) all radiation cannot be turned off or shielded, and (b) there are marked advantages of many types to be gained from the use of radiation or radiation emitting materials. Consequently, the principle of "cost vs benefit" came into use, i.e., the harmful effects vs. the good effects, with the principle implying that the good must equal or exceed the harm. Further, the natural radiation environment in which we evolved is readily measurable and still contributes more total dose to humans and their environment than all that associated with human endeavors. Consequently, all policies regarding protection against risk from radiation must incorporate a cognizance of the natural radiation environment though they have not been based on that cognizance. Figure 1 is a reminder of the relative magnitude of several sources of radiation.

Existing guides for radiation protection were formulated largely on the basis of tumor induction in the bone of radium dial painters, but the ICRP/NCRP annual dose guides of 5 rem/yr are of the same general magnitude as the doses received in several parts of the world from the natural radiation environment. Because of the greater sensitivity of rapidly dividing cells and the assumption that radiation occupations would not begin before the age of eighteen, we were given the further guidance of 5 (N-18) rem/yr, where N is the exposed worker's age in years. However, in the case of the natural radiation environment, exposure commences, in a sense, with the exposure of the ovum of the individual's mother; and the ovum is formed during the fetal development of the mother. Therefore, a thirty year old person whose mother was age thirty at his/her birth has received sixty years of gonadal exposure to the natural radiation environment. Of course, in occupational exposures, the professional health physicist has always practiced the "as low as practical" philosophy; and exposures have generally averaged far below the guidelines. The average annual exposure of the radiation worker in modern plants and laboratories is approximately equal to the average natural radiation environment exposure rate and far lower than the natural radiation environment in many parts of the world; e.g., figure 2 shows annual exposure levels at Oak Ridge National Laboratory and figure 3 shows some of the high radiation areas of the world and the approximate number of people exposed in each area. Though this has not figured in standards setting, it must be kept in mind in considering cost/benefit criteria for radiation protection purposes.

Another major factor in radiation protection guides must be the effect of radiation as a function of dose; e.g., is the relationship linear so that the person-rem concept is valid or are there thresholds for some effects? There is considerable data to prove that the relationship can be linear, threshold, or curvilinear, depending on many factors, especially the biological end-point. Data for the survivors of the bombings of Hiroshima and Nagasaki appear to show a linear increase in probability of leukemia with increasing dose for neutrons and possibly the same holds for gamma rays if only chronic leukemia is considered (Fig. 4), but with lower slope. Other effects are certainly threshold in nature with strong dose-rate dependence being evident, e.g., erythema due to x-rays. It is clear that for some effects, repair mechanisms dominate at low dose rates, especially for low L.E.T. radiations, though some effects do not show repair for high L.E.T. radiations. Cataracts, for example, can be caused by neutron exposure at low levels but over long time periods, e.g., a few rads/week over a period of a few years. Gamma ray exposures at these rates appear to be repairable to such a degree that radiation cataracts have not been observed for chronic exposures of any level. This is an example of the differing biological effects of the same doses and/or dose rates with different types of radiation.

There are numerous similar complications and uncertainties in quantifying radiation effects on humans. However, of all the uncertainties, the greatest is that due to having to extrapolate from high dose levels at which effects have been measured and quantified, to low levels at which most exposures occur but at which no effects have been observed.

Therefore, the big problems in radiation protection generally reduce to one factor: application of the cost/benefit concept without precise knowledge of the biological effects (costs) and, sometimes, without an accurate measure of the benefits. Of course, if the benefits are not sufficiently clear, the radiation protectionist has, traditionally, attempted to prevent the operation considered.

The foregoing is based on the assumption that the managers of radiation related operations are fully supportive of safety and concomitant health physics practices. In fact, most are supportive, but some are not. The current regulatory climate is such that most organizations are forced to maintain some acceptable level of supportiveness.

Therefore, assuming that the national and international standards setting bodies have all taken appropriate account of all factors and that their exposure guidelines are worth enforcing, the health physicist can feel comfortable that he or she is protecting people if exposures are kept within the guidelines. How is this done? Let us look at some of the things done at ORNL, which is typical in this sense, to accomplish radiation protection.

Figure 5 shows a radiation surveyor checking a loaded shipping container for radiation leakage and/or contamination. Figure 6 shows barracades and signs warning of exposure potential in a radiation area.

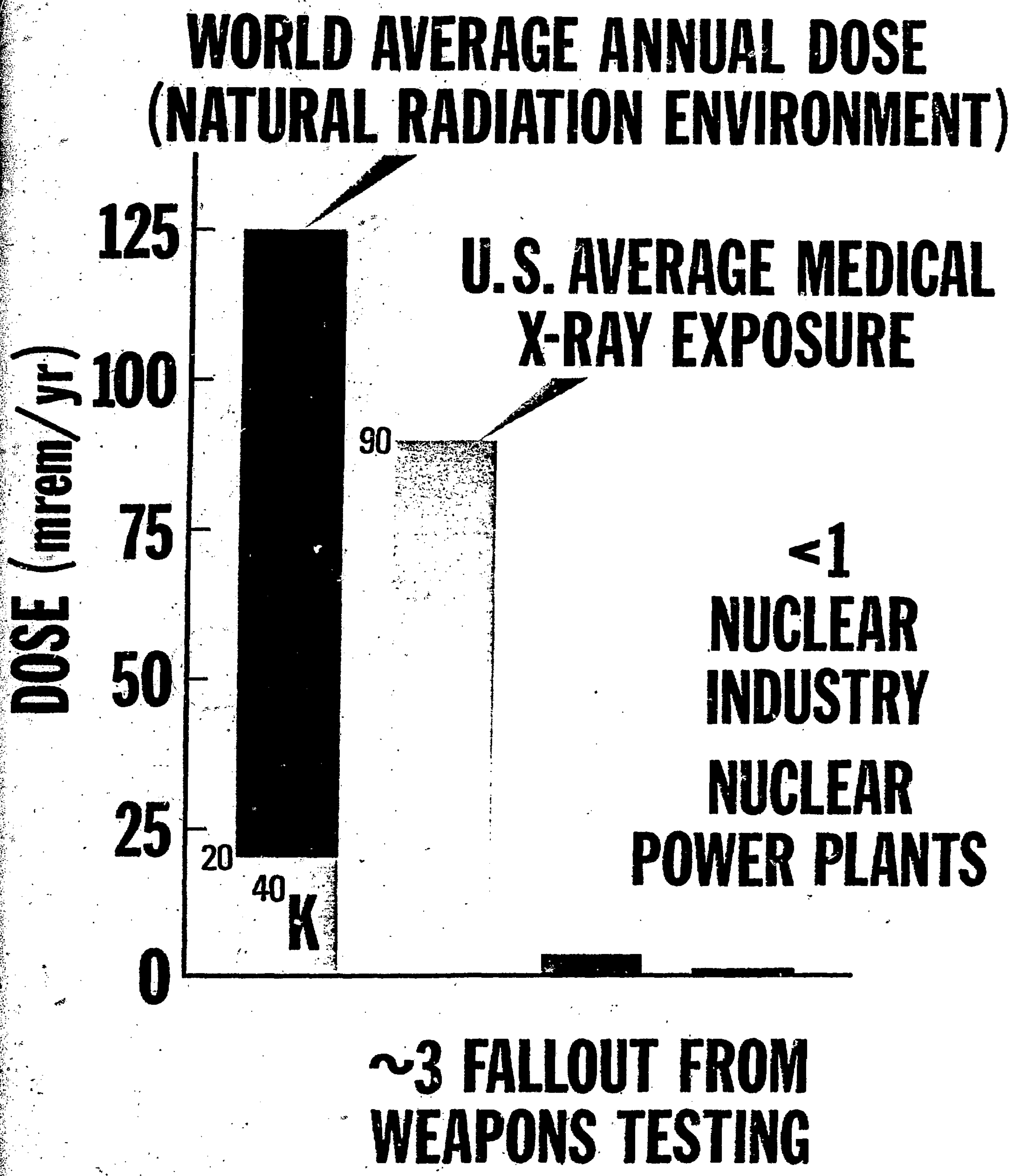
A large part of the health physicist's duty is monitoring, i.e., looking for radiation sources and contamination to which people get exposed. Some types of monitoring involve badging or metering people who will work in radiation fields. Hence the badge system pictured in Fig. 7. Other examples include: checking clothing worn by workers for contamination prior to laundering (Fig. 8); sampling water leaving a potentially contaminated area (Fig. 9); in some instances, checking the fish that live in potentially contaminated waters (Fig. 10); checking sample vegation and soil for contamination that might get in the food chain and hence to man (Fig. 11); sampling for unusual sources of contamination; checking insects that have hatched in potentially contaminated water or entered contaminated zones (Fig. 12); or, more commonplace (Fig. 13), just checking x-ray diffraction units to ascertain that shielding is still appropriate. Microwave ovens must be checked (Fig. 14) for leakage radiation. As indicated in figure 15, there is always a lot of bench work to be done, in this case, the counting of samples for radioactivity..

The next figure (Fig. 16) shows the whole body counter, or in vivo counter, in use, i.e., a man being checked for internal contamination that is incorporated into his body, for example, by inhalation.

Any good professional, of course, must strive to improve. In the case of the health physicist, it is important that his/her activities include some research. Figure 17 displays new types of detectors placed on an anthropomorphic phantom being evaluated at the Health Physics Research Reactor. Figure 18 shows a mock up of the mathematical model of a human used in internal dose studies.

Though it is beyond the scope of this paper, research related to radiation protection ranges from the simplest engineering applications to fundamental studies in the disciplinary sciences.

The practice of health physics is relatively new, is improving steadily with time, and is generally much more quantitative than other safety related fields. There has been a concerted emphasis on lowest practical exposures and cost/benefit analyses. However, due partly to the diligent efforts of the health physicist, there are no data which show adverse effects on people due to occupational exposure, hence calculated risks at low levels are based entirely on extrapolation from much higher doses. Let us hope that this condition is maintained.


WORLD AVERAGE ANNUAL DOSE
(NATURAL RADIATION ENVIRONMENT)
U.S. AVERAGE MEDICAL
X-RAY EXPOSURE
DOSE (mrem/yr)
125
100
75
50
25
0
90
20
40K
<1
NUCLEAR
INDUSTRY
NUCLEAR
POWER PLANTS
~3 FALLOUT FROM
WEAPONS TESTING

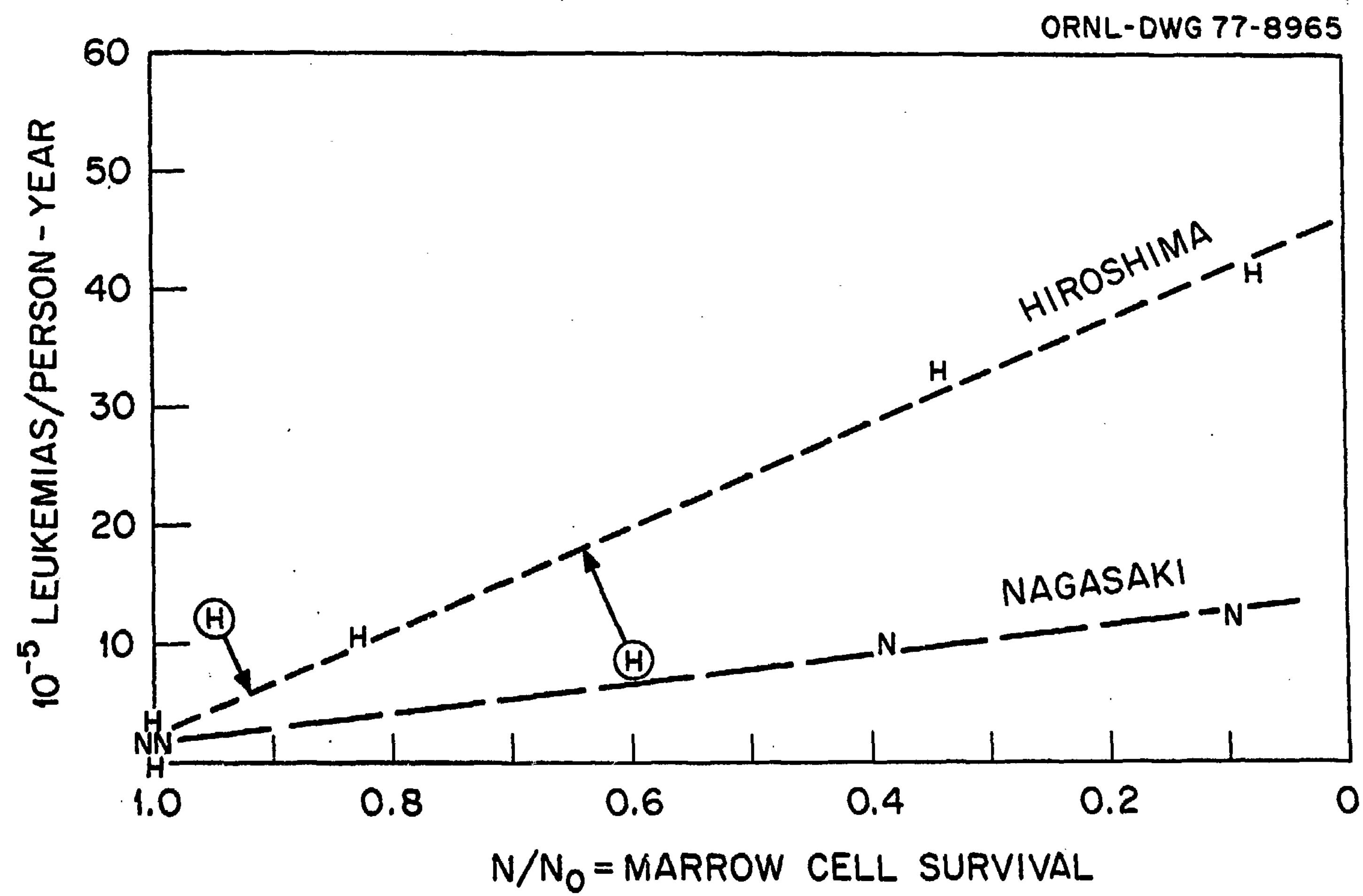
ORNL-DWG 76-16433

DOSE DATA SUMMARY FOR LABORATORY POPULATION INVOLVING EXPOSURE TO WHOLE BODY RADIATION—1975

Group	Number of Rem Doses in Each Range							Total
	0-0.1	0.1-1	1-2	2-3	3-4	4-5	5 up	
ORNL Employees	4906	465	58	[illegible]	0	0	0	5442
ORNL-Monitored Non-Employees	19	17	0	0	0	0	0	
TOTAL	4997	482	58	13	0	0	0	5550

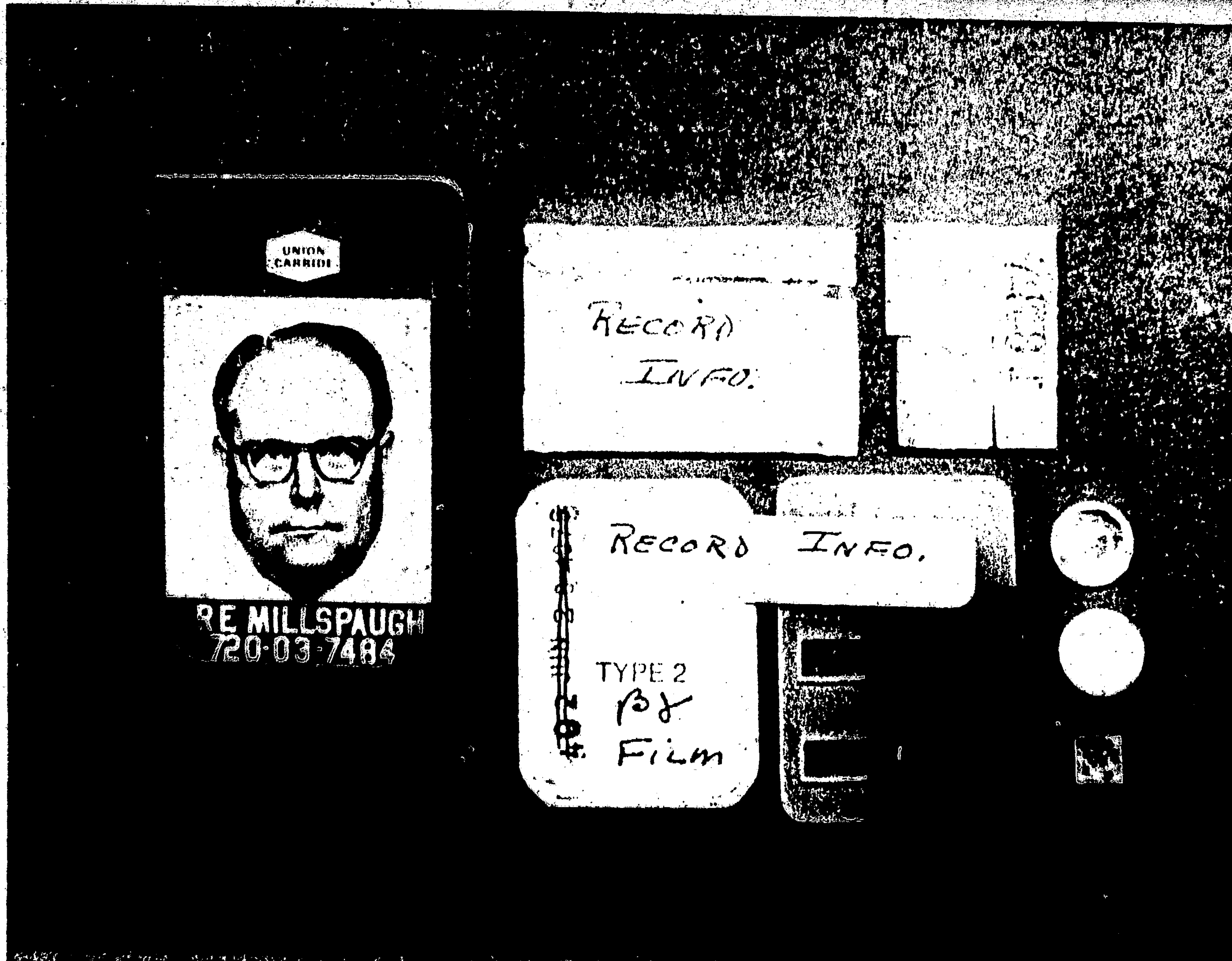
ORNL-DWG 75-5438

AREAS	DOSE RATE, RANGE AND ESTIMATED AVERAGE	EXPOSED POPULATION (ROUGH ESTIMATE)
Mountain cities		
Denver, Quito, La Paz, Bogota	150-330 mrem/year; avg. ∿ 225	2,000,000
Central France	180-350; avg. ∿ 200	7,000,000
Egypt		
Monazite Sands areas	200-475; avg.∿ 200	7,000
All Egypt	avg.∿ 160	40,000,000
Brazil		
Rio de Janeiro Beach areas	550-1,250; avg.∿ 600	50,000
Minas Gerias	1,700-12,000; avg.∿ 2,000	600
Ceylon Granite areas	3,000-7,000; avg. ∿ 3,000	1,000
All Ceylon	avg. ∿ 280	10,000,000
Niue Island (Pacific Ocean)	1,000-2,000; avg. ∿ 1,000	6,000
Kerala, India	avg. ∿ 1,500	100,000
World	100-200; avg. ∿ 125	5.5×10^9



Incidence of Chronic Leukemia in A-Bomb Survivors (BEIR)


NOTICE
NO FOOD/DRINK
SAFETY GLASSES
MUST BE WORN
IN THIS AREA
DO NOT
ENTER


UNION CARBIDE
RE MILLSPAUGH
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RECORD INFO.
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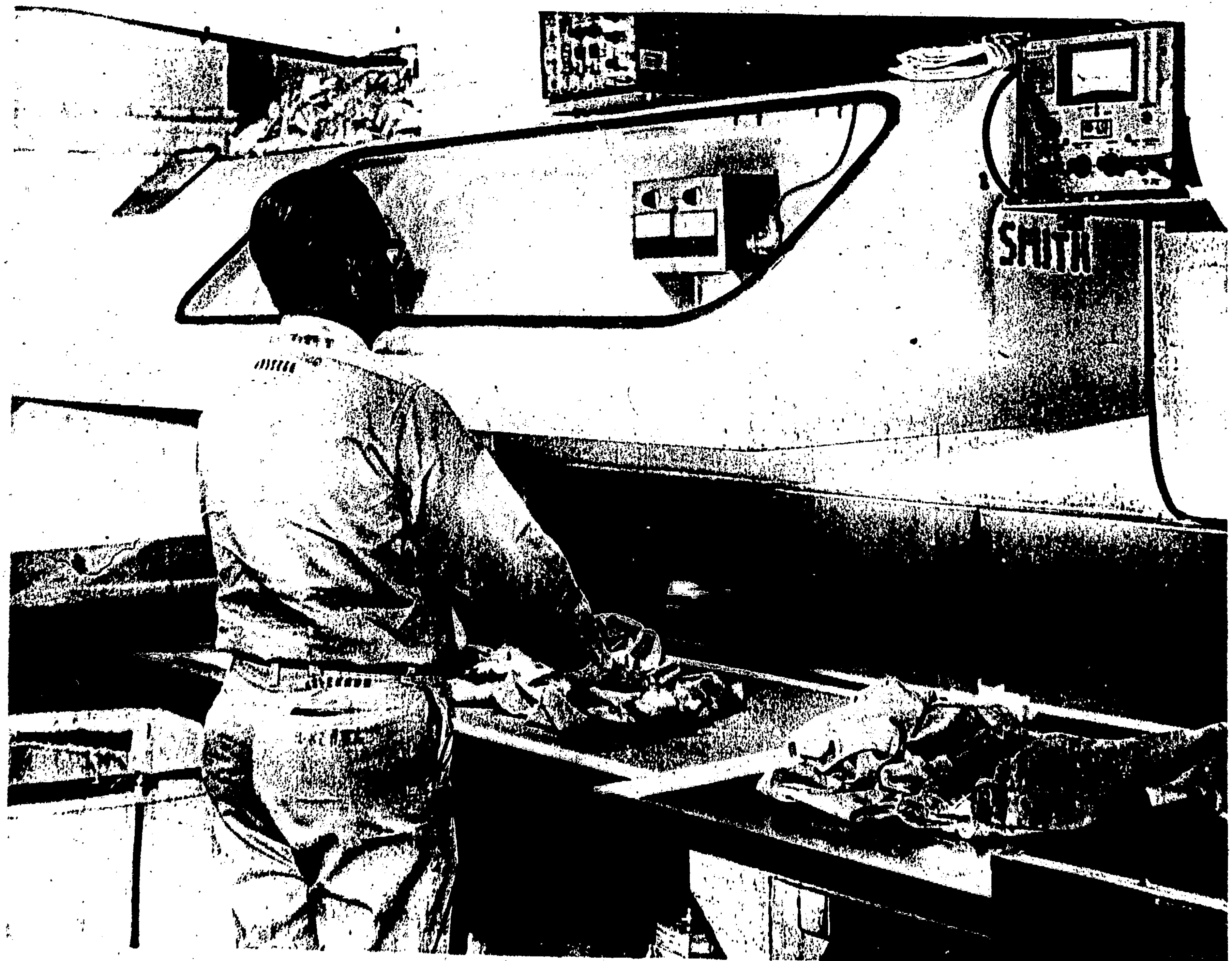
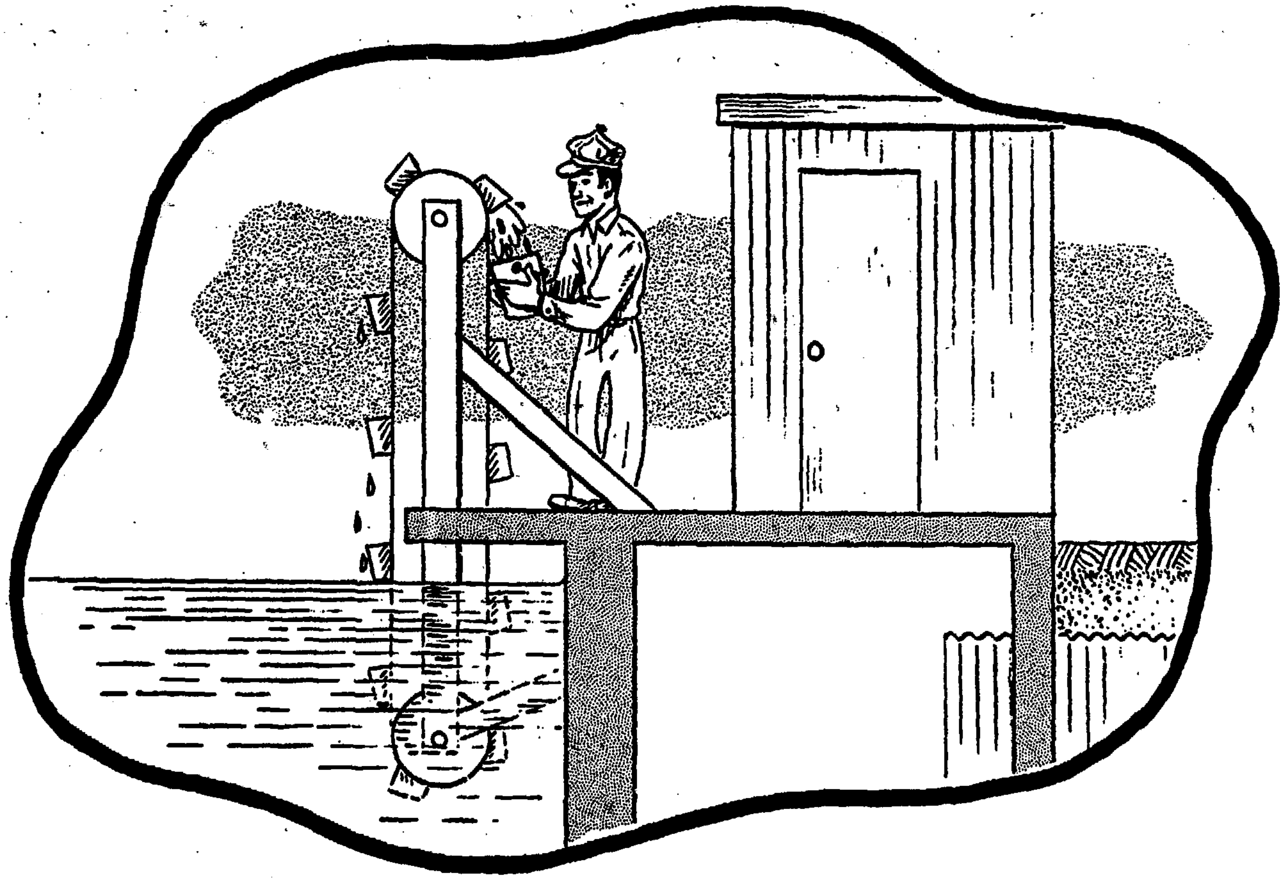
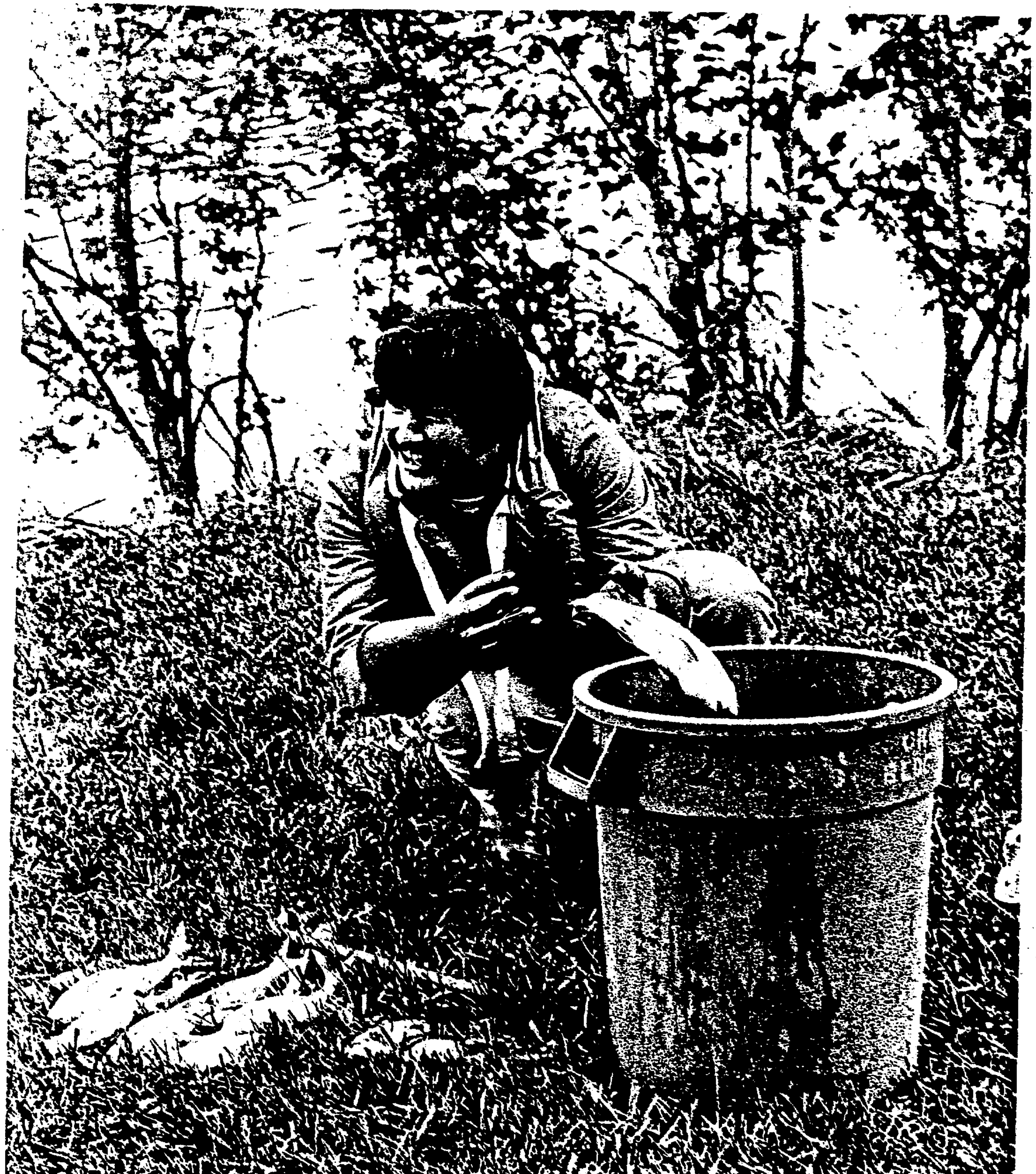
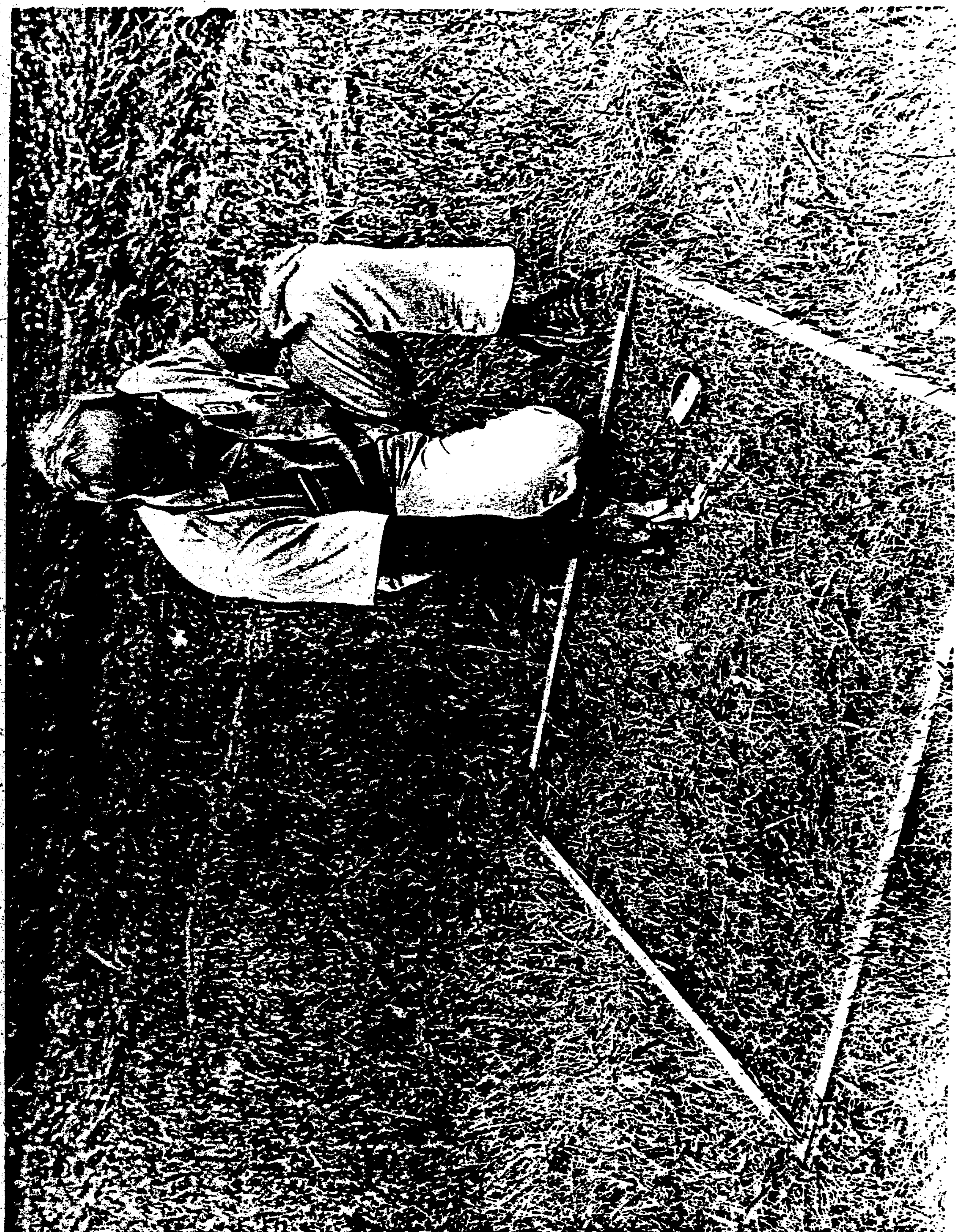
TYPE 2
BY
FILM


SMITH

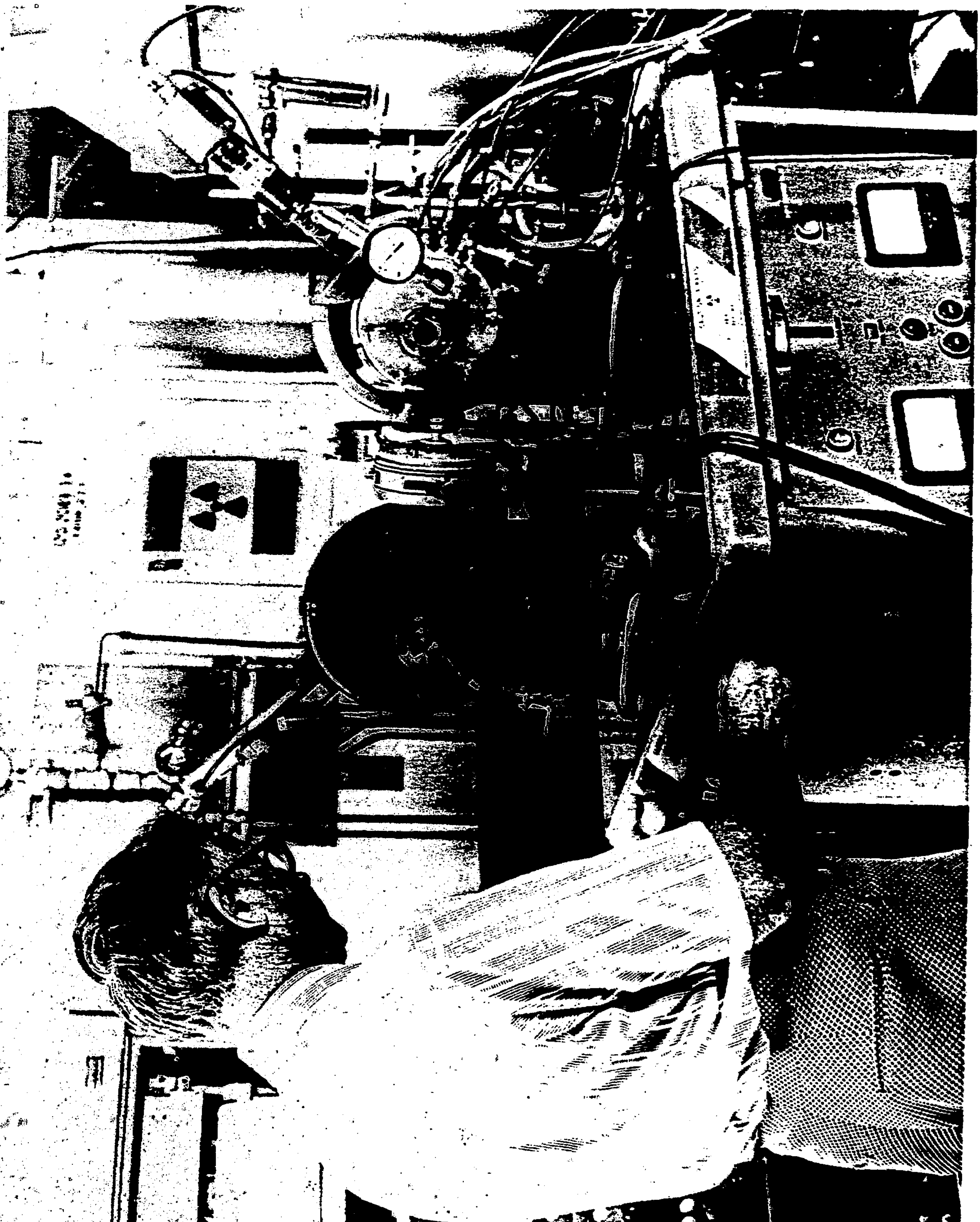
WATER SAMPLER

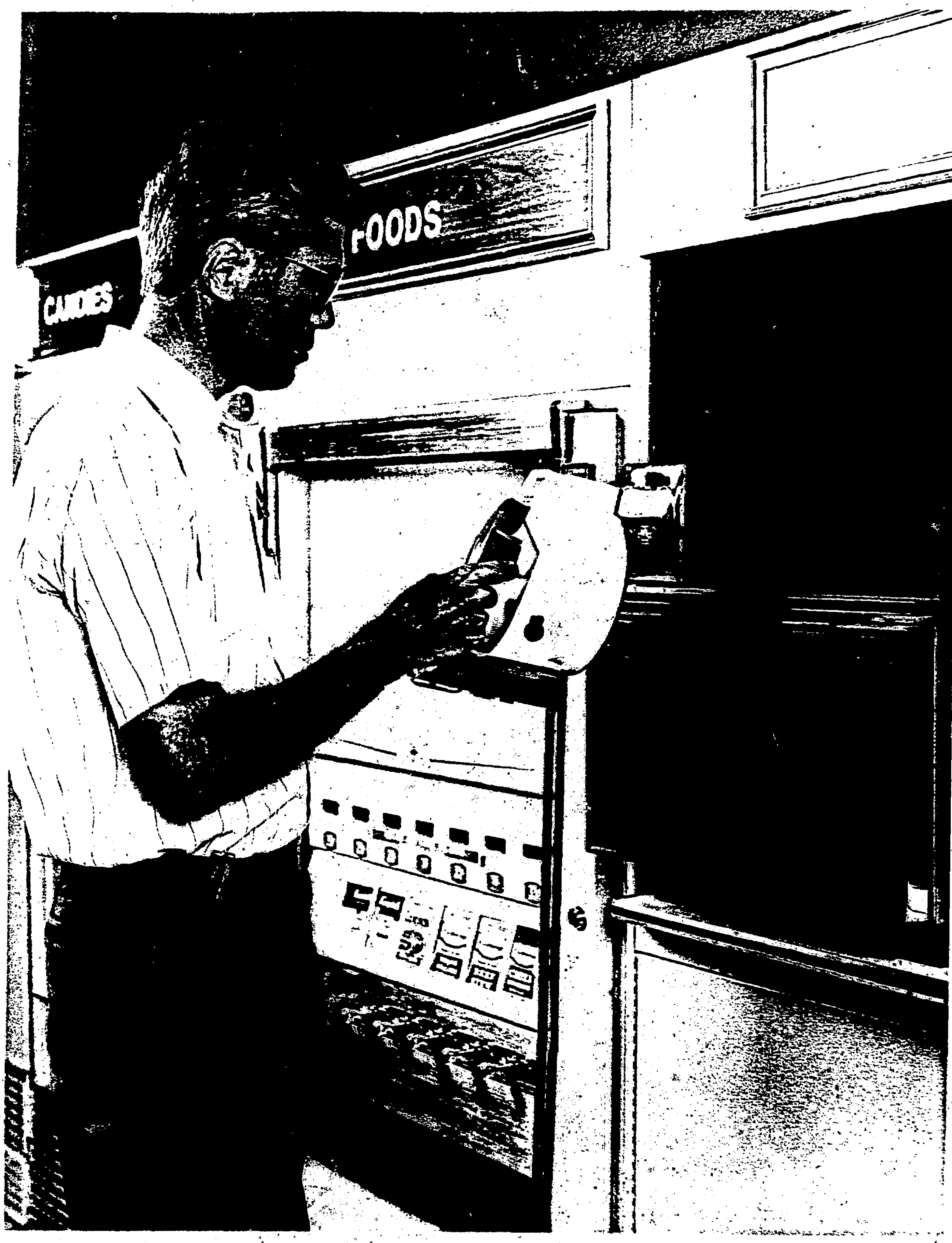


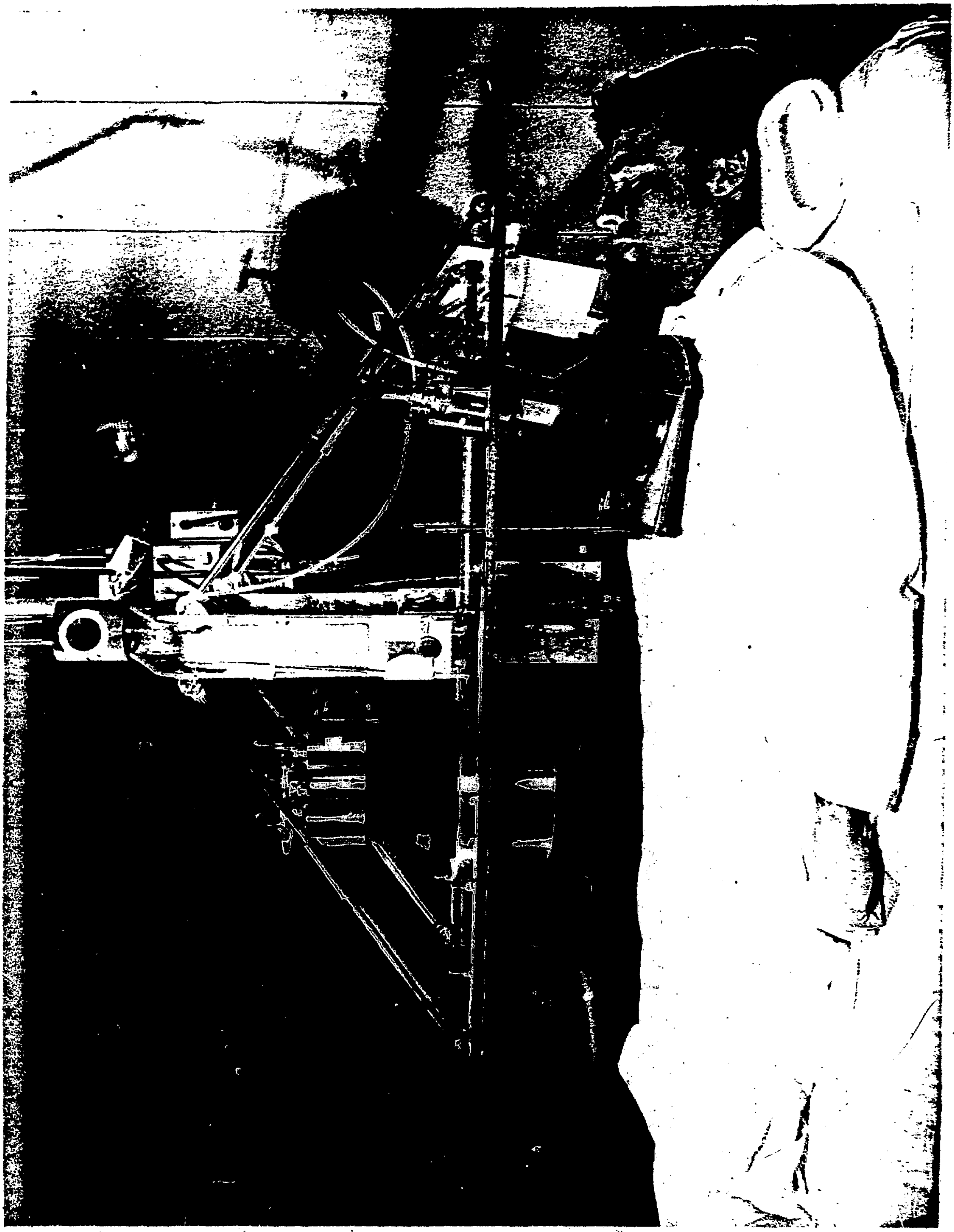


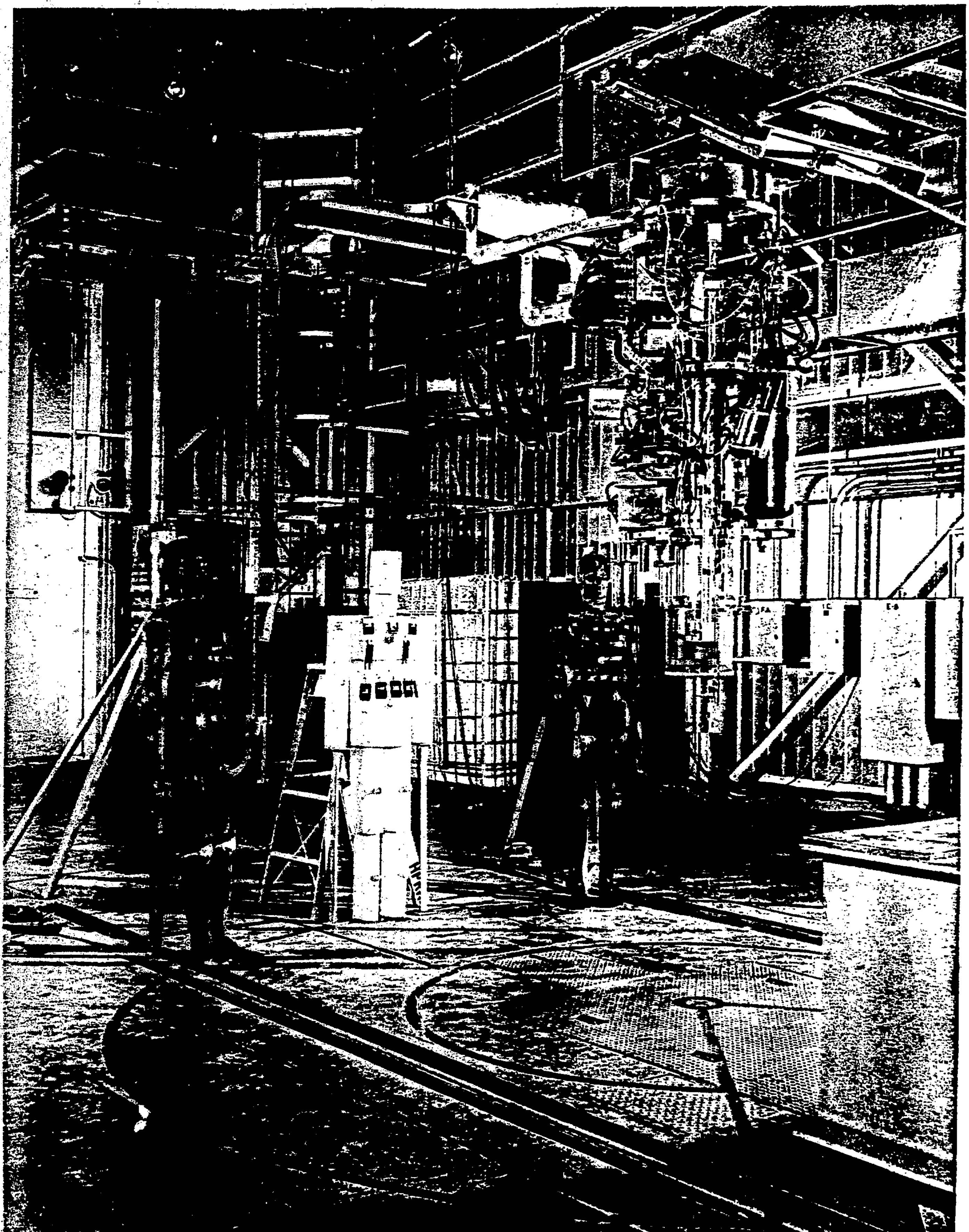



HEALTH PHYSICS
LOCAL AIR MONITOR
STATION NO 5




CANDIES
FOODS





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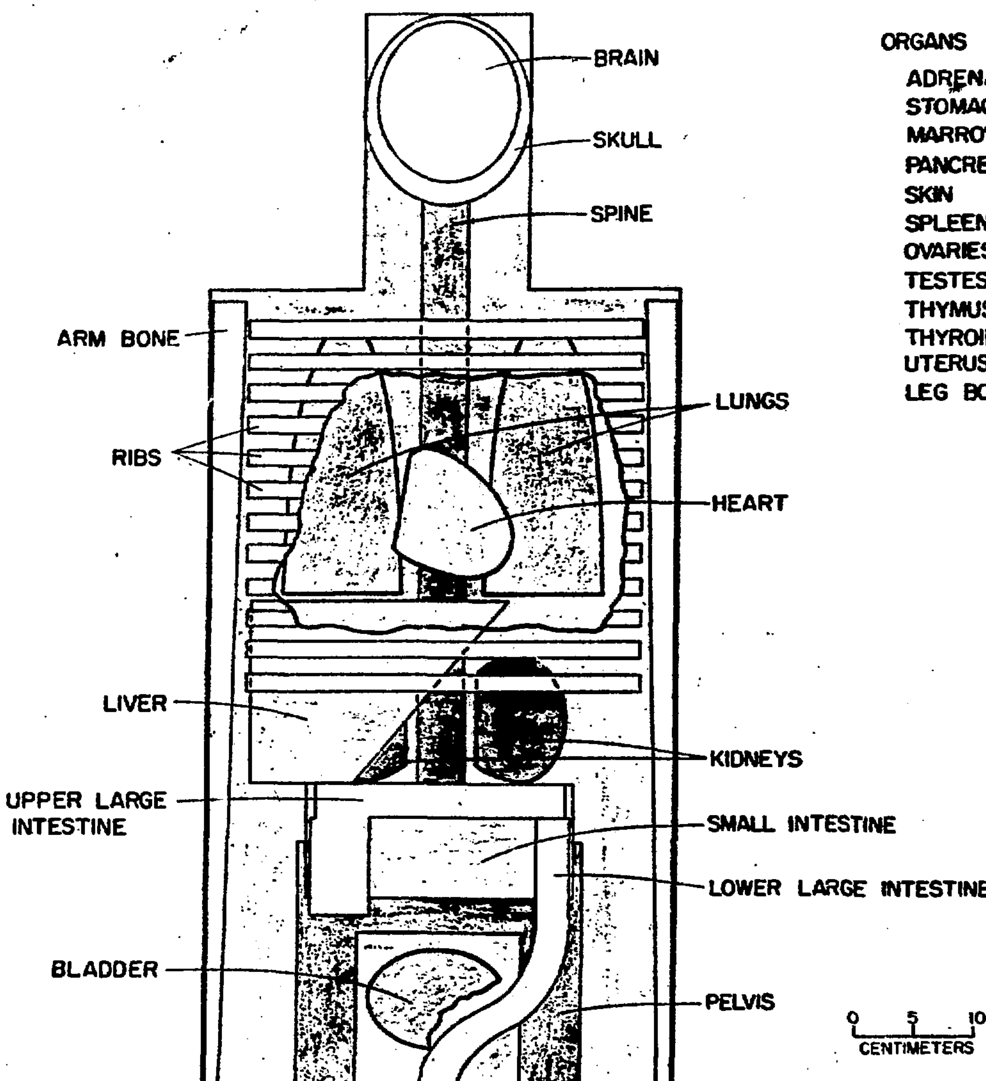
ANTERIOR VIEW OF THE PRINCIPAL ORGANS IN THE HEAD AND TRUNK OF THE PHANTOM



ORGANS NOT SHOWN

ADRENALS
STOMACH
MARROW
PANCREAS
SKIN
SPLEEN
OVARIES
TESTES
THYMUS
THYROID
UTERUS
LEG BONES