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UNITED STATES OF AMERICA

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NUCLEAR REGULATORY COMMISSION

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INCIDENT INVESTIGATION TEAM

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INTERVIEW OF ROBERT K. BURGESS

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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WEDNESDAY, OCTOBER 18, 1995

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3:15 P.M.

INTERVIEWERS:

SAM SHERBINI

ALAN L. MADISON

THOMAS O'CONNELL

ADDENDUM

Page	Line	Correction and Reason for Correction
9	13	720 VOLTS NOT 107 OR 120 VOLTS
13	25	Him instead of them

Page ____ Date 10/24/95 Signature Robert K. Burgess

P-R-O-C-E-E-D-I-N-G-S

3:15 P.M.

MR. SHERBINI: Okay. Are we on the record? Okay. This is an interview with Mr. Bob Burgess. The time is about 3:15.

Bob, I'll just go quickly, explain to you what we are doing here. We are an investigation team from the NRC. We are here to try and determine what happened with Dr. Li's contamination, trying to figure out how it happened, the causes, and try and see if there are any lessons to be learned from this so we can use it to prevent future occurrences anywhere else.

The reason for interviewing you is to find out from you first hand as much as you can tell us what actually went on with -- (indiscernible) -- and at what time it happened and so forth. We understand that you were directly involved at some point in the occurrences in connection with this incident.

MR. BURGESS: Yes.

MR. SHERBINI: Or at least some aspect of the incident.

MR. BURGESS: Yes.

MR. SHERBINI: So we'd like to know from you. The interview is being transcribed. The transcript will eventually be made public. In other words, anybody who

wants to read it can read it. So I just thought I'd let you know. At some point you will get a copy of the transcript and you'll have a chance to review it.

MR. MADISON: We can be specific on that. Within 24 hours, the transcript will be made available to you to review.

MR. BURGESS: Fine.

MR. MADISON: You can make an appointment. We'll give you a number at the close of the interview of who you can contact so that you can review the transcript. At that time, you can if you see that there's a mistake that was made or you find something you think needs clarifying, there will be an addenda sheet that you can make that clarification or that correction on. That also becomes part of the transcript.

MR. BURGESS: Okay.

MR. MADISON: The main purposes of this is so that we get the facts and not what our memories tell us, but what was actually said during the interview.

MR. BURGESS: All right.

MR. SHERBINI: Okay. Having said that, I don't think any of us here is familiar with how you -- what your role was in this. So if you'll give us some --

MR. MADISON: We need to identify everybody that's here.

MR. SHERBINI: Oh. I'm sorry.

MR. MADISON: Before we get started.

MR. SHERBINI: For the record, my name is Sami Sherbini with the NRC. If everyone identifies themselves.

MR. O'CONNELL: Tom O'Connell. I'm with the Commonwealth of Massachusetts, Radiation Control Program.

MR. MADISON: I'm Alan Madison. I'm with the NRC AEOD.

MR. BURGESS: I'm Bob Burgess. I work at MIT in the Radiation Protection Office.

MR. SHERBINI: What is your position, Bob?

MR. BURGESS: I am presently the counting room technician in this department. I do whole body counting, liquid scintillation counting, beta gamma counting, gamma spectroscopy, pretty much anything that's being in our counting room.

How I was involved, what my involvement is in this particular investigation is that I did whole body counting on Dr. Li.

MR. SHERBINI: Could you tell us when the first time was and so forth?

MR. BURGESS: As far as a date goes, it has to be that Monday following the incident.

MR. MADISON: Can you give us a date?

MR. BURGESS: I'd have to look at the counting

sheet.

MR. MADISON: Would the 21st of August be --

MR. BURGESS: That would be probably, if that's the Monday, that would be probably.

MR. SHERBINI: About what time?

MR. BURGESS: I believe it was in the afternoon, if I'm not mistaken. Subsequently after that, it was like on a daily basis I was counting him.

MR. SHERBINI: After that Monday, it was every day?

MR. BURGESS: Yes. Every day, yes, for a period of about three weeks. It was generally in the morning that this count was taken. You try to keep it about the same time during the day, usually in the morning just before lunch.

Also we have a P-32 standard that I was counting. I was also counting that daily just following it, just to make sure the equipment was operating, functioning properly at the time.

MR. SHERBINI: So I guess you also calibrate the equipment in the lab?

MR. BURGESS: Yes.

MR. SHERBINI: The P-32 standard, could you tell us, is that a standard you maintain in the lab?

MR. BURGESS: This standard was prepared

following this incident, so that we'd have some basis. You'd have an idea of the calibration of the instrument itself, make sure what the counting was.

MR. SHERBINI: Could you tell us what the standard is like? What kind of standard?

MR. BURGESS: It consists of three sections. Each section, we have a thigh section where there are two containers in this with --

MR. SHERBINI: Two cylinders.

MR. BURGESS: Two cylinders, right, bottles with a specific amount of activity in each.

There are two kidney in the trunk part of it. GI tract, and there's one more.

MR. SHERBINI: That's okay. We can get the details later.

MR. BURGESS: And then there's the lung section, but we didn't have any of those that were clean. We didn't have anything in the lung section. Just in the trunk and the thighs. We'd count that for the same amount of time we counted Dr. Li's.

MR. SHERBINI: How did you prepare the standard?

MR. BURGESS: Mitch Galanek made up the standards. He prepared everything, just put them in for me. Actually he was actually counted the first time when

he made it up. Then I followed it after that. He said count it in the morning just to follow the decay.

MR. SHERBINI: So just to make sure we understand, the phantom is liquid filled or does it have source implants?

MR. BURGESS: No. It's liquid filled.

MR. SHERBINI: Liquid filled.

MR. BURGESS: Yes.

MR. SHERBINI: And the activity is uniformly distributed throughout all the sections?

MR. BURGESS: Yes. Yes.

MR. SHERBINI: What's the concentration of P-32 in your standard?

MR. BURGESS: In the standard we have in it a total of about 109 microcuries. It's divided up. There's about, the kidneys I think had 14 microcurie each. I'm just trying to remember what they were.

MR. SHERBINI: That's okay. We can get that number.

Is that the first time that P-32 phantom was used here on site?

MR. BURGESS: That I've used, yes. There may have been previously, but I don't remember.

MR. SHERBINI: Previously meaning how many years?

MR. BURGESS: Thirty years.

MR. SHERBINI: Oh, before 30 years?

MR. BURGESS: Yes.

MR. SHERBINI: So you were here for 30 years?

MR. BURGESS: Yes.

MR. SHERBINI: So from 30 years on.

MR. BURGESS: Yes. I'd say it's possible there has been P-32 counted, but this is previous to my being in the counting as much as -- at one time I was the survey technician. There were other people running the counting room, so I wasn't involved like I am now.

MR. MADISON: How long have you been running the counting room?

MR. BURGESS: Maybe six or seven years. I have been in and out. Even while I was survey technician, I'd go in there and do my own sample sometimes and count them, things like that. I was always involved in one way or another.

MR. SHERBINI: Now, when you calibrate the phantom, what does the calibration factors look like? I mean how do you relate the calibration with the counting say of Dr. Li to determine his activity? Is there some formula or some --

MR. BURGESS: That was being done by the staff members here. I was just giving them numbers.

MR. SHERBINI: What numbers do you give them?

MR. BURGESS: Usually the total count for the channels that we counted and the time it was taken, that it was done.

MR. SHERBINI: What are the detectors on this sodium iodide?

MR. BURGESS: Three inch sodium iodide, three by three crystal.

MR. SHERBINI: Do you have settings? It's a multi-channel?

MR. BURGESS: Yes. It's multi-channel. I couldn't give you right off the top of my head of what the settings were. But high voltage is about 107, 120 volts.

MR. SHERBINI: How many channels do you have?

MR. BURGESS: We used 2,000.

MR. SHERBINI: Two thousand?

MR. BURGESS: Yes. On this we'd taken and used up the first half.

MR. SHERBINI: Is that used for jelly or something else as well?

MR. BURGESS: No. Not this one. We do have a jelly, but that's a different set-up for that.

MR. SHERBINI: So you use the 2,000 channels on the sodium iodide.

MR. BURGESS: On the sodium iodide, yes.

MR. SHERBINI: And you take all the counts and put it in the calibration?

MR. BURGESS: Yes.

MR. SHERBINI: How about background?

MR. BURGESS: That was taken out after. The counts I gave them was --

MR. SHERBINI: Corrected.

MR. BURGESS: No. Everything was the total counts, including background. Then you subtract the background out afterwards.

MR. SHERBINI: How long do you count for background?

MR. BURGESS: We were counting when we did this one, we just took 10 minutes, the same as what we counted when we were counting Dr. Li's.

MR. SHERBINI: Ten minutes?

MR. BURGESS: Yes.

MR. SHERBINI: And the background?

MR. BURGESS: That's for 10 minutes too.

MR. SHERBINI: Also?

MR. BURGESS: Yes.

MR. SHERBINI: Is there some or has any of the staff determined roughly how good the activity estimate is using this method? In other words, is it good to within a factor of two, within a factor of --

MR. BURGESS: That, they have not informed me of.

MR. SHERBINI: To your knowledge, is there any kind of estimate on how uncertain this is?

MR. BURGESS: No. They haven't told me that. I give them the numbers and then they -- apparently they -- I don't know. What I'm saying now is that my understanding is that they pretty much are the same as what they get using the urine sample methods.

MR. MADISON: Maybe we can answer some of your questions by talking about Bob's background, training, what his job duties and functions are.

MR. SHERBINI: Sure. I guess, Bob, also you also do the liquid scintillation counting?

MR. BURGESS: Yes.

MR. SHERBINI: I suppose, did you count his urine as well?

MR. BURGESS: No. I didn't.

MR. SHERBINI: Who?

MR. BURGESS: Either Don Haes or Mitch Galanek.

MR. SHERBINI: In your lab?

MR. BURGESS: Yes.

MR. SHERBINI: Why was that arrangement?

MR. BURGESS: They just did that. I would be doing the whole body counting on him and they would do the

liquid scintillation.

MR. SHERBINI: Okay. Is that normal procedure? Do they normally count?

MR. BURGESS: Mitch normally does the urine samples, yes.

MR. SHERBINI: For anybody?

MR. BURGESS: Anybody, yes.

MR. SHERBINI: Oh, I see. And he does the set-up for the urine counts?

MR. BURGESS: Yes.

MR. SHERBINI: Could you tell us a bit about your background, Bob?

MR. BURGESS: I graduated two-year technical school in nuclear engineering, you know, the basic learning of radioactive materials and things, handling them and counting techniques and things like that.

Then I came here and I was trained by the staff at that time. Also training going out into the labs with other technicians who were here before me and learning from them. Counting room, from the counting technician that was in here before, from some of the staff that are still here, Mitch.

I have attended classes for health physics. Not really a credited class type of thing, but just class like maybe four or five nights going to a class. Most of

it I think is just learning from reading and doing the work itself.

MR. SHERBINI: I guess most of your experience is here at MIT.

MR. BURGESS: Yes it is. I would say all of it is.

MR. SHERBINI: All of it?

MR. BURGESS: Yes.

MR. SHERBINI: You did surveys and things?

MR. BURGESS: Yes.

MR. SHERBINI: In the lab?

MR. BURGESS: I did that for I would say 20 years anyway. When I first came they started doing that.

MR. SHERBINI: When you counted Dr. Li, I guess for the several weeks, did he have any concerns, did he have any discussions with you about how good the body counter was or --

MR. BURGESS: No. He seemed very comfortable to me.

MR. SHERBINI: He didn't have any problems with the counting?

MR. BURGESS: No. No. He obviously would come in. He'd want the numbers. He'd take the numbers down himself. He'd write down the times. In fact, today he came in and we counted them. He took down the numbers.

MR. SHERBINI: He's still being counted?

MR. BURGESS: Yes. He'll probably be, he'll be in tomorrow I think again. Then he said probably once a week for a while. He's pretty much down now to almost a background level.

MR. SHERBINI: Speaking about background, how much higher than background is he?

MR. BURGESS: At the present?

MR. SHERBINI: When you started counting.

MR. BURGESS: When we first started?

MR. SHERBINI: Was it a lot higher?

MR. BURGESS: Yes.

MR. SHERBINI: Very hot?

MR. BURGESS: Yes. I have the numbers --

MR. SHERBINI: Yes, we'll see the numbers.

MR. BURGESS: But the first count I believe was the night of the Saturday night, I think we did the count. Something like 119,000 counts total. The background is about 6,300. So it's quite a bit higher.

MR. SHERBINI: Is there any problem with counting that high?

MR. BURGESS: No. The dead time (phonetic) is very low. So there's no problem.

MR. SHERBINI: Then now he's down to --

MR. BURGESS: He's down to I think today was

about 8,000.

MR. SHERBINI: So he's approaching background.

MR. BURGESS: Yes. Yes.

MR. SHERBINI: Is the whole body counter used often here on campus?

MR. BURGESS: Yes.

MR. SHERBINI: For what purpose?

MR. BURGESS: Mainly reactor people, people from the reactor, they come over at least once a year. They come over.

MR. SHERBINI: They all come to do routine?

MR. BURGESS: Yes.

MR. SHERBINI: Whole body count?

MR. BURGESS: Yes.

MR. SHERBINI: And you do the counts for them?

MR. BURGESS: Yes. I do or my associate in the counting room, yes. If I'm not there, he'll do it. If we're not there, someone else will do it. One of the other staff will do it.

MR. SHERBINI: How do you calibrate for them? Is it the same way?

MR. BURGESS: Yes. We have the same phantom, different nuclides in the phantom, various nuclides in the cobalt-60, cesium.

MR. SHERBINI: Okay. But that's the same kind

of thing as phosphorous 32?

MR. BURGESS: No.

MR. SHERBINI: They usually have gamma rays.

MR. BURGESS: Yes. You'll see the peaks and such, yes.

MR. SHERBINI: So you don't really normally handle things without peaks?

MR. BURGESS: Right. Exactly. This is not generally what the whole body count was made for, counting a beta, getting the brems off the beta. But it's normally used for gamma, yes.

MR. SHERBINI: How much of the body can you see when you use this counter? I mean can you see the whole thing?

MR. BURGESS: You see from probably just above the knees up to the neck, this whole area, trunk area.

MR. SHERBINI: Do you have a shield in front of the detector or something?

MR. BURGESS: It's shadow shielded. It has the detectors with a lead shielding this way, looking at you at the chair, because the chair wraps around.

MR. SHERBINI: Oh it's a chair?

MR. BURGESS: Yes.

MR. MADISON: Do you have a magazine or a brochure on the unit?

MR. BURGESS: We may have one, yes.

MR. MADISON: You may want to consider a picture of the unit.

MR. SHERBINI: I'll probably go and see it, see how it works.

MR. MADISON: I mean for later reference.

MR. SHERBINI: Oh okay. Okay great. I think these are all the questions I had. Anyone have any questions?

MR. O'CONNELL: Yes. I just need some clarification. On the P-32 standard that you made up and the three different sections.

MR. BURGESS: It's two. We have three, but we only used two. There was nothing in the lungs, the lung section.

MR. O'CONNELL: So for this particular calibration you were performing with the P-32, you used thighs and then the trunk?

MR. BURGESS: Yes. The trunk, right, exactly.

MR. O'CONNELL: With the uptake of P-32, there's a little more distribution throughout the body. At least that's the way it seems listening to some of Mitch's information. That it's a bone seeker. So you'd have some distribution up in the heavy area and so forth. So was performing those type of calculations for a correction

factor to account for that when the calibration standard that was made up basically didn't have anything in from basically, I guess you could say the lung region up. Or does that come into play?

MR. BURGESS: That I don't know. When they made it up, he just says we don't need -- apparently we didn't need anything in the lung area of the calibration.

MR. MADISON: You were basically, as a technician, you were taking his word for whatever he developed?

MR. BURGESS: Yes.

MR. MADISON: He developed the channel.

MR. BURGESS: Right. Exactly. What he made it up to. That was the configuration he made.

MR. SHERBINI: More questions?

MR. O'CONNELL: No.

MR. SHERBINI: Alan?

MR. MADISON: No.

MR. SHERBINI: No more questions. Thanks a lot, Bob.

MR. MADISON: We're not quite done.

MR. SHERBINI: We are required to give you this. What this is is it describes to you how we handle the transcripts. It tells you what we do with them. It tells you how you can look at them, review them, what you

can and can not do with them, whether you can write on them or not and so forth. So it gives you the detailed procedure of what we do with the transcripts and how you can effect -- (inaudible.)

Is there anything else we didn't ask that you might want to add to this that might help us?

MR. BURGESS: Not that I can think of. Not that I can think of right now, no.

MR. MADISON: Is there anybody else that you think we should talk to?

MR. BURGESS: That, I don't know. Who else was involved, I don't know. I just do my little thing they involve me. I'm in the counting room, so they have me count him. So that I don't know.

MR. MADISON: If you can think of anybody after this is over, or anybody talks to you and asks you if they can talk, we'll give you a number. In fact, you may have seen it on some of the bulletin boards already of who they can call and make contact with.

MR. BURGESS: Okay. Okay sure.

MR. SHERBINI: Thank you very much, Bob.

MR. BURGESS: You're quite welcome.

MR. SHERBINI: For the record, the interview ended about 3:30.

(Whereupon, at 3:38 p.m. the interview was

concluded.)

C E R T I F I C A T E

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

Name of Proceeding: INTERVIEW OF ROBERT K. BURGESS

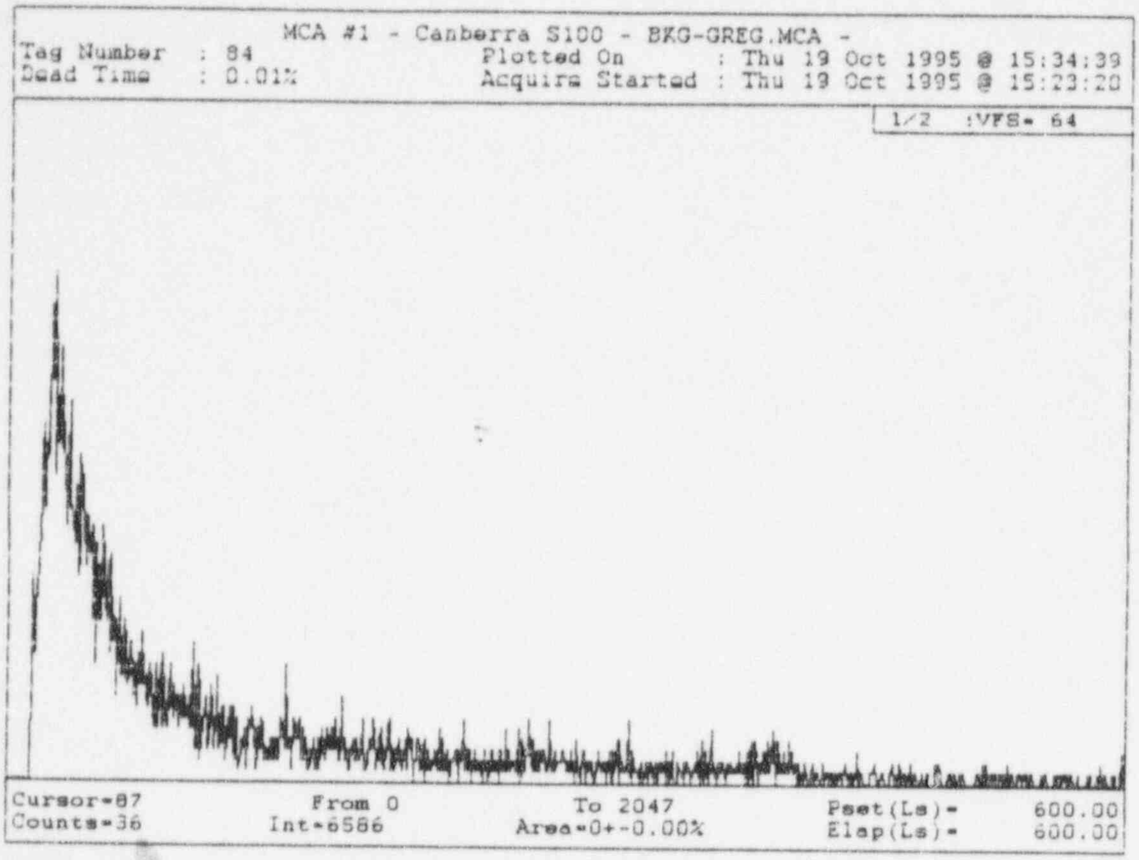
Docket Number: --

Place of Proceeding: Cambridge, Massachusetts

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and, thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.

C. Pyott
Official Reporter
Neal R. Gross and Co., Inc.

10-95-46



Background spectrum with Greg Goneconto in the whole body counter chair.

Published study of the MIT whole body counter

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Health Physics Pergamon Press 1970. Vol. 19 (July), pp. 27–35. Printed in Northern Ireland

EXPERIENCE WITH A LOW-COST CHAIR-TYPE DETECTOR SYSTEM FOR THE DETERMINATION OF RADIOACTIVE BODY BURDENS OF M.I.T. RADIATION WORKERS

F. X. MASSÉ and M. M. BOLTON, JR.
Occupational Medical Service, Medical Department, Massachusetts Institute of Technology, Cambridge, Massachusetts

(*Received* 24 *March* 1969; *in revised form* 10 *November* 1969)

Abstract—A low cost chair-type device capable of absolute determination of radioactive body burdens in the range of interest for radiation protection purposes has been in use in the M.I.T. Radiation Protection Program for more than 3 yr. Experience has shown that this unit represents a practical compromise between expensive, research oriented whole-body counters capable of minute measurement, and the generally less demanding needs of the health physicist. The calibration of the unit, first accomplished by phantom studies and measurements of persons with known body burdens and later expanded by cross-calibration with the whole body counting facility at the M.I.T. Radioactivity Center, is discussed in detail. The findings of zinc-65 in cyclotron workers, iodine isotopes in the thyroids of perons working with millicurie quantities of radioiodine, activation products in reactor personnel who handle irradiated samples, and detectable radionuclides in radiochemistry workers are presented.

FOR SEVERAL years the M.I.T. Radiation Protection Program has included the routine whole body counting of the following groups of people:

1. persons who are working with more than 1000 times the maximum permissible body burden of unsealed gamma emitters with a half life more than one week (this automatically includes the operators and maintenance workers at the M.I.T. Research Reactor and Cyclotron).
2. all persons registering to begin work with such radioactive materials to obtain background information and
3. all persons registering who have had a previous history of exposure to such materials elsewhere, regardless of what they propose to work with at M.I.T.

To facilitate the operation of such a program, a low-cost, shadow-shield, chair-type whole body counter was designed about 4 yr ago to ease the burden of this program on the M.I.T. Radioactivity Center's iron-room whole body counter. This unit, which was described by the authors in May 1966, at the annual meeting of the New England Chapter of the Health Physics Society[1] combines the advantages of low-cost, light weight, shadow-shielded, screening devices[2,3] that have been reported, and the absolute counting abilities of the fixed-geometry, heavily shielded, research-oriented whole body counters such as the one it was designed to relieve.[4–6]

The unit, pictured in Fig. 1, incorporates a ½ in. lead lined chair, which constitutes the shielded pocket for the subject to be monitored, and a 3 × 3 in. sodium iodide scintillation detector mounted in a 2 in. thick lead shield that is open only in the direction of the chair. The built-in relationship between chair and detector result in a fixed-geometry, 50-cm arc whole body counting configuration (a standard whole-body counting geometry) that may be calibrated to yield absolute results in terms of microcurie body burden. Figure 2 illustrates the value of the shielding components around this 3 × 3 in. detector.

A special collimator with a 0.5 × 1.5 in. diameter crystal is mounted on top of the main crystal shield for selectively measuring the radioactivity content of the thyroid gland. Again, a reproducible geometry and absolute counting is featured. This crystal is provided with a 0.001 inch aluminum window to improve counting efficiency for low energy emitters such as ^{125}I. Only ½ in. of steel shielding is provided in this assembly, but the crystal is directionally shielded from the body by the main detector shield on which the thyroid assembly is mounted.

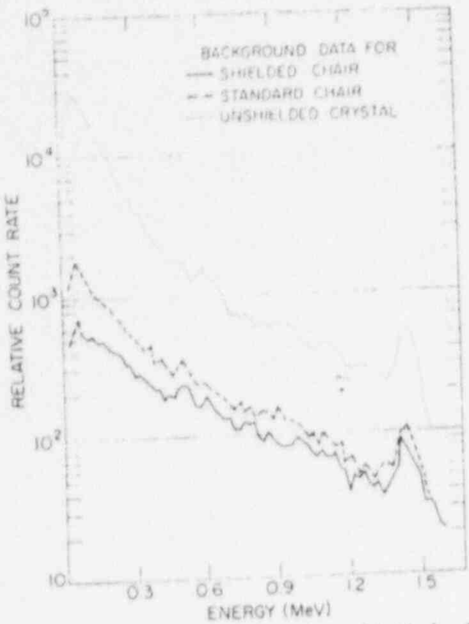

FIG. 2. Background data for shielded chair, standard chair and unshielded crystal.

The geometry of the main detector is schematically represented in Fig. 3. Note that the major organs of the body, including the lungs and GI tract, are in full view of the crystal, and the head, hands and forearms, and feet and lower legs are not included in the field of view. Thus the low-level contamination customarily found on shoes, in the pant cuff, in the hair, on the hands, or under the nails, is shielded from the

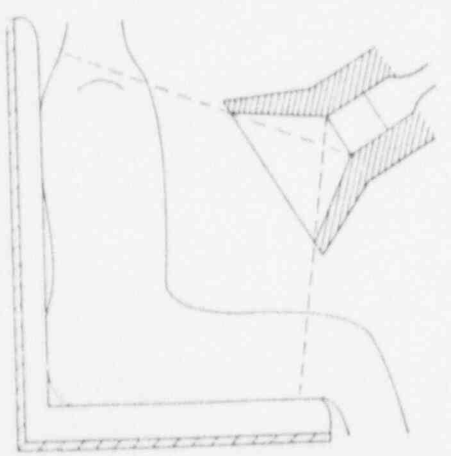

FIG. 3. Counting geometry.

detector. Experience has shown that most people may be counted in this unit in street clothing, the only requirement being that they wear freshly laundered clothing on the day they are scheduled to be counted (scheduling is for early morning measurement before the worker goes to his laboratory). A clothing change may be effected if positive results are obtained.

Calibration of the device for several radionuclides was first accomplished by measurement of people with known body-burdens. Data for additional radionuclides was then obtained by cross-calibration between radionuclides for which efficiencies had been so established and others of interest. Such comparison was made in a simple two compartment phantom consisting of two polyethelene 5 gal containers in which the radionuclides of interest were dissolved in distilled water. Finally, the calibration was completed by follow-up measurement at Radioactivity Center for all persons in the routine monitoring program whose initial results in the chair were positive. The data from the chair measurement was fully interpreted into a microcurie body-burden figure and compared with the absolute results of the Radioactivity Center by an independent referee until it became evident that our techniques were consistently reliable.

Figure 4 illustrates the absolute efficiency of the unit for detection of a wide range of gamma ray energies uniformly distributed in this simple phantom. We have determined that the unit measures 65% of standard man for such uniformly distributed isotopes as ^{137}Cs and ^{24}Na.

Non-uniformity of distribution may yield an error of as much as 50% if no correction is made for such non-uniformity, but the body burden so determined would always be on the high side of the true figure. Errors due to a "non-standard" subject are usually within 20%; this is acceptable for such a program, but again corrections can be made. Considering the fact that the method is being used to supplement external exposure data as determined by film badges, we suggest that the accuracy of the method will yield data that is at least as good as the data with which it is being combined, and that it offers real advantages in both accuracy and ease of measurement over standard bioassay techniques for most radionuclides.

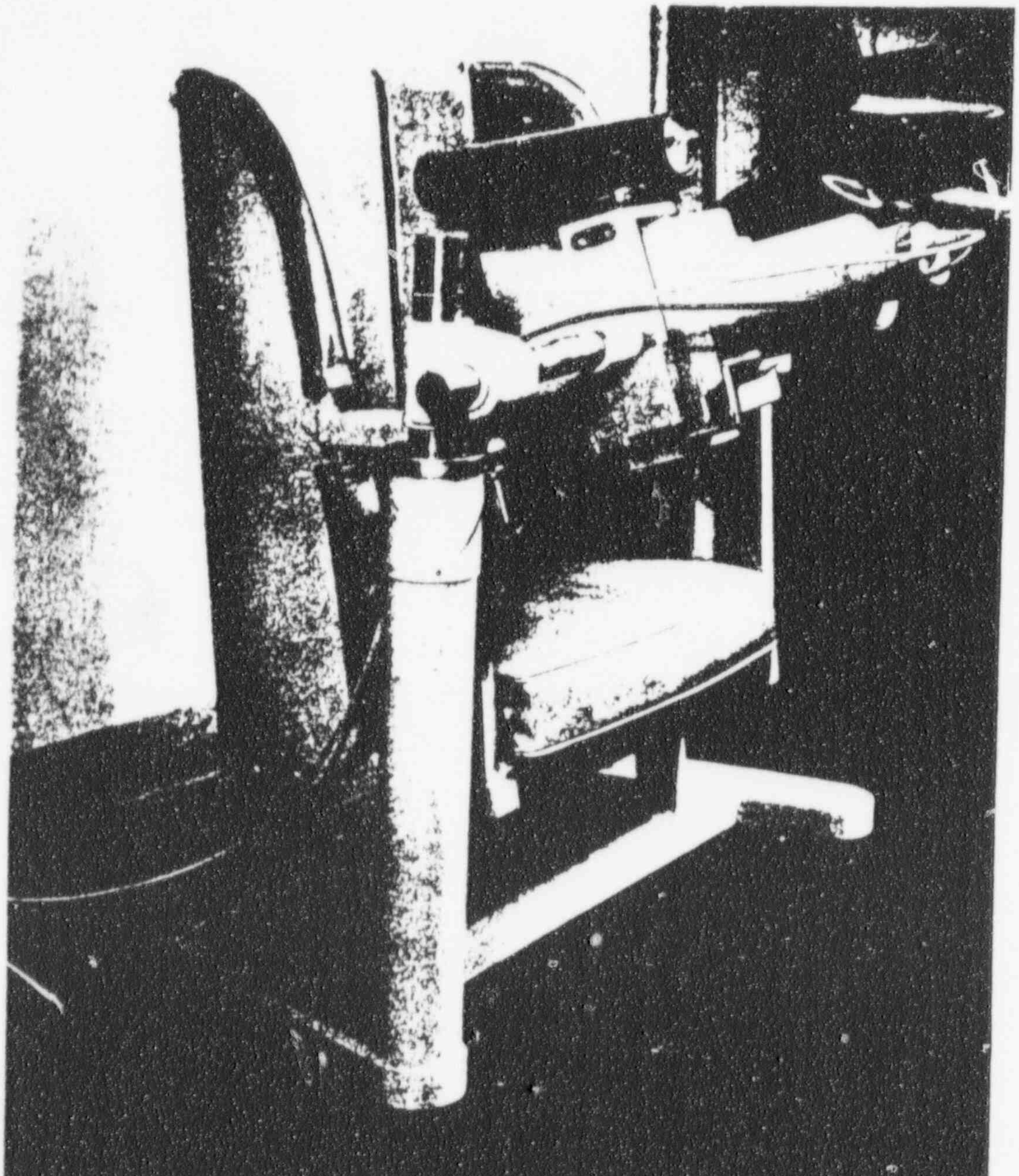

Fig. 1. The chair.

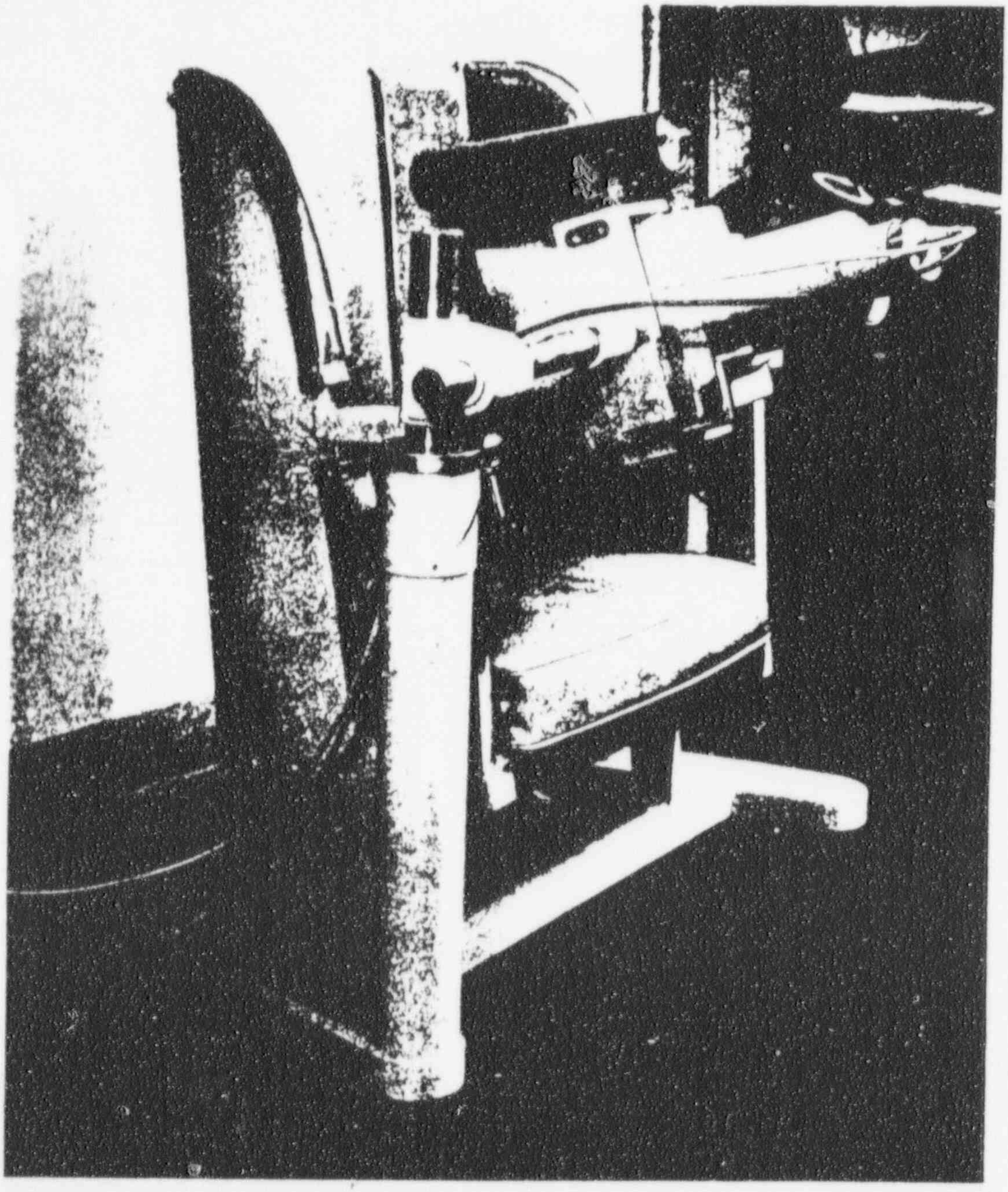

FIG. 1. The chair.

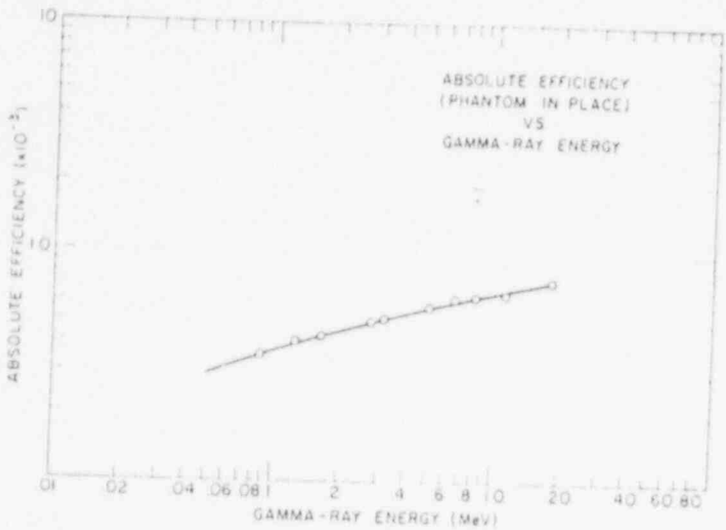

FIG. 4. Absolute efficiency (phantom in place) vs. gamma-ray energy.

The minimum detectable activity of the ...tem has been defined as that amount of ...tivity that will result in a 3σ increase above the subject's baseline in the area of the observed photopeak. Table 1 compares the minimum

Table 1.

Nuclide	Gamma energy (MeV)	Minimum detectable body burden (μCi)	NCRP Maximum permissible body burden (μCi)
^{109}Cd	0.09	0.018	20
^{51}Cr	0.32	0.130*	800
^{85}Sr	0.51	0.012	60
^{137}Cs	0.66	0.012	30
^{54}Mn	0.84	0.011	20
^{65}Zn	1.11	0.026*	60
^{60}Co	1.17, 1.33	0.010	10

* Low branching ratio.

detectable activity, so defined, in our system with the maximum permissible body burden as currently listed by the NCRP. Note that the sensitivity of the method is usually the order of 1% or less of the per...issible body burden for gamma emitters. We therefore suggest that sensitivity for most isotopes compares favorably ... the currently accepted sensitivity of com-...plementary monitoring techniques.

It should be noted, however, that the practical limit of sensitivity of this device is in the 10–20 nCi region for gamma emitters with a 100% abundant gamma ray. Radionuclides with very low permissible body burdens (such as many of the transuranics), a very low gamma ray abundance, or gamma rays of low enough energy to present self-absorption problems may still have to be analyzed in other ways. These are limitations that generally apply to whole-body counting as a technique, rather than problems specific to this unit.

Routine whole body counting as a monitoring technique for radiation workers began at M.I.T. because of our concern for the potential radioactive body burdens of Cyclotron workers. Figure 5 shows the spectrum obtained on a typical Cyclotron technician following a recent repair operation that involved roll-back and hand sanding of the *D*'s. Experience over the years has taught us to expect such deposition even though we now provide a complete mobile hood enclosure for containment of the *D*'s during such an operation, and require the wearing of absolute filter respirators and full protective clothing by all persons involved. Figure 6 shows the spectrum obtained on the Health Physics surveyor who observed this operation as remotely as practical while also wearing a respirator. Although calculated body burdens are well within permissible limits,

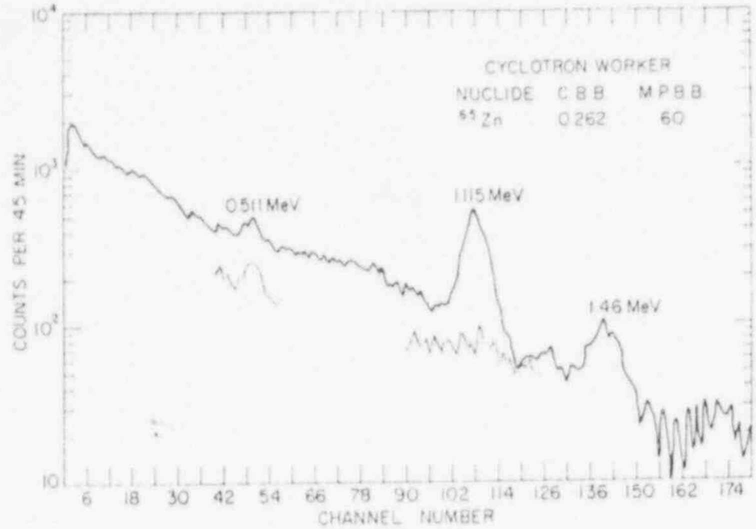

FIG. 5. Cyclotron worker.

they must be considered in the light of the typical 500-1000 mR external whole body radiation exposures regularly associated with such a repair operation.

Similar problems arise during routine reactor operations. Figure 7 shows the spectrum obtained from measurement of a reactor operator the morning after the cleanout of a reactor port despite the fact that such a cleanout operation routinely includes the utilization of local exhaust ventilation directly over the port. Routine measurements on reactor workers regularly yield such traces of activity attributable to their work.

Nuclear chemists, though they are all required to work in good radioisotope hoods, are often found to have detectable body burdens also. Figure 8 shows the results obtained from measurement of such a nuclear chemist following the rupture of a reaction flask containing less than a millicurie of ^{22}Na. The body deposition occurred despite the fact that the reaction flask

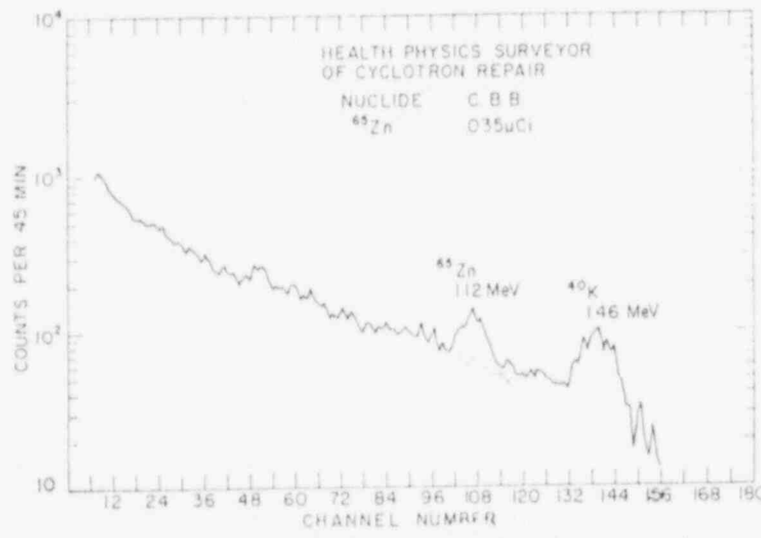

FIG. 6. Health physics surveyor of cyclotron repair.

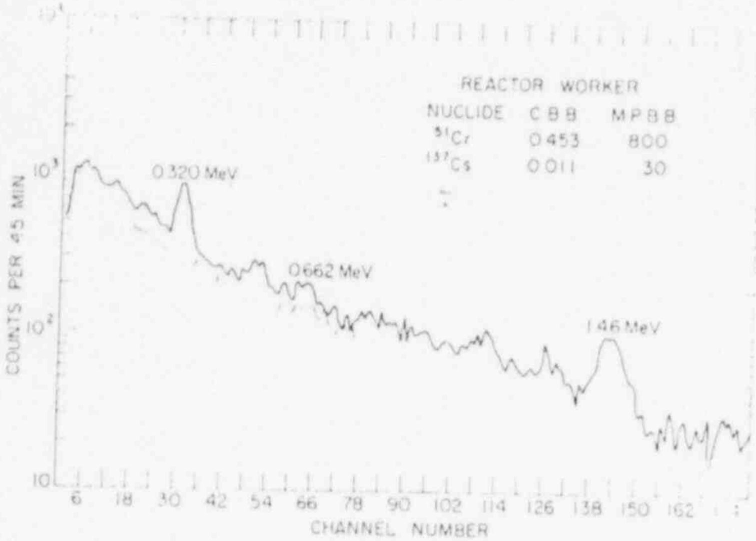

FIG. 7. Reactor worker.

was in a hood that was determined to be functioning properly when the incident occurred. Figure 9 shows the spectrum obtained on another nuclear chemist whose principle assignment was the preparation of submillicurie level calibration sources, again working under well controlled conditions. Figure 10 shows the spectrum obtained on a nuclear chemist who was working with a millicurie of ^{131}I which he assumed was in a basic solution, in a hood which he assumed was functioning properly. Unfortunately, neither assumption was valid; the solution was acidic, and the belt on the hood exhaust fan was broken.

Iodine isotopes are a common source of difficulty because of their volatility. We have come to expect detectable thyroid burdens in all persons who perform any manipulation with millicurie amounts of the iodines without benefit of exhaust ventilation. Figure 11 shows the spectrum obtained from a radioisotope worker who opened a 5 mCi vial of $Na^{125}I$ on the bench top, then moved to the hood to continue his work. The figure shows 2 spectra. The first

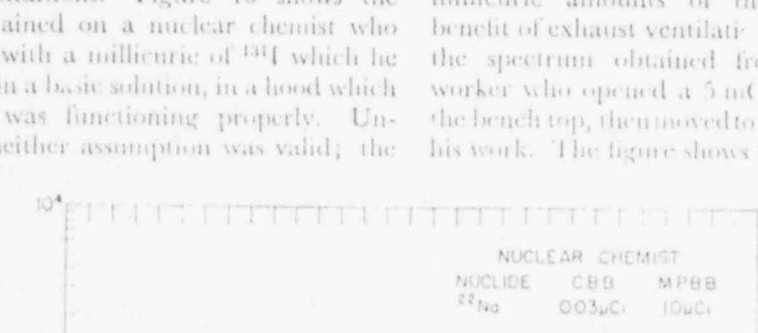

FIG. 8. Nuclear chemist.

FIG. 9. Nuclear chemist.

one, obtained with the 3 × 3 in. crystal, shows a hint of a low energy emitter in a short counting time. The second spectrum is that obtained by looking only at the thyroid after switching to the thyroid probe and expanding the low end of the spectrum.

These are not, however, the only sources of body deposition of radionuclides. Figure 12 is the spectrum obtained during the routine initial measurement of a prospective nuclear chemistry technician who claimed never to have worked with radioactivity before. The subject later admitted that he had recently participated in a volunteer program at a local hospital during which he had received 60 μCi of ^{51}Cr and 10 μCi of ^{125}I. Figure 13 is the spectrum obtained by measurement of an 83 yr old woman who had faithfully taken one of the "miracle drugs" of the early part of this century. Her body burden has been carefully documented by Professor R. D.

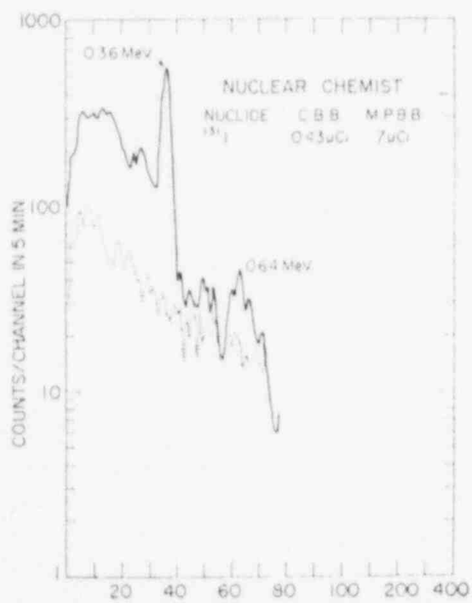

FIG. 10. Nuclear chemist.

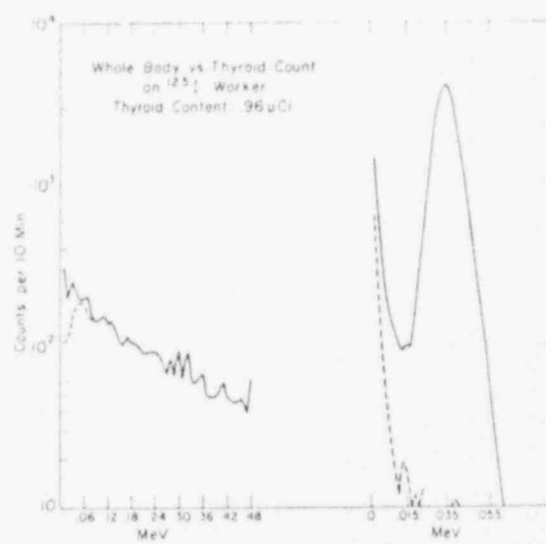

FIG. 11. Whole body vs. thyroid count on ^{125}I worker.

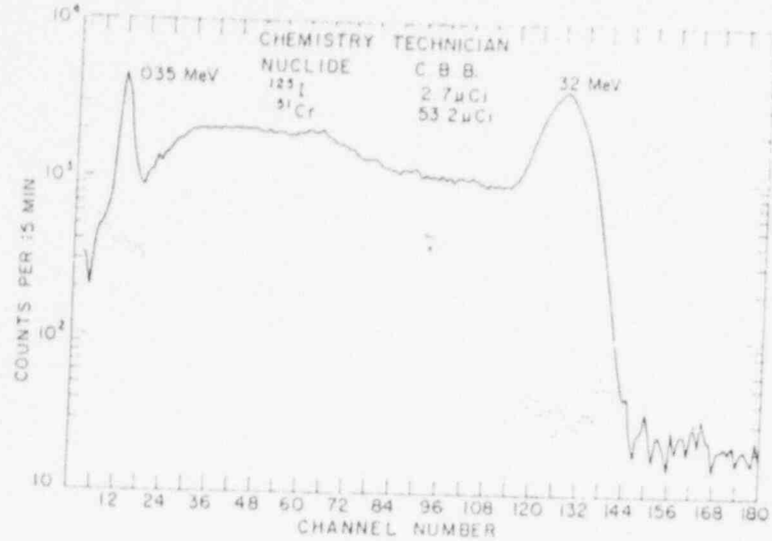

Fig. 12. Chemistry technician.

Evans over the years, and she graciously conceded to provide us with important calibration data for our unit. Similarly, Fig. 14 is the spectrum obtained from measurement of a young European dial painter who worked originally with radium, but later switched to ^{90}Sr. While both radium and ^{90}Sr contribute to the count rates obtained, it was possible, by spectrum stripping in the bremsstrahlung region, to determine that portion of the contributed count rate that was due to ^{90}Sr and hence make an estimate of ^{90}Sr body burden. This estimate proved later to be in agreement with the findings of other investigators. This also provided valuable calibration data, and verified our abilities to measure accurately pure hard beta emitters in quantities below the permissible body burden. While preliminary investigation had indicated a capability for such measurement with this unit (see Fig. 15) this subject represented the first opportunity to measure a known body deposition of such an isotope.

Approximately 7% of all subjects measured in

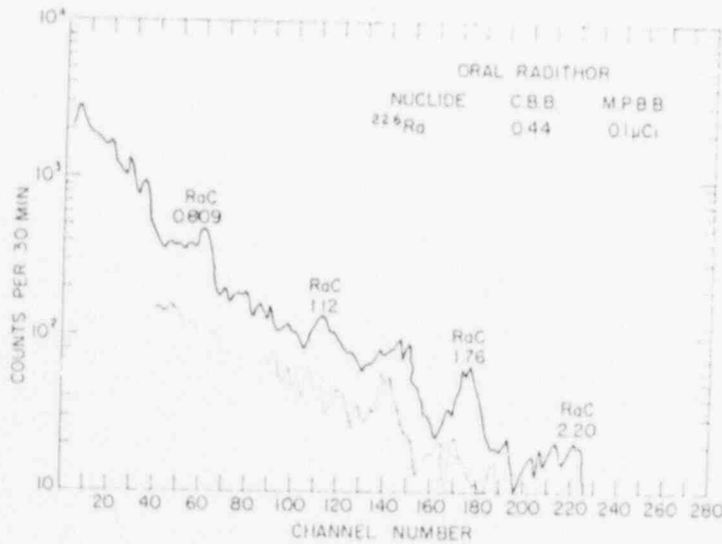

Fig. 13. Oral radithor.

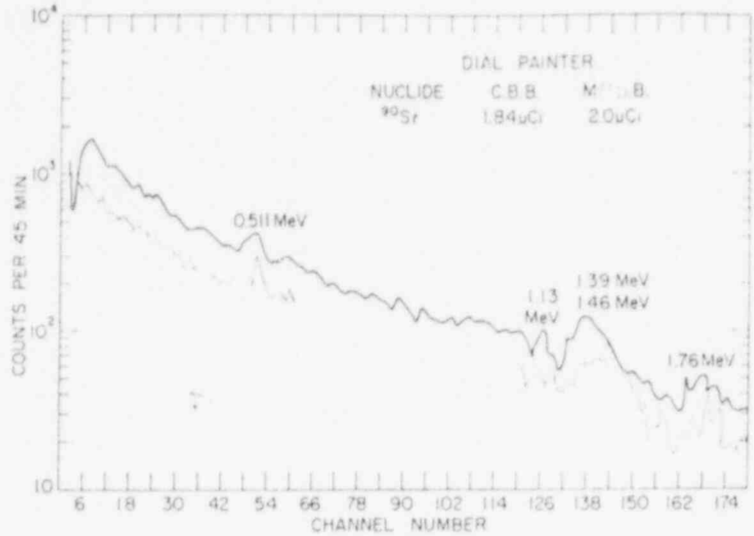

FIG. 14. Dial painter.

our routine monitoring program are found to have a detectable body burden. While few of these approach a maximum permissible burden, the data is valuable in assessing the adequacy of the radiation protection precautions involved in the related project. The data obtained in the baseline measurements has proven to be essential

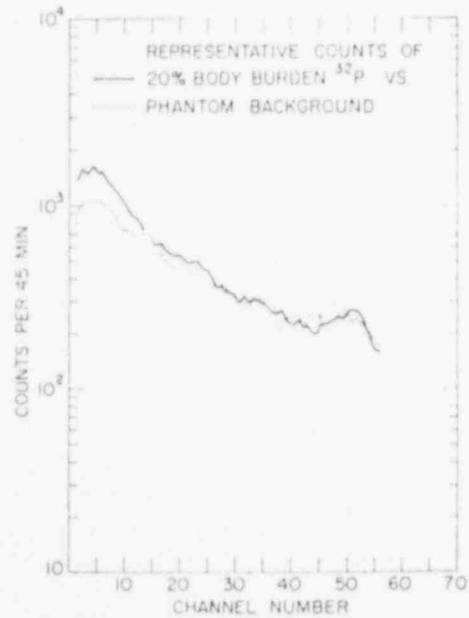

FIG. 15. Representative counts of 20% body burden ^{32}P vs. phantom background.

as we find people coming from areas of the world where normal body burdens are abnormal by our standards, new workers with a radioactive body burden that they have not revealed and with no apparent past history, and new workers with a previous history that would not lead one to suspect the presence of an unusual body burden. Finally, the ready availability of a means of quickly assessing the radiation hazard due to internal emitters is invaluable in the event of a radiation emergency involving the possible release of activity. The *psychological* effect on those exposed of a delay in determining the extent of the exposure while a mobile service is called in or while arrangements are made for whole-body counting at a near-by facility, cannot be ignored.

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