10-95-13 B

Official Transcript of Proceedings

NUCLEAR REGULATORY COMMISSION

Title: INCIDENT INVESTIGATION TEAM MEETING

Docket Number: ---

Location: CAMBRIDGE, MASSACHUSETTS

Date: OCTOBER 17, 1995

Work Order No.: NRC- 370 Pages 33

NEAL R. GROSS AND CO., INC.
Court Reporters and Transcribers
1323 Rhode Island Avenue, N.W.
Washington, D.C. 20005
(202) 234-4433

ADDENDUM

Page	Line	Correction and Reason for Correction
5	15	constant should read "system"
8	3	insert word "mouth" before pipetting
8	8	We were making aliquot measurements (not on top of)
8	15	maybe in two words
9	5	strike "how much activity"
9	16	change "where" to "worth"
10	2+3	delete first phrase, start sentence with "We were skeptical"
11	7	Comma after back, much to our surprise. We were
13	6+7	remove "we questioned" (change of thought)
13	13	"Irem" should be "Rem."
13	16	We ~~be~~ said
13	21	We set down early ~~doors~~ with - - -
14	11	So Prof Sharp asked the - - -
14	12	identify to give ~~to~~ his - - -
15	7	daily basis, seven days a week, and whole - - -
15	15	"Rem", not Irem
~~16~~	~~14~~	~~We (not He) surfaced the canopies prior~~ - OK as is

Pg 18

Page ___ Date _____ Signature _____

10-95-BA October 17 - opening meeting - balance of session began earlier

ADDENDUM/ERRATA SHEET

Page	Line	Correction and Reason for Correction
20	6	"14 days" is not correct - should probably be 40 days
20	23	"clock" should be plot
26	4	-- should be NIH incident review

Page 2? Date 11/13/95 Signature [illegible]

(session began earlier)

ADDENDUM

Page	Line	Correction and Reason for Correction
3	16	Change "isn't" to "is"
3	25	Change "instant" to "incident"
24	10 & 11	Change "under the . . ." to "to the public document room"
24	21 & 22	Change "in the case. I'm the last guy." to "Here is a case I will explain."
24	22	Delete "Then"
24	23	add "with" before "an affidavit"
27	12	Change "of who" to "with whom" Delete "with"

Page 1 of 1 Date 11/7/95 Signature Cherie Siegel

10-95-13B

UNITED STATES OF AMERICA

- - - - -

NUCLEAR REGULATORY COMMISSION

- - - - -

INCIDENT INVESTIGATION TEAM MEETING

- - - - -

TUESDAY, OCTOBER 17, 1995

The participants met in Room 234, Building 20, 18 Vassar Street, Cambridge, Massachusetts at 4:00 p.m. John Glenn, Team Leader, presiding.

PRESENT: JOHN GLENN, Team Leader
ALAN L. MADISON
CHERIE SIEGEL
MARY GLENN CRUTCHLEY
LARRY L. ROBINSON
SAMI SHERBINI
AGOSTINO SAVASTANO
MITCHELL S. GALANEK
FRANK MASSE
DAVID LITSTER
RONALD R. BELLAMY
BETSY ULLRICH

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

4:06 P.M.

MR. GLENN: My name is John Glenn. I'm with the Nuclear Regulatory Commission in the Office of Research. I have been designated by the Executive Director of Operations of the NRC to lead an incident investigation team concerning the P-32 contamination incident that involved an employee here at MIT.

First, before we get started, I would like to go around the table here for those people who are in this conference, if you would identify yourself and your affiliation.

MR. SHERBINI: Sami Sherbini, NRC.

MR. SAVASTANO: Agostino Savastano, Massachusetts Department of Public Health.

MR. ROBINSON: Larry Robinson, NRC, Office of Investigations.

MR. GALANEK: Mitchell Galanek, MIT.

MR. MASSE: Frank Masse, MIT Radiation Protection Officer.

MR. LITSTER: David Litster, MIT.

MR. BELLAMY: I'm Ronald Bellamy, with the Nuclear Regulatory Commission out of Region I.

MS. ULLRICH: Betsy Ullrich, NRC Region I.

MR. MADISON: Alan Madison, NRC/AEOD.

MS. SIEGEL: Cherie Siegel, NRC/AEOD.

MR. GLENN: Okay. The purposes of the incident investigation are to establish what happened, to identify the probable causes, and to document our findings and conclusions and issue a published report within 45 days. So there will actually be a printed summary of the findings that will be available, I guess as the NUREG document at the conclusion of the investigation.

We will also be issuing status reports to our headquarters organization to keep them informed of the progress of our investigation. In this regard I'll mention that during the course of this investigation I am working for the Executive Director of Operations, not for my regular Office of Research. In fact, all of us are working directly under the Executive Director for Operations.

The investigation isn't intended to understand and document this incident. It is not a compliance inspection. We will not be issuing inspection findings. However, our report can be used to form the basis for an enforcement action. We request that any information that becomes available as a result of your investigation, that you would make that available to us as promptly as possible.

In particular, the scope of the team's charter is to develop an instant chronology, to determine the

source of the P-32 and the contamination characterization, to do an analysis of the actual and potential dose consequences, to look at your radiation safety program, to look at the event reporting and licensee response, an evaluation of any potential wrongdoing that may have occurred on the part of anyone at the center, and whether the NRC's regulatory process and activities preceding the event contributed to it.

So we'll be looking both for omissions and commissions on the part of the NRC as well. Then our findings could include issues outside of any compliance space, but would be related to the adequacy of the structure that was set up for radiation inspection.

There are several things we would like to accomplish with this meeting. First, we want to get your understanding of what occurred, and your hypothesis of why it occurred. So in a little bit I'll be asking one of you to brief us on that.

Second, we would like to establish our interfaces for the investigation. As you see, we have a rather large organization. We're going to have a lot of administrative kinds of demands. So we do need to work out some sort of interface structure.

We need to know where we can seek technical information or ask for assistance, such as getting escorts

or looking for records or samples or data. Then finally, we would like to review with you the process that we are going to use for the investigation, which includes interviews, reviews of involved procedures or equipment, the handling of press inquiries, and the exchanging of information between your staff and the team. That is our agenda for this meeting.

I guess at this point, I'd like to ask someone from MIT to give us your chronology of what happened and then your best hypothesis at this point as to why it happened.

MR. MASSE: Okay. Frank Masse speaking. The incident first came to our attention on a Saturday night on August 19th. We got a call from the emergency response assistant here at MIT. The worker in question had called for help. He had been working that day with radioactive material in the laboratory, with P-32 specifically, in the laboratory. As he attempted to do his close-out survey at the end of the day, he discovered that he had a high background that he could not get away from. He eventually finally turned the detectors on himself, and discovered that he was the source of the high background. This was on Saturday evening of the 19th.

The call went out. Mitch came in. Another one of our staff people came in that night. I got a call and

was in touch with them. That sort of began the whole episode.

They took him over to the medical department, checked him out. Discovered that he indeed had widespread contamination. It was systemic. It was in him and not on him.

They went to the laboratory. They could not find any unusual circumstances in the laboratory, no spread of contamination, no suspicion of any problem in the laboratory. They analyzed him enough to determine that this isn't something that had just happened. It was in his bones at that stage in the game. There was no contamination on his clothing. No contamination on anybody else who was still working in the laboratory.

Mitch went to his house later that evening. Found no measurable contamination anywhere in his home. He had already measured, or he measured afterwards, his wife was not home that time, but he measured his wife later and there was no measurable contamination there. He was able to produce his work clothing from the last few days in the laboratory. There was no measurable contamination on the front of his outer clothing that was measured that evening, and no explanation for this situation at that stage in the game.

They did a whole body count on him that

evening. They collected a sample of just aliquot of his urine that evening. They identified the radioisotope as P-32. The Bremstrahlung spectrum from the whole body count was clearly consistent with P-32.

So they sent him home with specimen jars and asked him to continue to get specimens of his urine on a routine basis, over the Sunday and then come and see us first thing Monday morning.

Monday morning, we put a full team into the laboratory and did an extensive survey of the laboratory. Requested that the other workers in the laboratory, I believe 24 other workers in the laboratory, submit urine for urinalysis. Did a thorough search for any contamination, anything that might explain this issue.

Then on Tuesday morning, I made the decision to after meeting with everybody Monday afternoon, reviewing the findings that had occurred so far Monday, on Tuesday morning I made a decision to withdraw all of the radioactive materials from the laboratory, essentially put their approvals on hold and try to get a complete control of the situation, requiring them all to take some time, sit down, go through their records and do a complete inventory analysis. What had been purchased, what had been used, to try to account for the radioactivity in the laboratory as best they could.

We spent a lot of time with the individual trying to analyze his work activities, question about whether or not pipetting might have been an issue to be addressed, whether or not there was anything that he might have done in the laboratory that could have led to an accidental ingestion.

The urine results that we were following at that time, we were on top of measurements on a routine basis. As soon as we got an aliquot of urine from him, we would measure it. They were all over the map. We had real problems in the first few days with his urine counts. We were doing daily whole body counts, which were very consistent, but the urine counts were all over the place.

We finally gathered from him that he had taken it upon himself, and it maybe that he had gotten some medical advice, but taken it upon himself to force fluids. So we then said okay, we will require 24 hour complete collections. We started getting six, seven liters a day from him for his urinary excretions which clearly explained why we had such crazy numbers, just looking at aliquots.

So from then on, have done 24 hour samples where we really didn't care what the volume was --

MR. MADISON: Then being what time?

MR. MASSE: I'm sorry?

MR. MADISON: Then being what date or time?

MR. MASSE: That was probably --

MR. GALANEK: I think that was Wednesday the 23rd or Thursday the 24th.

MR. MASSE: In that range, okay. Then we didn t care how much activity, how much volume was there. We were just looking at the total activity. We could plot that and manage that very nicely.

We met with Tonegawa Laboratory repeatedly. We looked at other floors in the building. We tried to get the best handle we could on what was going on in the area. We saw nothing unusual. We did just GM survey meter measurements of other people. We didn't go into urinalysis on everybody in the building. There's hundreds of research workers in the building.

But we determined for the record that you can see where the GM pancake survey meter measuring the top of your head, which gives you a nice big flat surface of bone, you can easily see five percent of an ALI, just a nice measurement. So it's a nice trick. If you look like Gus, it's an even better measurement. So it's something that we adopted as a technique that really works, and works well.

We continued our measurements. We continued our investigations. We have all of that data. We have samples of every urinalysis that we took. We have everything for you.

By nine days in, which would be what, the 29th or 30th I think I met, the 31st I met with them again. We made the decision that we could allow -- we were besieged with requests from people in the group for permission to move into another group and begin work again in other groups. There were ongoing studies that were crucial with respect to the ongoing work that was going on. So we really had a lot of pressure to resume some work.

Rather than let people start moving around, we felt that it was better to maintain the cluster and the control by reopening that laboratory under tight conditions. So effective the first of September, I authorized work to resume in the laboratory with everybody but this particular researcher going back to work with radioactive material, but under much tighter controls.

The radioactive materials had always been under lock and key, accessible to all of the authorized users. Now they were under lock and key, available only to the laboratory management. In fact, only three people, a laboratory manager and his two assistants had access to the radioactive material. It was their responsibility to dole out that material to people as necessary, on a tight inventory control basis. They had to justify their need for the activity and they had to account for that activity before they could get more. There was a clear listing of

who was authorized to work with the material.

So we allowed the resumption of work on that basis. We also escalated our surveillance of the laboratory and made sure that we had a presence over there on a much for frequent basis than before.

We continued with the assessment. The results of the inventory review came back. Much to our surprise, we were estimating at that stage in the game that the activity ingested had been somewhere in the range of 450 to 550 microcuries. The inventory balance indicated that there was a missing amount of activity on a shipment that arrived on the day of intake that amounted to about 475 microcuries.

We tied down the day of intake rather precisely by two methods. One was that this gentleman worked with P-32 only sporadically. He would do a labelling procedure, and then take several days just working with the data before he'd get back to working with raw material again.

Previously to that Saturday, he had worked on the previous Monday, which was the 14th is it?

MR. GALANEK: Correct.

MR. MASSE: So that was the last time he had personally worked with radioactive material. He had had a mishap on that day in that he'd had to run his labelling process twice. He did it in the morning and his labelling

was not successful. We inquired into that to see if maybe that's where this occurred. He satisfied us that that was not the case. He worked with only 50 microcuries that morning. He could account for it all. It wasn't in his cells, but it was still in the incubation vat. So he could account for everything and that was not the answer.

But he had then worked into the afternoon, repeating his experiment which was unusual. Usually he would only do it maybe once a week sort of thing. But he had not had any difficulty with his close-out survey on that day. So that was an interesting bit of data.

He then, he suggested to us that maybe there was some information in his laundry. So he brought in his laundry for the last 10 days catalogued. I don't know how many of you can do that, but he did. This was Friday's, Thursday's, Wednesday's, and so forth, his underwear and so forth.

Mitch in his surveys did a very nice piece of detective work and looked at the right place in his underwear where the last drop is always going to be deposited. He was able to see the P-32 in the drop from Friday and Thursday and Wednesday and Tuesday and Monday, but not Sunday and not Saturday and not the previous Friday. So it really tied in rather nicely.

So we then could back calculate from the

measurements of urinary excretion and body retention on any given day back to a day of intake. Now you begin to have some numbers that you can have some faith in.

We have watched the laboratory very closely now for five weeks or six weeks, whatever it's been, with no difficulty. Things have been operating smoothly. He questioned -- we worked very closely with him.

This is a Ph.D. post-doc in his fifth year here as a post-doc. He let us know in no uncertain terms that he is a scientist and a Ph.D. and he knows about these things. He certainly impressed us with the fact that the Sunday after the initial finding, he spent the day in the library. He knew what an ALI was and he knew what a brem was, and he really had brought himself up to speed.

So he then decided that he was going to be the referee over everything we did, which was fine. We've said come on, we're going to be talking about this and working through the data, sit down and join us.

We sat down with him with his immediate supervisor. Professor Tonegawa was out of the country. He was in Japan at the time. We sat down early down with Professor Phil Sharp, who is the head of the Biology Department. He in the discussion told Professor Sharp that he had no faith in our ability to do what we were doing, and he really didn't think that our numbers were correct,

and so on and so forth.

MR. MADISON: Do you remember the date of that meeting?

MR. GALANEK: Friday, 24th. Let me just pull out a calendar.

MR. MASSE: It's around the 24th, 25th.

MR. GALANEK: Twenty five.

MR. MASSE: So Professor Sharp asked me if I had any problem with a referee. I said none whatsoever. We'd be happy to have all the help we can have, we can get, and I have no problem at all. So asked the researcher if there was anybody who he would like to identify to be his second opinion, if you will. He indicated that he didn't know anybody and wouldn't know who to suggest.

So Phil asked me if I would suggest somebody. I said yes, I would get Ken Skrable right up here at University of Mass. at Lowell. He certainly knows about internal beta emitters and retention and that sort of thing. He wrote the NUREG. He would be ideal. Phil thought that that was great. Turned to the researcher and said was that okay with him. He said not if Mr. Masse suggested it. So I said I don't think I'll suggest anybody else.

So then Professor Sharp asked if he knew anybody at Harvard. The answer was no. He asked me if

there was somebody at Harvard who could do it. I said yes, certainly. I suggested Joe Ring. So Joe has been looking over our shoulders since then, and doing some independent measurements of split samples and just reviewing our data. We fed him all of our whole body -- we have continued to do whole body counting on a daily basis, and continued to do urinalysis on a daily basis. Seven days a week in whole body counting, five days a week. We have all that data. We have already shown you the results of that data.

So we followed through since then. I finally came to the conclusion that we knew where we were, enough that we iterated the numbers enough to all agree on them. So I issued a report just last Thursday to the researcher sort of summarizing his intake and what it means in terms of brem dose and total effective dose equivalent.

Then we heard on Friday that Nature has hold of this thing and was interested in some information and that it obviously was going to become public. So in a conversation I had with administration hierarchy on Friday or Saturday, over the weekend I guess we decided that on Monday morning I would give you people a heads up on what was going on. That is where we stand.

MR. GLENN: Do you have a hypothesis as to how the material was ingested?

MR. MASSE: First of all, you have to

understand that the activity that they are handling is very concentrated material. It's a very small drop. Five hundred seventy five microcuries is a very small drop of activity. It's not beyond the realm of possibility that it was simply accidental. Just a drop hitting his tongue, if you will. I don't know, but it's possible.

It obviously is possible that it was a deliberate act, either a random act of somebody in the laboratory, a deliberate act against him from somebody in the laboratory, or he clearly had the capability of doing it himself.

MR. GLENN: At one point you informed the campus police?

MR. MASSE: Yes. He informed the campus police during that first week. Was it Wednesday?

MR. GALANEK: Thursday.

MR. MASSE: Thursday of that first week. So it would have been the 24th. We deliberately got in touch with the campus police to tell them that we felt that this was a very serious issue and urged them to please work with him, and that we would be very interested in helping them or doing whatever we could to work with them.

I should say too that we had a radiation protection committee meeting in September on -- my calendar is beside me here.

MR. GALANEK: I have it as the 12th.

MR. MASSE: The 12th, okay. The 12th of September I reported this whole thing to the Radiation Protection Committee. We spent quite a bit of time discussing it. The committee voted to have the chairman and myself draft, and the chairman submit a letter to the researcher expressing regret of the committee and the concern of the committee for looking into this and making sure that it didn't reoccur. The fact that we took this as a very serious incident. And a letter to the campus police urging them to do everything reasonable to find out how this occurred, and again, help us to prevent its recurrence if in fact it was a malicious act.

MR. GLENN: But at this point, you haven't drawn any preliminary conclusions?

MR. MASSE: No. No preliminary conclusions. I have got a million hypothesis which aren't worth the paper that you can write on.

MR. GLENN: One thing we will be wanting to have MIT provide us with is your preliminary sequence of events analysis. It may be that the report that you are talking about in fact does that. So we would be interested in getting those kinds of internal analysis.

MR. MASSE: Ron has a copy of the minutes of the meeting. I think that does it as well as anything.

MR. GLENN: Okay. Some things that we will be doing in the short-term, and then need to get your cooperation in doing this. One thing is part of our investigation we'll be requesting that you post a notice on bulletin boards, doors, or something like that that essentially says the IIT is here, that I'm the leader of it, that they can phone me and that we would be willing to talk to anybody who believes they have information concerning this incident. This bulletin would tell them how to get a hold of us.

MR. MASSE: The best place for that I would suggest would be right in the Cancer Center Building over in that area.

MR. GLENN: As widespread on the bulletin boards over there as possible.

MR. MASSE: Okay. That's fine.

MR. GLENN: Maybe you can clarify one thing for us. How big is the Cancer Center?

MR. MASSE: It's the building over across Ames Street. It's a relatively small building. Ron was over there with us yesterday. The Biology Building is right across the street from it, the new main Biology Building. There is a lot of traffic between the two. We certainly could post it in the Biology Building as well. That would be quite reasonable.

MR. GLENN: Mary Glenn, do we have --

MS. CRUTCHLEY: I've typed it up, but I didn't have a phone number.

MS. SIEGEL: No. We need a phone number.

MS. CRUTCHLEY: I can add that on.

MR. MASSE: We'll talk.

MR. GLENN: The other thing is in the confirmatory action letter that was negotiated this morning, or at least that I understand was negotiated this morning.

MR. MASSE: Yes, it was.

MR. GLENN: You were asked to protect certain samples of records and that sort of thing. We'll need a list, I guess, of what you have captured under that then so we can track that and what happens to it.

MR. MASSE: Anything we have, John, you are more than welcome to.

MR. GLENN: What I'm asking for now is a little more formality and actual listing of what you have identified so that we can then track the final disposition.

MR. MASSE: No problem. We'd be glad to do that.

MR. GLENN: It's possible that we will be in fact, if samples still exist, splitting samples, having laboratory analysis done, those kinds of things.

MR. MASSE: As I've indicated, I mean we had a room full of gallon jugs of urine that was beginning to affect our living conditions. So we have now taken representative samples of all that and measured the volume, but disposed of most of the urine, but we have every sample properly represented with volumes from that day, 14 days.

MR. GLENN: So basically you have a sample, a representative sample of every sample that you --

MR. MASSE: Of every data point except the whole body counts obviously. It's hard to keep those.

MR. GALANEK: We have a computer file with all of those whole body counts for you.

MR. GLENN: Okay. I don't know, is that computer file perhaps the way for us to get a listing of what you've got? I am asking you, I guess, to produce a list of the samples that you have.

MR. MASSE: Yes. Actually the data that I sent Betsy yesterday shows every data point that we've got. We certainly can back that up with a listing.

MS. ULLRICH: John, I think maybe we need to clarify what level of detail you want on this list, the data that Frank is referring to is a summary with a linear clock showing results.

MR. GLENN: I am looking for something with sufficient detail that it has some identifying, sample A or

sample P or sample 1, 2.

MR. MASSE: We've got it any way you want it.

MR. GLENN: Okay.

MR. MASSE: We can generate whatever you want.

MR. GLENN: So something that identifies the sample and where it's kept and how it is protected from being taken away or tampered with.

MR. MADISON: It's -- you are basically quarantining that basically, so wanting to control the quarantine and then releasing it to you as we've reviewed it.

MR. MASSE: Okay. If you've got a place where you want us to -- we'll turn that over to you right now if you like. We certainly can.

MR. GLENN: I guess what we need to know is how it is controlled and then --

MR. MADISON: Maybe we can see that on the tour.

MR. GLENN: Okay. When we're through here, we would like to just take a tour of the Cancer Center so we have some idea of the --

MR. MASSE: The data is all right in this building. It's right down the hall. Our offices are right here.

MR. GLENN: I guess there probably the thing to

do is get a list and get our official copies of that information as quickly as possible and then release it back to you so that doesn't stay quarantined very long.

MR. MASSE: Okay.

MR. GLENN: The samples we'll need to quarantine until we decide what we want to do with those.

We will be having interviews with people who we identify who think they have some information about this incident. We have some -- a guidance document for the team which we will be handing out.

Do we have Exhibit 3.1?

MR. MADISON: I'm going to hand that out for everyone. This meeting will also be treated the same as an interview, because there will be a transcript made of this. Transcripts are available, will be made available for review for everyone.

Which one of you gentlemen should have a copy of this? I guess what I can do is just go over this.

The transcript will be made available to anybody that was involved in the meeting for review. We will be arranging that through Region I, am I correct?

MS. SIEGEL: Yes. We're going to have a custodian of the transcript so that they will be available for review, but not for keeping until after the entire investigation.

MR. MADISON: How can they then contact? Who should they contact?

MS. SIEGEL: Well, as soon as we get -- you mean to review their transcripts?

MR. MADISON: Yes.

MS. SIEGEL: As soon as we get a central receiving office, we'll make appointments for them to review their transcripts. We'll have somebody there with them and give them errata sheets, so that if they feel that they want to change anything, it wasn't clear or --

MR. MADISON: I'm going to go over that. The main purpose of the transcript is for us to review and to have a record of what was said so we can review it. We don't have to take notes. We don't have to rely upon our memories of what was said. But we do have to treat them fairly controlled, because later on they may become publicly available as a record of this investigation.

You are allowed to review it. You are encouraged to review the transcript. If there are any problems, any corrections you want to make, we don't allow that on the transcript. There will be an addenda, errata sheet. I've got a copy here. It will look similar to this. You can make any corrections, any comments, clarifications. If you think something didn't come out quite the way you wanted to say it, you want to make that

comment in here, that will become part of the record and part of that transcript.

At the close of the investigation, the incident investigation, copies will be made available on request only to the people that were involved in that particular interview or that particular meeting.

Are there any questions?

MS. SIEGEL: However, they will probably become a part of the public record once the entire investigation is completed. All the documents go under the public document, unless they contain any personal medical information or of that type.

MR. MADISON: T t would bring up the question of propriety information.

MR. GLENN: Yes.

MR. MADISON: If there is any information that we receive, documentary or through interviews that is proprietary, we rely upon you to identify that to us immediately. We will mark it and control it as proprietary information.

MS. SIEGEL: Until -- again, I'm the caveat, I'm the bad guy. Then at the conclusion of the IIT, you will have to provide us an affidavit as to why that is such under 2.790 of the Federal regulations. We'll talk.

MR. GALANEK: During this interview process,

you will ask for opinion or fact, or both?

MR. MADISON: We are interested in getting facts. That is another reason why we want documentary evidence, because that is factual information. If people wish to share their opinions with us, it will be clearly noted in the transcript as an opinion.

MR. GALANEK: Okay. Thank you.

MR. GLENN: But I think you are quite aware that when you ask people questions, they quite often volunteer opinions. The transcript should make that clear.

Another issue that may come up, and I guess one thing I might want to ask you some questions about is how much you know about the upcoming Nature article, because one of my responsibilities is to respond to press inquiries. If I feel it's necessary, to in fact have press briefings as the investigation goes along. So at this point, I don't know what plans I have for holding briefings, but if on Thursday there is going to be an article, I may be counting on having to have a briefing on Thursday.

So I was wondering if you can comment something on what you know about the Nature article.

MR. MASSE: I don't know anything. I only know what I've heard from Ken Campbell, indicating that the Nature reporter whom he knows quite well, has been in touch

with him looking for information. He issued a press release to him yesterday.

It was my understanding from Ken that they were doing it sort of as a -- and heard about this, were doing it as a side-note on a story that they had planned for the NIH incident. I heard from I believe the NRC that MIT was more likely to be in the lead in that article rather than NIH. But I really I don't know anything directly from Nature.

MR. MADISON: Are you in contact with them at all?

MR. MASSE: No.

MR. LITSTER: Ken, our news office has been. The only information we have provided Nature with is in the press release. You have a copy of it.

MR. GLENN: Yes.

MR. LITSTER: However, I did speak with Ken Campbell who is our news officer this afternoon. He told me that he had heard from the employee involved in this incident, the employee had been contacted by Nature. So somehow Nature had learned his name.

MR. MASSE: Nature also had the name of the laboratory, the name of the director of the laboratory, which was not in the news article, the news release.

MR. GLENN: Okay. Some other issues. You have

heard Cherie speak up several times about needs. We do need a contact on your staff who Cherie can interact with to express our needs both in terms I guess of administrative support and in terms of scheduling interviews, receiving documents, those kinds of issues.

MS. SIEGEL: Right. Because if I may, any documents that you have given to the team so far, I will be collecting from them. They will become part of a bibliography. You, along with the team, will get updated copies of the bibliography to keep you informed.

Any request for documents will come from me. I need a contact of who I will communicate with. Who will be the liaison from you folks, so that there will be a one on one contact and we won't go hither, thither and yon, so to speak. The same thing with the physical arrangements which we can take care of after the meeting. We'll talk about our needs there, our needs versus what you can supply. We understand the limitations.

MR. MASSE: You are going to be the contact?

MR. GALANEK: Yes. I would suggest it be me, unless in setting up interviews with the people in the lab because I'm more lab oriented, that I become too busy and then I would get an assistant of mine to fill in for me.

MS. SIEGEL: Right. That's fine.

MR. GALANEK: So I would suggest me.

MS. SIEGEL: That's fine. I'll need your telephone number, Mitch.

MR. GALANEK: Okay.

MR. GLENN: Okay. One other issue. I don't know whether it is going to come up or not, but if we needed photographic services, would you be able to supply those to us if we needed a lab photographed or a piece of equipment photographed? Could you do that for us?

MR. MASSE: Sure. We have a graphic arts -- we have a photographic -- we have a couple of professional.

MS. SIEGEL: Photographers? That's wonderful. That's good.

MR. GLENN: Al, can you or Cherie think of any other issue that we haven't --

MS. SIEGEL: I'll talk to Mitch afterwards about our physical facilities, if you don't mind, because we will need something.

MR. GLENN: Do you have any questions about the process at this point?

MR. MASSE: No. I think I understand it enough to get started. Obviously I'll understand it more as time goes on.

MR. GLENN: I guess one comment I'll make is I don't know how long we are going to be here on site. Essentially we'll remain here until we feel we have

fulfilled the charter. Then of course we have more work to do when we go back. It could be that when we go back and start writing our reports and finishing our analysis, we might determine we need to come back and do some more interviews.

MR. GALANEK: Could you tell me when you would like to interview the researcher involved? Because I need to contact him at his home for that.

MR. MADISON: We would probably want to interview him first thing tomorrow morning.

MR. GLENN: Yes. Certainly the first interview.

MR. MADISON: Probably our first interview. There will be more than one interview going on at a time I would imagine. We'll talk again about spaces for that. We will again be scheduling those interviews through Cherie. She will be contacting you telling you who we would like to interview and you kind of set up a time for us to work that out.

MR. GALANEK: Okay.

MR. MADISON: We'll know some more tonight. One of the things we would like to get and wasn't requested, is a list of the names of the individuals in the lab and an organization chart for the lab, including your organization, the -- (indiscernible) -- and safety.

MR. MASSE: We have that. That's easy.

MR. MADISON: That will help us kind of point out who we want to interview.

MR. GLENN: One thing, on that chart, if you could indicate those individuals who were responsible for maybe some aspects of the investigation, that would be very --

MR. MADISON: Including the campus police, if they were involved.

MR. MASSE: Okay. One thing that we talked about is there are a lot of people in the laboratory. It's across campus. Would it be helpful to you in your interview process if they could find a room or two over there that you could use?

MR. MADISON: It would actually be better if we could meet as a team, have a meeting space as a team over there, as well as the interviewing rooms being over there. It would be easier for us, and it would be more convenient for them.

MS. SIEGEL: Wait a minute. What I would like to do is have this all centralized together.

MR. MADISON: If we can, over in that location would be preferable.

MS. SIEGEL: Do you have space?

MR. GALANEK: We don't own space there. We

will now go and find out. I don't know if that request can be fulfilled.

MR. MADISON: We'll work with you.

MR. GALANEK: Okay.

MR. MADISON: But that would be preferable to interview them in those locations.

MR. GALANEK: There just isn't a lot of free space in research laboratories.

MR. MADISON: Do they have offices?

MR. LITSTER: They have offices. I can tell you they have been beating on me to get space.

MS. SIEGEL: Yes. See I don't want us scattered all over the place.

MR. MADISON: No. I don't want to go all over.

MR. GALANEK: See we have this, which you can have until you decide to vacate. We have an office next door. Maybe we could clear out a couple of spaces here for the interviewing.

MS. SIEGEL: This doesn't have to be on the transcript.

MR. MADISON: This doesn't have to be on the transcript. We're talking administrative.

MS. SIEGEL: We'll talk after the meeting.

MR. GALANEK: There's a conference room --

MS. SIEGEL: I need to tell you what our real

needs are.

MR. MADISON: Do you have any more?

MR. GLENN: I think I've covered the items that I had on my checklist.

MR. MADISON: This will be a fairly intrusive visit by the NRC. We will try to work with you so that we don't shut down your operation. We want to gather the facts as best we can, but we don't want to cause MIT to have to close shop while we're here.

MR. GLENN: Don't be embarrassed to tell us if we are impacting you in some way. If all you are doing is responding to us and you are not getting your safety job done, tell us that. We'll try to accommodate.

MS. SIEGEL: We can talk.

MR. GLENN: Off the record.

(Whereupon, at 4:49 p.m. the meeting was concluded.)

CERTIFICATE OF REPORTER AND TRANSCRIBER

This is to certify that the attached proceedings before: JOHN GLENN, Team Leader in the Matter of:

INCIDENT INVESTIGATION TEAM MEETING

Place: Cambridge, Massachusetts

Date: October 17, 1995

were held as herein appears, and that this is the true, accurate and complete transcript prepared from the notes and/or recordings taken of the above entitled proceeding.

G. Pyotte
Reporter

10/17/95
Date

10-95-14 C

METABOLIC DATA FOR PHOSPHORUS

1. Metabolism

Data from Reference Man (ICRP, 1975).

Phosphorus content of the body	780 g
of the skeleton	700 g
of muscle	50 g
Daily intake in food and fluids	1.4 g

2. Metabolic Model

(a) *Uptake to blood*

Dietary phosphorus is well absorbed from the gastrointestinal tract as are various inorganic compounds of the element (ICRP, 1975; Wiseman, 1964; Honstead and Brady, 1967; Castle *et al.*, 1964). In this report f_1 has been taken to be 0.8 for all compounds of the element.

(b) *Inhalation classes*

The ICRP Task Group on Lung Dynamics (1966) assigned all compounds of phosphorus to inhalation class D except for phosphates of some particular elements which it assigned to inhalation class W. This classification is adopted here and for information concerning the inhalation class appropriate to a phosphate of a particular element the metabolic data for that element, or the task group report, should be consulted.

Inhalation class	f_1
D	0.8
W	0.8
Y	—

(c) *Distribution and retention*

The retention of phosphorus in the body has been reviewed by Jackson and Dolphin (1966). They conclude that the whole-body retention of phosphorus is well described by a function of the form

$$R(t) = 0.15\, e^{-0.693t/0.5} + 0.15\, e^{-0.693t/2} + 0.40\, e^{-0.693t/19} + 0.30$$

These four terms have been associated with blood plasma, intracellular fluids, soft tissues and mineral bone respectively (Jackson and Dolphin, 1966; Dyson, 1966).

In this report the model used for the distribution and retention of phosphorus has been based on that proposed by Dyson (1966). Phosphorus entering the transfer compartment is assumed to be retained there with a half-life of 0.5 days. Of this phosphorus 0.15 is assumed to go directly to excretion, 0.15 to intracellular fluids where it is assumed to be retained with a half-life of 2 days, 0.40 to soft tissue where it is assumed to be retained with a half-life of 19 days and 0.30 to mineral bone where it is assumed to be permanently retained. Although permanent retention of phosphorus in mineral bone has been assumed, consideration of the data from Reference Man (ICRP, 1975) indicates a half-life of retention in this tissue of about 1 500 days. However, for dosimetric purposes, permanent retention may be assumed,

since the radioactive half-lives of all isotopes of phosphorus considered in this report are much less than 1 500 days.

Phosphorus going either to intracellular fluids or to soft tissues is, for the purposes of dosimetry, assumed to be uniformly distributed throughout all organs and tissues of the body excluding mineral bone.

3. Classification of Isotopes for Bone Dosimetry

Stable phosphorus is uniformly distributed in mineral bone. For purposes of dosimetry, isotopes of phosphorus with radioactive half-lives greater than 15 days are assumed to be uniformly distributed in mineral bone and those with shorter half-lives are assumed to be retained on bone surfaces.

References

Castle, J. N., Scott, K. G. and Reilly, W. A. (1964). The skeletal uptake of radiophosphorus (P^{32}). *Am. J. Roentgenol.* **91**, 1128–1131.

Dyson, E. D. (1966). A specific activity method for derived working limits of phosphorus-32. *Health Phys.* **12**, 1521–1526.

Honstead, J. F. and Brady, D. N. (1967). The uptake and retention of ^{32}P and ^{65}Zn from the consumption of Columbia River fish. *Health Phys.* **13**, 455–463.

ICRP Task Group on Lung Dynamics (1966). Deposition and retention models for internal dosimetry of the human respiratory tract. *Health Phys.* **12**, 173–207.

ICRP Publication 23, Task Group Report on Reference Man. Pergamon Press, Oxford, 1975.

Jackson, S. and Dolphin, G. W. (1966). The estimation of internal radiation dose from metabolic and urinary excretion data for a number of important radionuclides. *Health Phys.* **12**, 481–500.

Wiseman, G. *Absorption from the Intestine*, pp. 241–243. Academic Press, London, 1964.

Annual limits on intake, ALI(Bq) and derived air concentrations, DAC(Bq/m³) (40 h/wk) for isotopes of phosphorus

Radionuclide		Oral	Inhalation	
			Class D	Class W
		$f_1 = 8 \times 10^{-1}$	$f_1 = 8 \times 10^{-1}$	$f_1 = 8 \times 10^{-1}$
^{32}P	ALI	2×10^{7}	3×10^{7}	1×10^{7}
	DAC	—	1×10^{4}	6×10^{3}
^{33}P	ALI	2×10^{8}	3×10^{8}	1×10^{8}
	DAC	—	1×10^{5}	4×10^{4}

10-95-14L

log book of week 207.

********** f207

The main priority of this week: August 13 - August 19, 1995

1. ----------
2. ----------;
3. ----------
4. ----------
5. ----------

arrive at MIT leave MIT time spent on research at MIT

August 13, Sunday, 10:00 to 15:30 04:00 develop IP plates; southern failed;
day 337 literature for PCR labeling; went to see Toyota car dealer;

14, Monday, 8:10 to 20:15 12:40 label the probe by PCR failed; label
day 338 again, partially succeeded; got library membranes from Yanyan and Hayden; buying car decision;

August 15, Tuesday, 7:55 to 19:15 12:00 got e-mail from UIUC to apply for
day 339 Searle Scholar and realized I have to work hard to publish another major journal paper; literature search to decide which proposal to write;

16, Wed. 8:10 to 19:45 12:20 went Harvard and bought 4 books;
day 340 literature search about mental retardation; phoned Dr. Goodman in Oregon;

17, Thursday 8:20 to 19:50 12:00 grant writing; wrote to Greg;
day 341 colony check;

18, Friday 08:40 to 20:00 12:00 grant writing;
day 342

19, Sat. 09:50 label probe; see movie; found
day 343 myself got seriously contaminated; called MIT police ----------
---

total,

Interactions with Dr. Zhuo Qian arranged chronologically

compiled by Yuqing Li, Sept. 26, 1995

August 9, 1994

I talked to Zhuo about getting the KII promoter but failed to get it. I sent fax to Susumu to ask for the permission to contact people in Columbia to get KII promoter.

August 10, 1994

I got Susumu's portion of promoter from Dr. King after Susumu phoned Zhuo.

Numerous incidents happened in between but I do not have a log for exact time and people involved. However, I did remember once he removed my gel while I was photographing the gel. Maz was the witness of this incident.

March 10, 1995

I got note from Zhuo to order me to give him mice. see attached

March 13, 1995

I complained to Susumu about Zhuo's note.

May 15, 1995

Susumu talked to me and I agreed to give zhuo mice in exchange for a coauthorship in the first significant paper not in all the papers I originally asked.

Days my wife cooked for me around August 14
based on the credit card transaction at supermarket:

DATE	SUPERMARKET LOCATION	AMOUNT	NOTE
07/27/95	STOP AND SHOP, #62, MALDEN	8.45	
07/30/95	STOP AND SHOP, #62, MALDEN	18.96	CONFIRMED BY MY WIFE & HER COLLEAGUE
08/02/95	LAVERDES STAR MARKET, MEDFORD	9.81	THIS STORE IS OUT OF BUSINESS NOW
08/06/95	STOP AND SHOP, #62, MALDEN	24.11	
08/10/95	STOP AND SHOP, #62, MALDEN	10.90	
08/13/95	THE 88 SUPER MARKET AT CHINATOWN	35.73	THIS IS CONFIRMED BY MY WIFE

AFTER AUGUST 19, 1995, I RESUMED TO EAT AT FOOD COURT.

In conclusion, the lunchbox I used at noon of August 14 was made on August 10 and was left overnight at MIT on August 13, 1995. The supper I had on August 14 was made on August 13 and brought into the lab on the morning of August 14, 1995.

I have phoned my credit card company to get exact transaction time for the above transaction, I will get them within one to two weeks.

 # If for other reasons you want to show my log book and credit card transaction copy to people outside of MIT campus police department, please let me know in advance and get my permission.

Hi Yuqing:

Susumu wants you to give us some NR1$^{+/-}$ mice today. Thanks

ZHUO 3-10-95

10-95-140

Are you still alive.???

I was suprised ~~that you still have crazy~~ like to hear that you are working so hard.

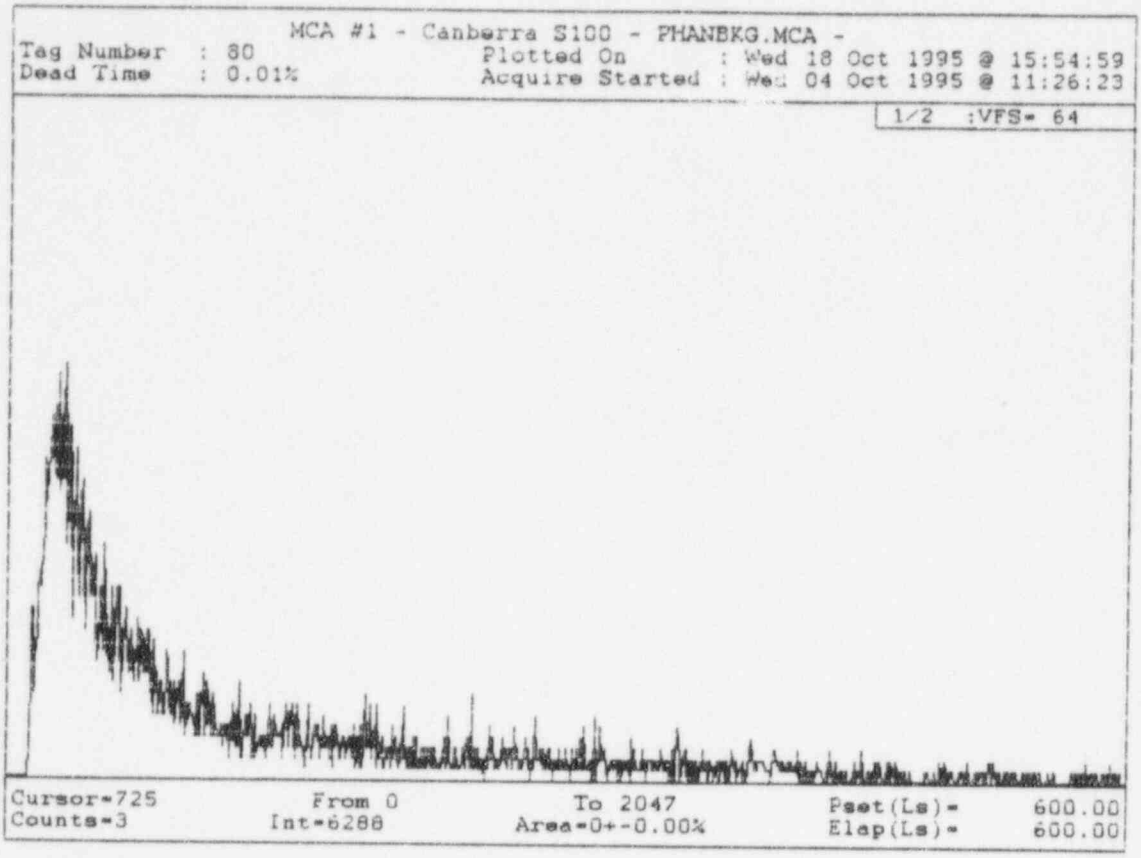
You have been working restlessly ~~so~~ long time. I would ~~Don't eat~~ but don't say you are stupid. You (of course you ~~I also think it is better you do whatever you think~~ think it is the best. It is important to satisfy yourself. if you compromise you may regret.

Please try to eat ~~something~~ good stuff.

Dat eat American junk. too much Metica food They are too spicy Your body must be exausted. take something soft to your stomach.

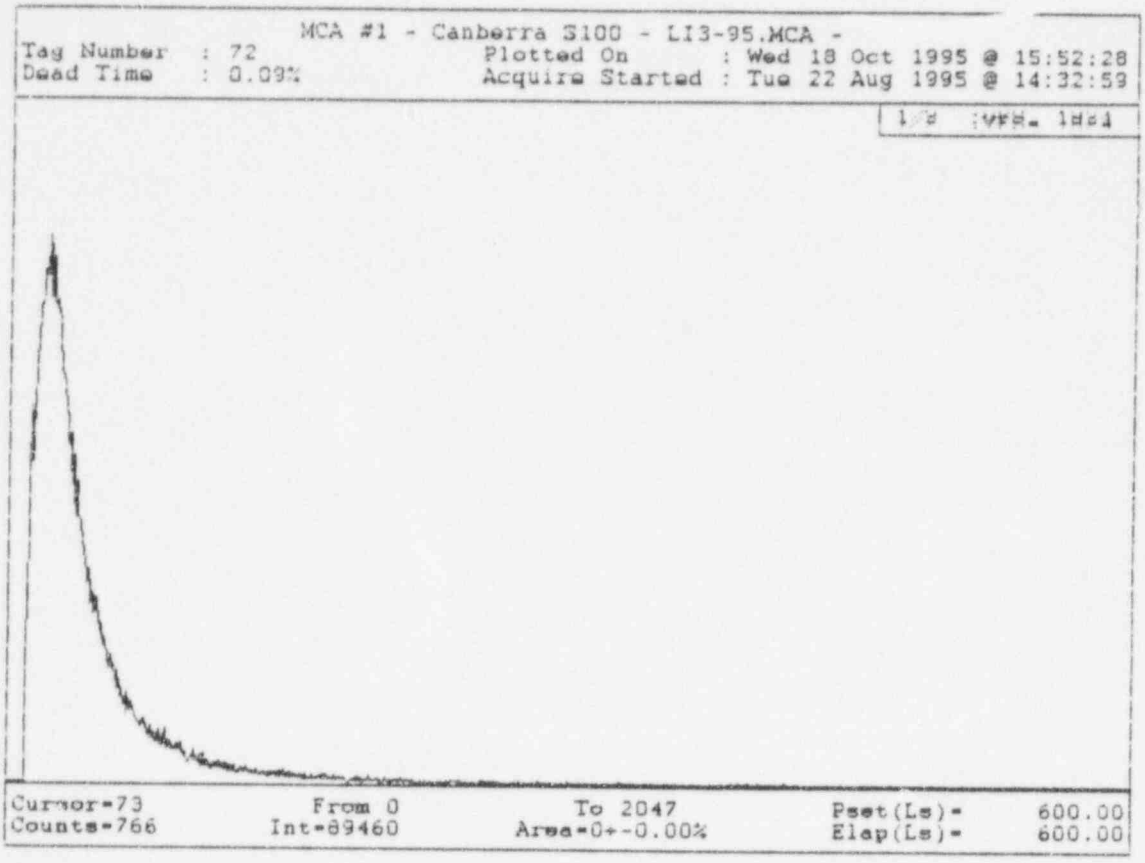
9/23/94 8:40 PM found on my desk

10-95-15



Whole Body
counter spectrum
of background

10-95-16



~~Sub~~ Whole Body Counter Spectrum from subject

10-95-17

Directory listing of B:\

Run ID		Date of Count	Time of Count
BKG-BOBE.MCA	8.320	10-16-95	10:05a
BKGBOBC.MCA	8.320	10-16-95	10:22a
LI-95.MCA	8.320	8-19-95	8:49p
LI10-95.MCA	8.320	8-31-95	1:48p
LI11-95.MCA	8.320	9- 1-95	2:48p
LI12-95.MCA	8.320	9- 5-95	3:38p
LI13-95.MCA	8.320	9- 6-95	2:29p
LI14-95.MCA	8.320	9- 7-95	2:34p
LI15-95.MCA	8.320	9- 8-95	1:47p
LI16-95.MCA	8.320	9-11-95	2:36p
LI17-95.MCA	8.320	9-12-95	12:51p
LI18-95.MCA	8.320	9-13-95	2:19p
LI19-95.MCA	8.320	9-14-95	1:44p
LI2-95.MCA	8.320	8-21-95	5:05p
LI20-95.MCA	8.320	9-15-95	2:07p
LI21.MCA	8.320	9-18-95	2:48p
LI22.MCA	8.320	9-19-95	1:43p
LI23.MCA	8.320	9-20-95	3:15p
LI24.MCA	8.320	9-21-95	3:43p
LI25.MCA	8.320	9-22-95	10:51a
LI26.MCA	8.320	9-25-95	1:31p
LI27.MCA	8.320	9-26-95	1:33p
LI28.MCA	8.320	9-27-95	1:09p
LI29.MCA	8.320	9-28-95	1:39p
LI3-95.MCA	8.320	8-22-95	2:43p
LI30.MCA	8.320	9-29-95	2:14p
LI31.MCA	8.320	10- 2-95	1:44p
LI32.MCA	8.320	10- 3-95	1:44p
LI33.MCA	8.320	10- 4-95	2:42p
LI34.MCA	8.320	10- 5-95	3:55p
LI35.MCA	8.320	10- 6-95	2:56p
LI36.MCA	8.320	10-10-95	2:52p
LI37.MCA	8.320	10-11-95	2:37p
LI38.MCA	8.320	10-12-95	2:08p
LI4-95.MCA	8.320	8-23-95	3:13p
LI5-95.MCA	8.320	8-24-95	4:41p
LI6-95.MCA	8.320	8-25-95	4:25p
LI7-95.MCA	8.320	8-28-95	4:46p
LI8-95.MCA	8.320	8-29-95	1:25p
LI9-95.MCA	8.320	8-30-95	2:52p
P-32CAL2.MCA	8.320	8-22-95	6:46p
P-32CAL3.MCA	8.320	8-28-95	10:04a
P-32CAL4.MCA	8.320	9- 5-95	9:00a
P-32CAL5.MCA	8.320	9- 6-95	9:06a
P-32CAL6.MCA	8.320	9- 7-95	9:16a
P-32CAL7.MCA	8.320	9- 8-95	10:40a
P-32CAL8.MCA	8.320	9-11-95	9:25a
P-32CAL9.MCA	8.320	9-12-95	9:32a
P-32CALB.MCA	8.320	8-22-95	6:20p
P-32STD.MCA	8.320	8-21-95	12:45p
P32CAL10.MCA	8.320	9-13-95	9:24a
P32CAL11.MCA	8.320	9-14-95	9:44a
P32CAL12.MCA	8.320	9-18-95	1:55p
P32CAL13.MCA	8.320	9-19-95	3:06p
P32CAL14.MCA	8.320	9-20-95	9:39a
P32CAL15.MCA	8.320	9-21-95	9:12a
P32CAL16.MCA	8.320	9-22-95	9:02a
P32CAL17.MCA	8.320	9-25-95	11:12a
P32CAL18.MCA	8.320	9-26-95	9:14a
P32CAL19.MCA	8.320	9-27-95	9:49a
P32CAL20.MCA	8.320	9-28-95	9:36a

Printout showing times and dates of whole body counts on subject

P32CAL21.MCA	8.320	9-29-95	9:20a
P32CAL22.MCA	8.320	10- 2-95	9:59a
P32CAL23.MCA	8.320	10- 3-95	9:38a
P32CAL24.MCA	8.320	10- 4-95	9:28a
P32CAL25.MCA	8.320	10-11-95	10:01a
P32CAL26.MCA	8.320	10-16-95	3:05p
PHANBKG.MCA	8.320	10- 4-95	11:37a

10-95-19

AUTH	ORDERED_BY	ROOM	NUCLIDE	AMOUNT	PO_NUM	VENDOR	DATE_APP	DATE_REC	INVENTORY	REMARKS
CCR-M	TONEGAWA, SUSUM	E17-360	P-32	0.2500	GFR576540	DUPONT/NEN	06/02/95	06/05/95	0.0000	
CCR-M	TONEGAWA, SUSUM	E17-342	P-32	0.2500	GFR576925	DUPONT/NEN	06/05/95	06/06/95	0.2500	
CCR-M	TONEGAWA, SUSUM	E17-342	P-32	0.2500	GFR578552	AMERSHAM	06/09/95	06/12/95	4.0000	
CCR-M	TONEGAWA, SUSUM	E17-346	P-32	1.0000	GFR583449	DUPONT/NEN	06/26/95	06/27/95	3.0000	
CCR-M	TONEGAWA, SUSUM	E17-530C	P-32	0.2500	GFR584265	DUPONT/NEN	06/28/95	06/29/95	0.0000	
CCR-M	TONEGAWA, SUSUM	E17-342	P-32	1.0000	GFR585468	DUPONT/NEN	06/30/95	07/05/95	0.0000	
CCR-M	TONEGAWA, SUSUM	E17-346	P-32	3.0000	GFR593003	DUPONT/NEN	07/28/95	07/31/95	2.0000	
CCR-M	TONEGAWA, SUSUM	E17-346	P-32	1.0000	GFR598493	DUPONT/NEN	08/18/95	08/21/95	2.0000	
				7.0000					11.2500	

P.O. #030F7006

DATE RECEIVED	AMOUNT RECEIVED
6/5/95	1 mCi
6/12/95	1 mCi
6/19/95	1 mCi
6/26/95	1 mCi
7/5/95	1 mCi
7/10/95	1 mCi
7/31/95	1.25 mCi
8/7/95	1.25 mCi
8/14/95	2.5 mCi
8/21/95	1 mCi

P.O. #030F7005

DATE RECEIVED	AMOUNT RECEIVED
6/12/95	1 mCi
6/26/95	1 mCi
6/19/95	1 mCi
7/10/95	1 mCi
7/24/95	1 mCi
8/7/95	1.25 mCi
8/21/95	1 mCi

10-95-22

Date	LSC Result (dpm/ml)	Date Counted	Time Counted	Time Correct (hours)	LSC Correct (dpm/ml)	LSC Bkg Correct (dpm/ml)	Volume (ml)	Activity (uCi)
8/26/95	1126	8/28/95	15:12	51.0	1248	1218	2670	1.456
8/27/95	949	8/28/95	15:12	27.0	979	949	3780	1.616
8/28/95	1339	8/28/95	15:12	3.0	1347	1317	3420	2.029
8/29/95	1623	8/29/95	13:02	1.0	1626	1596	2880	2.070
8/30/95	1274	8/30/95	15:41	3.75	1283	1253	2760	1.558
8/31/95	1514	8/31/95	13:30	1.5	1518	1488	2180	1.461
9/01/95	1488	9/01/95	16:06	4.0	1500	1470	2270	1.503
9/02/95	883	9/05/95	16:21	76.34	1030	1000	2940	1.324
9/03/95	561	9/05/91	16:21	52.34	623	593	3680	0.983
9/04/95	822	9/05/95	16:21	28.34	870	840	3250	1.230
9/05/95	892	9/05/95	16:21	4.34	900	870	2500	0.980
9/06/95	756	9/06/95	15:04	3.0	760	730	2720	0.894
9/07/95	800	9/08/95	8:22	20.34	833	803	2205	0.798
9/08/95	583	9/08/95	20:31	8.5	593	563	2750	0.697
9/09/95	447	9/13/95	7:40	91.75	538	508	2610	0.597
9/10/95	640	9/13/95	7:40	67.75	733	704	2490	0.790
9/11/95	593	9/13/95	7:40	43.75	647	618	2540	0.707
9/12/95	600	9/13/95	7:40	19.75	624	594	2520	0.674
9/13/95	450	9/14/95	7:34	19.5	468	438	2870	0.566
9/14/95	566	9/14/95	14:24	2.5	569	539	2150	0.522

9/15/95	276	9/19/95	7:27	91.5	332	302	3140	0.427
9/16/95	333	9/19/95	7:27	67.5	382	352	2420	0.385
9/17/95	244	9/19/95	7.27	43.5	266	236	3240	0.344
9/18/95	332	9/19/95	7:27	19.5	345	315	2220	0.315
9/19/95	287	9/20/95	8:23	20.5	299	269	2750	0.333
9/20/95	356	9/21/95	7:27	19.5	370	340	2500	0.383
9/21/95	286	9/22/95	7:59	20.0	298	268	2960	0.357
9/22/95	340	9/22/95	15:31	3.5	342	312	2120	0.298
9/23/95	226	9/26/96	9:04	69.0	260	230	2860	0.296
9/24/95	182	9/26/95	9:04	45.0	199	169	3250	0.247
9/25/95	197	9/26/95	9:04	21.0	205	175	3080	0.243
9/26/95	202	9/26/95	14:22	2.33	203	173	2660	0.07
9/27/95	202	9/28/95	16:15	28.25	214	184	2250	0.186
9/28/95	175	9/28/95	16:15	4.25	176	146	3230	0.212
9/29/95	180	10/2/95	15:39	75.75	209	180	2510	0.203
9/30/95	170	10/2/95	15:39	51.75	189	159	2800	0.200
10/1/95	177	10/2/95	15:39	27.75	187	157	2250	0.159
10/2/95	148	10/2/95	15:39	3.75	149	119	2800	0.150
10/3/95	156	10/3/95	15:35	3.5	157	127	2510	0.144
10/4/95	185	10/5/95	8:45	20.75	193	163	1750	0.128

10-95-23

Aug 95 16:56 Page #1

rotocol #:30 DIRECT DPM [redacted] User :

Urine Analysis Results

Time: 2.00
Data Mode: Direct DPM Nuclides:DIRECT-DPM
Background Subtract: None

	LL	UL	LCR	2SY	B/G
Region A:	0.0 -	2000	0	0.0	0.99
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

>	8/19/95	10:00 PM
>	8/20/95	0:45 AM ✓
>	8/20/95	2:00 AM ✓
>	8/20/95	8:20 AM ✓
>	8/20/95	5:10 AM ✓
>	8/20/95	8:30 AM ✓
>	8/20/95	2:55 AM ✓
>	8/20/95	4:22 AM ✓
>	8/20/95	9:00 PM ✓
>	8/21/95	6:30 AM
>	8/21/95	10:00 AM
>	8/19/95	4:00 PM

$6.3 \times 10^{-3} \frac{\mu c.}{ml} \times 600 ml = 3.78$

$3.6 \times 10^{-3} \frac{\mu c.}{ml} \times 600 ml = 2.16$

5 μc/L

Time: 2.00
...a Mode: Direct DPM Nuclides:DIRECT-DPM
Background Subtract: None

	LL	UL	LCR	2S%	BKG
Region A:	0.0	2000	0	0.0	0.00
Region B:	0.0	0.0	0	0.0	0.00
Region C:	0.0	0.0	0	0.0	0.00

BREATH TEST

						Vol
1	2.00	13576.5	13[illegible]	82.9	> 8/19/95	10:00 PM	600
2	2.00	14166.5	14[illegible]	28.[illegible]	> 8/20/95	0:45 AM	600
3	2.00	414[illegible]	41[illegible]	1[illegible]	> 8/20/95	2:00 AM	600
4	2.00	823.00	8[illegible]	[illegible]	> 8/20/95	8:20 AM	600
5	2.00	[illegible]	[illegible]	[illegible]	> 8/20/95	5:10 AM	600
6	2.00	[illegible]	[illegible]	[illegible]	> 8/20/95	8:30 AM	600
7	2.00	[illegible]	[illegible]	[illegible]	> 8/20/95	2:55 AM	600
8	2.00	579.50	583.84	57[illegible]	> 8/20/95	4:22 AM	90
9	2.00	914.50	920.06	57[illegible]	> 8/20/95	9:00 PM	570
10	2.00	[illegible]	[illegible]	[illegible]	> 8/21/95	6:30 AM	590
11	2.00	6651.00	2[illegible]	[illegible]	> 8/21/95	10:00 AM	440
12	2.00	3733.00	3[illegible]	334.50	>		5ml
13	2.00	40.00	4[illegible]	[illegible]			
14	2.00	28.50	[illegible]	[illegible]			
15	2.00	1834.00	1841.87	564.[illegible]			
16	2.00	1910.00	1915.81	529.[illegible]			
17	2.00	3216.50	3231.[illegible]	118.[illegible]			
18	2.00	3315.00	3339.[illegible]	338.[illegible]			
19	2.00	3713.50	3729.[illegible]	349.[illegible]			
20	2.00	3892.00	3910.[illegible]	344.[illegible]			
21	2.00	1227.00	1231.[illegible]	[illegible]			
22	2.00	1225.50	1236.[illegible]	2[illegible]			
23	2.00	6186.50	6220.[illegible]	285.[illegible]			
24	2.00	6284.50	6319.[illegible]	300.[illegible]			

8/20/95 Total excretion 1290 mL

8/21/95

Protocol #:30 DIRECT DPM User :

Time: 2.00

Data Mode: Direct DPM Nuclides:DIRECT-DPM

Background Subtract: None

	LL	UL	LCR	2S%	BKG
Region A:	0.0 - 2000		0	0.0	0.00
Region B:	0.0 - 0.0		0	0.0	0.00
Region C:	0.0 - 0.0		0	0.0	0.00

BREATH TEST

S#	TIME	CPMA	DPM1	tSIE	FLAG	EXCPTN
1	2.00	3496.00	3521.16	328.92		
2	2.00	3599.50	3633.19	328.22		
3	2.00	1319.50	1330.27	339.00		
4	2.00	1394.00	1403.27	330.38		
5	2.00	1983.50	1994.45	344.5[illegible]		
6	2.00	2006.50	2017.56	341.88		
7	2.00	324.00	328.98	358.[illegible]		
8	2.00	348.50	353.12	36[illegible]		

8/21 1200

Rows 1–2: > 8-22-95 6:20 Am — 600 ml

Rows 3–4: > 8-22-95 1:48 pm — (2,27 ml) 1.94 uCi

Rows 5–6: > 8-22-95 4:00 pm – 8-23-95 noon

Rows 7–8 (struck through): > 8-23-95 noon – 8/23/95 3 pm (180 ml)

Protocol #:30 DIRECT DPM User :

Time: 2.00
Data Mode: Direct DPM Nuclides:DIRECT-DPM
Background Subtract: None

	LL	UL	LCR	2SA	B+B
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

SQ	TIME	CHNA	DPM1	TBU FLOW	EXCPTN
1	2.00	492.30	492.95	365.47	
2	2.00	525.00	527.87	364.92	
3	2.00	1166.50	1171.65	18.21	
4	2.00	1197.00	1205.85	356.19	

200ml } 8123 12:00 - 3 pm
240ml } 8123 4:00 pm → 8124 12:00

Time: 2.00
Data Mode: Direct DPM Nuclides:DIRECT-DPM
Background Subtract: None

	LL	UL	LCR	2Σ%	BKG
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

S#	TIME	CPMA	DPMS	1σ IR FLAG	EXCESS
1	2.00	1933.00	1945.65	335.17	
2	2.00	1813.00	1889.80	350.60	

8/24 @ 1:40 PM –
8/25 @ 10:45 PM
3000 ml SAMPLE

28 Aug 95 15:12 Page #1
Protocol #:30 DIRECT DPM User :

Time: 2.00
Data Mode: Direct DPM Nuclides:DIRECT-DPM
Background Subtract: None

	LL	UL	LCR	2SX	2XB
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

SA	TIME	LSNA	DPM1	ESIE FLOO	EXCIN
1	2.00	1087.00	1104.59	335.08	
2	2.00	1139.00	1146.08	331.43	
3	2.00	976.50	990.42	344.64	
4	2.00	950.00	963.77	343.38	
5	2.00	1568.00	1576.72	342.48	
6	2.00	1292.00	1302.79	396.80	

2670ml (> 8/25 – 8/26 3
3780ml (> 8/26 – 8/27 2
3420ml (> 8/27 – 8/28 1

Time: 2.00
Data Mode: Direct DPM Nuclides:DIRECT-DPM
Background Subtract: None

	LL	UL	LCR	2S%	BKG
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

CS#	TIME	CPMA	DPM1	2S1E	FLAG	EXCPTN
1	2.00	1570.50	1581.28	332.79		
2	2.00	1651.00	1665.57	335.78		

2880 mds

>8/28/95 - 8/29

Time: 2.00
ta Mode: Direct DPM Nuclides:DIRECT-DPM
ackground Subtract: None

	LO	OL	LCR	2SS	BKG
Region A:	0.0	2000	0	0.0	0.00
Region B:	0.0	0.0	0	0.0	0.00
Region C:	0.0	0.0	0	0.0	0.00

BREATH TEST

SM	TIME	CPMA	DPM1	tSIE	FLAG	EXCPTN
1	2.00	1249.00	1256.31	345.25		
2	2.00	1249.00	1292.95	341.70		

2760 mR

> 8/29 - 8/30

8/29 -
8/30
12:00

Time: 2.00
Data Mode: Direct DPM Nuclides:DIRECT-DPM
Background Subtract: None

	LL	UL	LCR	2SS	SKS
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

S#	TIME	CPM0	DPM1	ESIE FLOW	EXCFIN
1	2.00	1446.00	1460.32	326.05	
2	2.00	1552.00	1568.97	332.45	

8/30 - 8/31

12:00

2130 ml

Time: 2.00
Data Mode: Direct DPM Nuclides:DIRECT-DPM
Background Subtract: None

	LL	UL	LCR	2SD	BKG
Region A:	0.0	2000	0	0.0	0.00
Region B:	0.0	0.0	0	0.0	0.00
Region C:	0.0	0.0	0	0.0	0.00

BREATH TEST

S#	TIME	CPMA	DPM1	ISIE	FLAG	EXCPTN
1	2.00	1416.80	1427.96	345.25		
2	2.00	1547.00	1558.31	341.77		

148

2220 ml

8/31 - 9/1/95

12:a - 12:a

Time: 2.00
Mode: Direct DPM Nuclides:DIRECT-DPM
Background Subtract: None

	LL	UL	LCR	2SX	BKG
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

	S#	TIME	CPMA	DPM1	tBIE	FLAG	EXCPTN	
2940 mL	1	2.00	824.50	834.13	357.55	>	9/1 - 9/2	
	2	2.00	919.50	932.47	359.00			
3680 mL	3	2.00	541.50	546.02	371.37	>	9/2 - 9/3	
	4	2.00	561.00	571.77	373.34			
3250	5	2.00	804.50	808.70	359.08	>	9/3 - 9/4	
	6	2.00	829.50	835.29	355.00			
2500 mL	7	2.00	882.50	891.37	360.12	>	9/4 - 9/5	9/5 16:20
	8	2.00	885.00	892.05	343.80			

Protocol #:30 DIRECT DPM User :

Time: 2.00
ta Mode: Direct DPM Nuclides:DIRECT-DPM
ackground Subtract: None

	LL	UL	LCR	2SΣ	BkG
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

S#	TIME	CPM0	DPM	ESIE	FLOW	EXCPTN
1	2.00	771.00	778.24	352.83		
2	2.00	722.00	733.90	352.97		

2720 ml

> 9/5 - 9/6

Time: 2.00
ta Mode: Direct DPM Nuclides:DIRECT-DPM
ackground Subtract: None

	LL	UL	LCR	2SX	BKG
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

S#	TIME	CPMA	DPM1	LS E	FLAG	EXCPTN
1	2.00	771.00	782.32	351.07		
2	2.00	811.00	818.21	345.48		

2205 m/ > 9/6 - 9/7

Protocol #:30 DIRECT DPM User :

Time: 2.00
Data Mode: Direct DPM Nuclides:DIRECT-DPM 9/7- 9/8
Background Subtract: None

	LL	UL	LCR	2S%	BKG
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

S#	TIME	CPMA	DPM1	tSIE	FLAG	EXCPTN
1	2.00	573.50	575.08	359.83	>	
2	2.00	584.00	591.98	359.28		

2750ml

Time: 2.00
ta Mode: Direct DPM Nuclides:DIRECT-DPM
ackground Subtract: None

	LL	UL	LCR	2S%	BKG
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

	S#	TIME	CPMA	DPM1	tSIE	FLAG	EXCPTN	
	1	2.00	438.50	443.88	354.98	>	9/8 - 9/9	t = 4.5
2610	2	2.00	448.50	451.89	355.92			
	3	2.00	631.50	636.07	354.21	>	9/9 - 9/10	t = 3.5
2490	4	2.00	632.00	643.85	351.90			
	5	2.00	574.00	584.30	354.30	>	9/10 - 9/11	t = 2.5
2540	6	2.00	598.00	602.82	351.93			
	7	2.00	582.50	586.71	361.64	>	9/11 - 9/12	t = 1.5
2520	8	2.00	610.00	614.88	356.75			

14 Sep 95 07:34 Page #1

Protocol #:30 DIRECT DPM User :

Time: 2.00
Data Mode: Direct DPM Nuclides:DIRECT-DPM
Background Subtract: None

	LL	UL	LCR	2S%	BKG
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

S#	TIME	CPMA	DPM1	tSIE	FLAG	EXCPTN
1	2.00	438.50	444.78	361.22	>	9/12 - 9/13
2	2.00	452.00	456.64	364.88	>	

2 t=1.5

2870 mL

Protocol #:30 DIRECT DPM User :

Time: 2.00
Data Mode: Direct DPM Nuclides:DIRECT-DPM
Background Subtract: None

	LL	UL	LCR	2S%	BKG
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

S#	TIME	CPMA	DPM1	tSIE	FLAG	EXCPTN
1	2.00	562.00	565.74	345.89	>	9/13 - 9/17
2	2.00	559.00	566.90	349.17		

25 pmol

Protocol #:30 DIRECT DPM User :

Time: 2.00
Data Mode: Direct DPM Nuclides:DIRECT-DPM
Background Subtract: None

	LL	UL	LCR	2S%	BKG
Region A:	0.0	2000	0	0.0	0.00
Region B:	0.0	0.0	0	0.0	0.00
Region C:	0.0	0.0	0	0.0	0.00

BREATH TEST

	S#	TIME	CPMA	DPM1	tSIE	FLAG	EXCPTN	
3140	1	2.00	256.50	263.04	356.83	>	9/14 - 9/15	4.5 d.
	2	2.00	283.00	289.86	375.06			
2420	3	2.00	339.50	343.34	356.38	>	9/15 - 9/16	3.5 d.
	4	2.00	319.00	323.38	358.02			
3240	5	2.00	243.50	246.98	374.70	>	9/16 - 9/17	2.5 d.
	6	2.00	233.00	242.07	372.24			
2220	7	2.00	336.00	346.74	356.61	>	9/17 - 9/18	1.5 d.
	8	2.00	312.00	317.31	355.12			
2 MISSING TUBE(S)								
	11	2.00	328.50	336.13	354.86	>	9/8 - 9/9	
	12	2.00	310.50	318.42	353.60			

Protocol #:30 DIRECT DPM User :

ae: 2.00

Data Mode: Direct DPM Nuclides:DIRECT-DPM

Background Subtract: None

	LL	UL	LCR	2S%	BKG
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

S#	TIME	CPMA	DPM1	tSIE	FLAG	EXCPTN
279 1	2.00	284.50	290.83	375.37	> 9/18 - 9/19	
2	2.00	271.50	285.61	372.33		

Protocol #:30 DIRECT DPM User :

ıe: 2.00

Data Mode: Direct DPM Nuclides:DIRECT-DPM

Background Subtract: None

	LL	UL	LCR	2S%	BKG
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

S#	TIME	CPMA	DPM1	tSIE	FLAG	EXCPTN
1	2.00	372.50	384.34	362.06		
2	2.00	324.50	329.87	362.10	>	9/19 - 9/20

2500 ml

Protocol #:30 DIRECT DPM User :

ıe: 2.00

Data Mode: Direct DPM Nuclides:DIRECT-DPM

Background Subtract: None

	LL	UL	LCR	2S%	BKG
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

S#	TIME	CPMA	DPM1	tSIE	FLAG	EXCPTN
2900 1	2.00	282.50	292.46	355.94	9/20 - 9/21	
ml 2	2.00	273.50	280.29	354.58		

ge: 2.00
Data Mode: Direct DPM Nuclides:DIRECT-DPM
Background Subtract: None

	LL	UL	LCR	2S%	BKG
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

S#	TIME	CPMA	DPM1	tSIE	FLAG	EXCPTN
1	2.00	336.50	338.73	340.65		
2	2.00	337.50	341.19	340.24		

Z120ND 9/21-9/22

Time: 2.00
a Mode: Direct DPM Nuclides: RECT-DPM
Background Subtract: None

	LL	UL	LCR	2S%	BKG
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

S#	TIME	CPMA	DPMi	tSIE	FLAG	EXCPTN		
1	2.00	228.50	235.57	354.72	> 2880 ml		9/22 - 9/23	12:00 - 12:00
2	2.00	214.50	217.30	350.97				
3	2.00	172.50	175.50	356.98	> 3250 ml		9/23 - 9/24	" "
4	2.00	184.00	188.79	353.51				
5	2.00	187.50	189.39	356.90	> 3080 ml		9/24 - 9/25	" -
6	2.00	198.50	204.38	355.51				

Protocol #:30 DIRECT DPM User :

Time: 2.00

Mode: Direct DPM Nuclides:DIRECT-DPM

Background Subtract: None

	LL	UL	LCR	25%	BKG
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

S#	TIME	CPMA	DPM1	tSIE	FLAG	EXCPTN
1	2.00	205.50	211.58	351.56	>2660mL	9/25 - 9/26 12:00 - 12:00
2	2.00	183.50	193.01	345.58		

Time: 2.00
Mode: Direct DPM Nuclides:DIRECT-DPM
Background Subtract: None

	LL	UL	LCR	2S%	BKG
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

S#	TIME	CPMA	DPM1	tSIE	FLAG	EXCPTN	
1	2.00	195.00	201.22	345.91	>	9/26 - 9/27	2250 ml
2	2.00	197.00	203.10	346.51			
3	2.00	176.00	181.30	360.65	>	9/27 - 9/28	3230 ml
4	2.00	163.00	169.93	364.37			

Protocol #:30 DIRECT DPM User :

Time: 2.00

Mode: Direct DPM Nuclides:DIRECT-DPM

Background Subtract: None

	LL	UL	LCR	2S%	BKG
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

S#	TIME	CPMA	DPM1	tSIE	FLAG	EXCPTN	
1	2.00	178.50	186.86	347.28	>	9/28 - 9/29	2510 ml
2	2.00	173.50	175.90	348.29			
3	2.00	163.50	167.70	348.76	>	9/29 - 9/30	2800 ml
4	2.00	173.50	173.75	354.84			
5	2.00	175.00	181.92	345.87	>	9/30 - 10/1	2250 ml
6	2.00	172.00	174.21	343.66			
7	2.00	150.50	156.59	356.30	>	10/1 - 10/2	2800 ml
8	2.00	133.50	140.03	356.80			

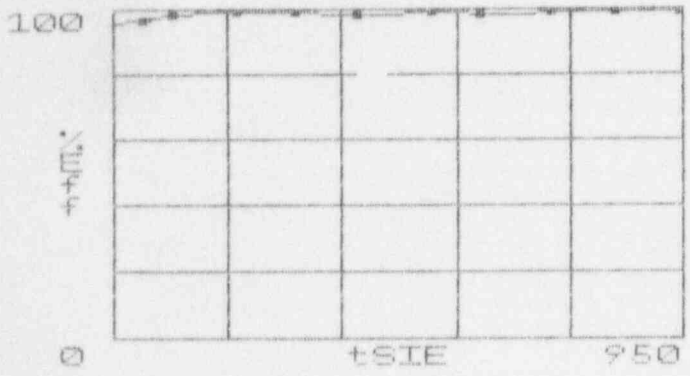
Protocol #: 8 P-32 DPM User :

Time: 2.00
Mode: DPM Nuclide: 32P Quench Set: 32P
Background Subtract: IPA

	LL	UL	LCR	2S%	BKG
Region A:	5.0 -	1700	0	0.0	23.60
Region B:	50.0 -	1700	0	0.0	11.83
Region C:	0.0 -	0.0	0	0.0	0.00

Quench Indicator: tSIE/AEC
Ext Std Terminator: Count

Color Quench Correction On



tSIE	%Eff
943.52	99.39
836.67	98.91
726.67	98.79
609.66	98.69
526.90	98.94
403.14	98.52
300.63	99.02
203.67	99.18
98.98	98.37
48.71	97.04

S#	TIME	CPMA	DPM1	SIS	tSIE	FLAG		
1	2.00	128.90	130.55	785.66	347.69	>	9/28 - 9/29	2510 ml
2	2.00	154.40	156.38	756.14	347.82			
3	2.00	130.90	132.60	797.78	351.16	>	9/29 - 9/30	2800 ml
4	2.00	132.90	134.65	814.01	354.79			
5	2.00	141.40	143.20	758.43	345.94	>	9/30 - 10/1	2250 ml
6	2.00	133.40	135.09	749.82	345.33			
7	2.00	97.90	99.19	795.48	354.30	>	10/1 - 10/2	2800 ml
8	2.00	97.90	99.20	656.96	356.41			

Protocol #:30 DIRECT DPM User :

Time: 2.00
Data Mode: Direct DPM Nuclides:DIRECT-DPM
Background Subtract: None

	LL	UL	LCR	2S%	BKG
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

S#	TIME	CPMA	DPM1	tSIE	FLAG	EXCPTN
1	2.00	144.00	151.29	351.76		
2	2.00	158.00	162.99	347.92		

> 10/2 -10/3 2510 ml

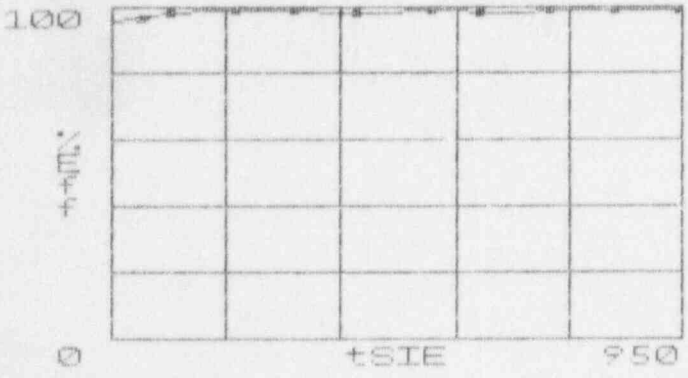
Protocol #: 8 P-32 DPM User :

Time: 2.00
Mode: DPM Nuclide: 32P Quench Set: 32P
Background Subtract: IPA

	LL	UL	LCR	2S%	BKG
Region A:	5.0 -	1700	0	0.0	23.65
Region B:	50.0 -	1700	0	0.0	11.95
Region C:	0.0 -	0.0	0	0.0	0.00

Quench Indicator: tSIE/AEC
Ext Std Terminator: Count

Color Quench Correction On



tSIE	%Eff
943.52	99.39
836.67	98.91
726.67	98.79
609.66	98.69
526.90	98.94
403.14	98.52
300.63	99.02
203.67	99.18
98.98	98.37
48.71	97.04

S#	TIME	CPMA	DPM1	SIS	tSIE	FLAG
1	2.00	136.35	137.96	728.38	329.31	
2	2.00	159.35	161.16	786.62	322.17	

> 10/3 - 10/4 1750 ml

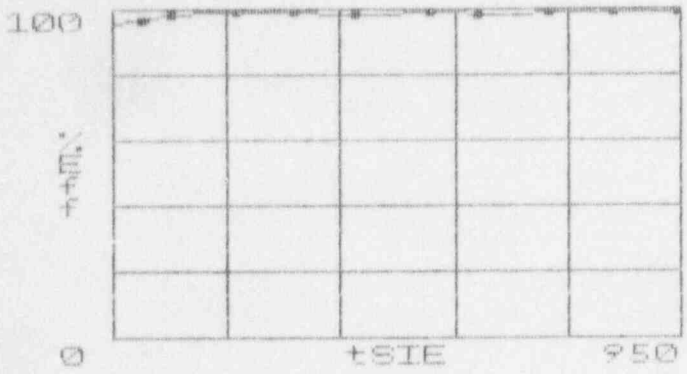
Protocol #: 8 P-32 DPM User :

Time: 2.00
's Mode: DPM Nuclide: 32P Quench Set: 32P
Background Subtract: IPA

	LL	UL	LCR	2S%	BKG
Region A:	5.0 -	1700	0	0.0	23.60
Region B:	50.0 -	1700	0	0.0	11.83
Region C:	0.0 -	0.0	0	0.0	0.00

Quench Indicator: tSIE/AEC
Ext Std Terminator: Count

Color Quench Correction On



tSIE	%Eff
943.52	99.39
836.67	98.91
726.67	98.79
609.66	98.69
526.90	98.94
403.14	98.52
300.63	99.02
203.67	99.18
98.98	98.37
48.71	97.04

S#	TIME	CPMA	DPM1	SIS	tSIE	FLAG
1	2.00	163.40	165.52	572.30	350.98	>
2	2.00	155.90	157.72	562.10	350.32	>

10/4 - 10/5 2320 ml

Protocol #:30 DIRECT DPM User :

Time: 2.00

Mode: Direct DPM Nuclides:DIRECT-DPM

Background Subtract: None

	LL	UL	LCR	2S%	BKG
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

S#	TIME	CPMA	DPM1	tSIE	FLAG	EXCPTN
1	2.00	169.00	173.63	330.99	>	1750 ml
2	2.00	191.00	197.22	321.76		

10/3 - 10/4

Protocol #:30 DIRECT DPM User :

Time: 2.00
Data Mode: Direct DPM Nuclides:DIRECT-DPM
Background Subtract: None

	LL	UL	LCR	2S%	BKG
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

S#	TIME	CPMA	DPM1	tSIE	FLAG	EXCPTN	
1	2.00	102.50	106.59	344.86	>	10/4 - 10/5	2320 ml
2	2.00	118.50	127.44	344.74			
3	2.00	100.00	106.98	354.47	>	10/5 - 10/6	3130 ml
4	2.00	91.00	96.67	354.28			
5	2.00	101.50	108.07	344.36	>	10/6 - 10/7	2250 ml
6	2.00	89.00	91.41	341.12			
7	2.00	100.00	104.94	347.39	>	10/7 - 10/8	2280 ml
8	2.00	95.50	96.36	347.16			
9	2.00	105.00	109.29	348.01	>	10/8 - 10/9	2290 ml
10	2.00	114.00	121.82	347.12			
11	2.00	96.50	102.94	342.32	>	10/9 - 10/10	2450 ml
12	2.00	98.00	99.95	344.52			
13	2.00	103.50	107.09	348.99	>	10/10 - 10/11	2350 ml
14	2.00	113.00	116.80	346.13			
15	2.00	108.00	112.52	344.69	>	10/11 - 10/12	3050 ml
16	2.00	122.50	128.48	341.55			

Protocol #:30 DIRECT DPM User :

Time: 10.00
Mode: Direct DPM Nuclides:DIRECT-DPM
Background Subtract: None

	LL	UL	LCR	2S%	BKG
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

S#	TIME	CPMA	DPM1	tSIE	FLAG	EXCPTN
1	10.00	28.40	31.85	462.22	> BKGD.	
2	10.00	29.70	34.80	467.34		

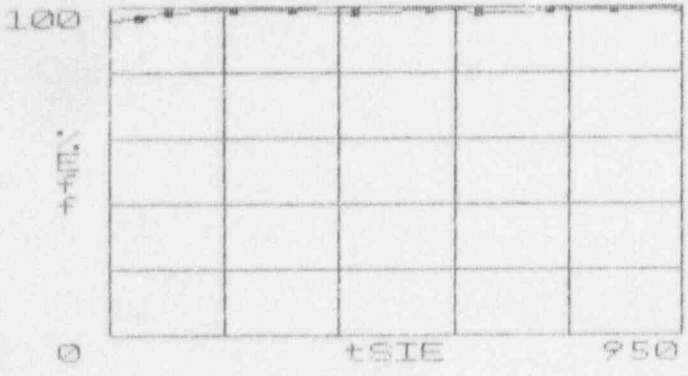
^{32}P counting efficiency $\approx$ 99 %

Time: 2.00
Mode: DPM Nuclide: 32P Quench Set: 32P
Background Subtract: IPA

	LL	UL	LCR	2S%	BKG
Region A:	5.0 -	1700	0	0.0	23.62
Region B:	50.0 -	1700	0	0.0	11.88
Region C:	0.0 -	0.0	0	0.0	0.00

Quench Indicator: tSIE/AEC
Ext Std Terminator: Count

Color Quench Correction On



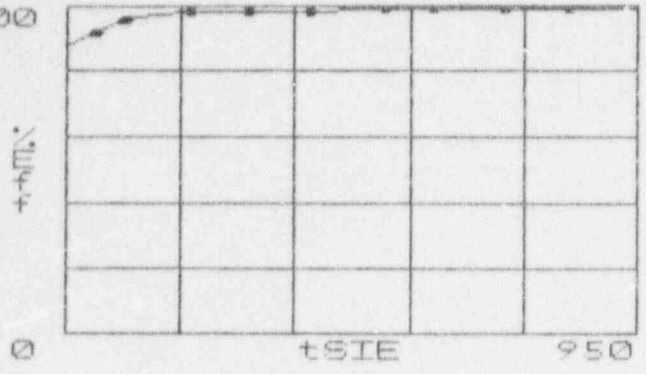
tSIE	%Eff
943.52	99.39
836.67	98.91
726.67	98.79
609.66	98.69
526.90	98.94
403.14	98.52
300.63	99.02
203.67	99.18
98.98	98.37
48.71	97.04

S#	TIME	CPMA	DPM1	SIS	tSIE	FLAG
1	2.00	117.88	119.37	854.56	344.24	
2	2.00	120.38	121.90	783.72	343.45	

10/2 - 10/3 2510

10-95-25

Data Mode: DPM
QIP Type: tSIE



tSIE	%Eff
943.52	99.61
836.67	99.17
726.67	99.11
609.66	99.08
526.90	99.22
403.14	98.50
300.63	98.54
203.67	98.18
98.98	96.11
48.71	91.89

^{32}P calibration curve

Packard LSC

Whole body calibration for ^{32}P 10-95-26

Purchased ^{32}P sample from NENC

activity on technical data sheet: 1.21 mC. in 500µl on 8/22/95

pipette 100 λ containing 242µC.
add 900 λ of H_2O

Thus standard solution → 242µC. in 1000µl

add additional 1000µl of H_2O to standard solution

Thus concentration of standard solution: 242µC/2000µl = 12.1µC/100µl

The activity was verified by Liquid Scintillation Counting (LSC)
(see attached results)

The standard solution concentration: 14.8µC./100µl

The phantoms were prepared as follows on 8/22/95:

Thigh 1	– 100µl	—	14.8µC.
Thigh 2	– 100µl	—	14.8µC.
Kidney 1	– 100µl	–	14.8µC.
Kidney 2	– 100µl	—	14.8µC.
GI Tract	– 300µl	–	44.4µC.
Liver	– 200µl	–	29.6µC.
Total	900µl	–	133.2µC.

The phantoms were analyzed in the whole body counter on 8/22/95.
Total integration: 94,185

Calibration by LSC:

Pipette 100 µl of stock solution – estimated 12.1 µCi from technical data sheet

add 100 ml of H_2O

Standard solution concentration determined at 12.1 µCi/100 ml

Specific Activity = 0.121 µCi/ml

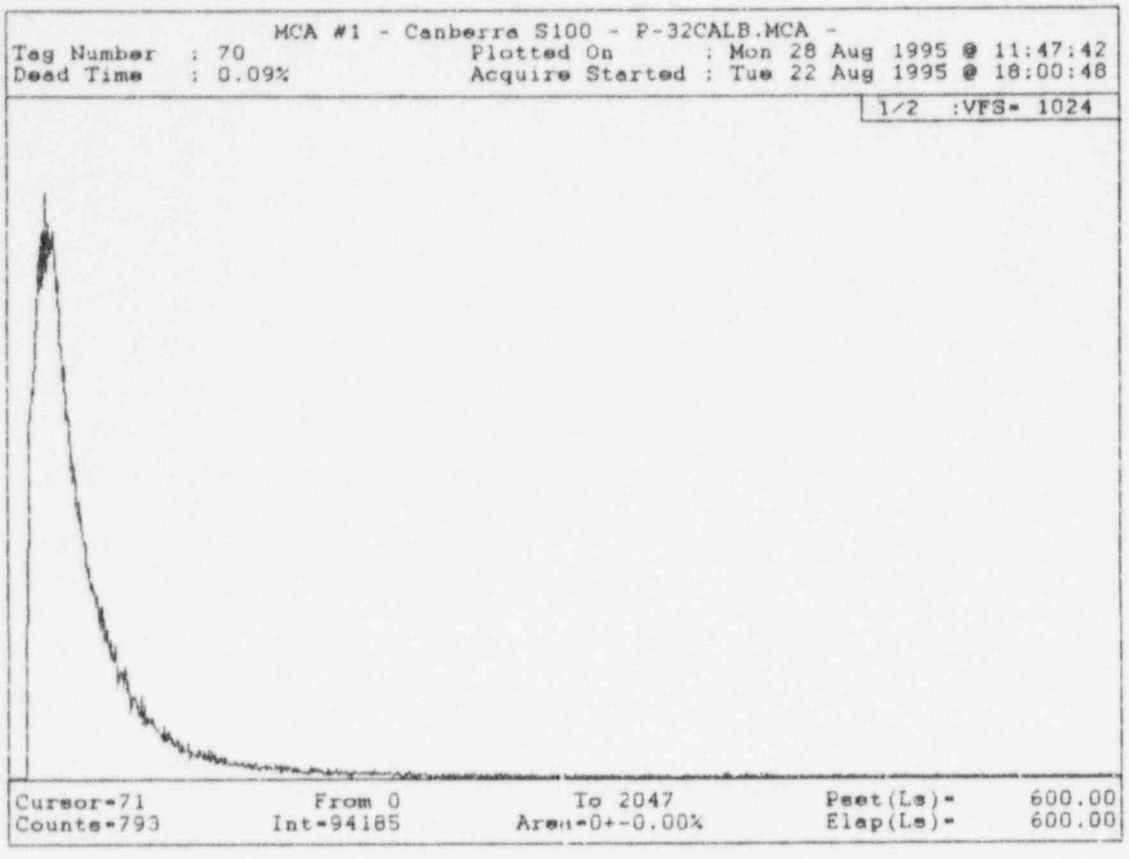
Analyze 100 µl and 50 µl samples

$$100\,\mu l - \frac{32828\ dpm}{100\,\mu l} \times \frac{1\ \mu Ci}{2.22\times10^{6}\ dpm} = 1.48\times10^{-1}\ \mu Ci/ml$$

$$- 1.48\times10^{-1}\ \mu Ci/ml \times 100\ ml = 14.8\ \mu Ci \text{ per } 100\,\mu l \text{ of stock solution}$$

$$50\,\mu l - \frac{16235\ dpm}{50\,\mu l} \times \frac{1\ \mu Ci}{2.22\times10^{6}\ dpm} = 1.46\times10^{-1}\ \mu Ci/ml$$

$$- 1.46\times10^{-1}\ \mu l/ml \times 100\ ml - 14.6\ \mu Ci \text{ per } 100\,\mu l \text{ of stock solution}$$



Calibration spectrum for ^{32}P in whole body counter

Activity = 133 μCi

22 Aug 95 19:03 Page #1

Protocol #:30 DIRECT DPM User :

LSC calibration

Time: 2.00

Data Mode: Direct DPM Nuclides:DIRECT-DPM

Background Subtract: None

	LL	UL	LCR	2σ%	BKG
Region A:	0.0 -	2000	0	0.0	0.00
Region B:	0.0 -	0.0	0	0.0	0.00
Region C:	0.0 -	0.0	0	0.0	0.00

BREATH TEST

S#	TIME	CPM	DPM	2σ%	FLAG	EXCPTN
1	2.00	32703.5	32893.4	432.50		
2	2.00	32096.5	32763.5	436.70		
3	2.00	16577.5	15669.0	441.93		
4	2.00	16694.0	16801.6	431.43		

$> 100\lambda$ 1.48×10^{-2} μC:

$> 50\lambda$ 7.31×10^{-3} μC:

ORDER NUMBER	PAGE
82737120	1

DUPONT

PONT de NEMOURS & CO. INC.

EDICAL PRODUCTS DEPARTMENT
IOTECHNOLOGY DIVISION
ILMINGTON, DE. 19898

LD TO:

MASS INSTITUTE OF TECHNOLOGY
ACCTS PAYABLE
PO BOX 69
CAMBRIDGE MA 02139-0901

DELIVER TO:
TECHNOLOGY
BLDG 20 RECEIVING
CAMBRIDGE MA 02139

(617) 253-0000
AC/BOS
ASSOCIATED COURIER
MITCH GALANEK WINGC/207
ISOTOPES: P32
TOT ACTIVITY: .044770 GBQ(001210 CI

LOCAL

ATTN:

82737120	GFR598808
ORDER NUMBER	CUSTOMER P. O. NUMBER

SHIP TERMS	VIA	PAID	COLL
FOB DESTINATION	TRUCK	X	

SHIPPING POINT: DUPONT/NEN 549 ALBANY ST. BOSTON, MA 02118

S NO. 51-0014090

CUSTOMER NUMBER	SHIPMENT COMPLETE	SHIPMENT PARTIAL	TECH REP	CSR	LICENSE NUMBER	RADIATION AT SURFACE	INSPECTOR	PKG
021770 001	X		128	RA	20-01537-02	.0181MR/HR		D1

ITY DATE	SCHEDULED DATE	SHIPPING DATE	AR NUMBER	TAX LOCATION	TAX CLASS	REN	SALES CLASS
08/21/95	08/22/95	08/22/95	559960	37193	00	09	00

QUANTITY ORDERED	QUANTITY SHIPPED	PART NUMBER	DESCRIPTION	PACKAGE SIZE	LOT/SERIAL NUMBER
1	1	NEG002X 0117	ADENOSINE 5'-TRIPHOSPHATE TETRA-(TRIETHYLAMMONIUM)SALT [G-32P]-	1MC 37000KBQ	002X08175

QUESTIONS REGARDING THIS ORDER CALL: 800-551-2121 3,1

OTOPES: P32
O.T. LABEL: 1 WHITE
TAL ACTIVITY .044770 GBQ
TAL ACTIVITY .001210 CI

TRANS. INDEX: 0

0687

4-A-02

COPY

10-95-27

Urinanalysis Bioassay Procedures

1. Pipette 10 ml of liquid scintillation fluid into 20 ml plastic counting vial.
2. Pipette 1 ml of urine into liquid scintillation fluid.
3. Prepare samples in duplicate.
4. Load samples into counting rack for Packard liquid scintillation counter.
5. Select appropriate counting protocol from menu for the radioisotope of interest (example: protocol 2 for tritium).
6. Analyze samples. Pay particular attention to the quench indicating parameter when reviewing results.
7. Record results in workers registration form for inclusion in dose history.
8. Run SNC protocol with tritium, ^{14}C, and background samples to check analyzer operability.
9. Any questions about results, please contact M. Galanek.

10-95-28

RP-37
Rev. 7/84

M.I.T. RADIATION PROTECTION OFFICE

RADIATION SURVEY RECORD

Room # _____ Department _____

Laboratory Classification _____ Results Recorded _____

Radiation Measurements : Unless otherwise specified, measurements recorded are in mrad/hr at 3 ft. above floor.

Floor Plan and Measurement Locations :

Laboratory's Survey Meters : _____

Authorized Radionuclides, Amounts, and Notes :

M.I.T. RADIATION PROTECTION OFFICE

RADIATION SURVEY RECORD

	Measurement Locations and Results *								Measurement Locations and Results *							
Date	1	2	3	4	5	6	WC	LSM	Date	1	2	3	4	5	6	WC	LSM

* A check (✓) designates an instrument reading of less than 0.5 mrad/hr.
WC = "Waste Container". A check (✓) indicates less than 0.5 mrad/hr at 1 foot.
LSM = "Laboratory Survey Meter". A check (✓) indicates instruments are operating properly.

____

Surveyor's Signature

RADIATION PROTECTION OFFICE

RP-315
Rev. 11/90

Work Sheet For Radiation Surveys

Survey Date	Room #	Waste Records	Instrument Check	Radiation Levels	Contamination Survey	Evidence of Eating & Drinking	Labcoats using Radioactivity	Comments & Action Taken by Survey Technician

Instructions: If a heading is not applicable for the room, insert NA. A check mark means satisfactory. If unsatisfactory, specify under comments, & give the appropriate Staff Member and Technician responsible for those areas reported unsatisfactory, a copy of the work sheet. Each Technician will keep the original copies in a loose-leaf notebook; in chronological order, with the most recent sheet as the first page.

Signature of Survey Technician _____

Copies given to: _____

(Name of Staff Member & Technician)

Type of Survey Requested: _____ _____

Location (room #): _____ Person Requesting Survey _____

Date: _____ Time _____ Telephone Ext: _____

Person Receiving Request _____

Description of Findings: _____ _____

_____

_____

Names of Persons Involved: _____

_____

_____

_____

RADIATION SURVEY RESULTS

Wipe Test Results: _____

_____

Survey Meter Results: _____

_____

Recommendations and Actions Taken: _____

_____

_____

_____

_____

Survey Performed By: _____ Date: _____

Staff Review By: _____ Date: _____

RP-34
Rev. 12/81

M.I.T. RADIATION PROTECTION OFFICE
RADIOISOTOPE LABORATORY INFORMATION

PI _____ Supervisor _____ Dept. _____

Person in charge of laboratory safety _____ Ext. _____

Laboratory Classification _____

Authorization #	Starting Date	Possession Limits		Comments
		Nuclide	Amount	

REGISTERED LABORATORY RADIATION SAFETY AUDIT

Date: _____

A. **General Information**:

1. Project Supervisor:

_____ _____ _____
(Title) (Name) (Authorization Number)

2. Room Inspected: _____ Level: _____ Department: _____

3. Radioactive Material Currently In Use:

Radionuclide	Chemical Form	Sealed/ Unsealed	Activity (max)
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

4. Radiation Producing Equipment:

_____ _____ _____
(Type) (Maximum energy) (Location)

B. **Initial Inspection**: A [✓] indicates proper radiation safety controls; a [*] indicates deficiencies noted, comments below; a [**N/A**] indicates not applicable.

[ ] 1. Room signs properly posted (NRC form 3, radiation signs, 10 CFR 19/20 posting).

[ ] 2. Areas in which radioactive material is used is adequately segregated and marked.

[ ] 3. Radionuclide inventory correct and up-to-date.

4. Solid/liquid waste:

[ ] a. Containers not full.

[ ] b. Waste cards (solid/liquid container, sink) properly filled out.

[ ] 5. No eating, drinking, smoking, or application of cosmetics in laboratory.

[ ] 6. All persons wearing safety glasses.

[ ] 7. Persons performing work with unsealed radioactive material wearing labcoat (buttoned, sleeves rolled down), gloves.

[ ] 8. Unattended radioactive material properly labeled/shielded.

[ ] 9. Radioactive material not stored in unregistered cold/warm rooms, freezers, refrigerators.

10. Survey meter(s):

[ ] a. Battery check O.K.

[ ] b. Meter(s) within calibration date (yellow sticker)

[ ] c. GM, NaI (circle) probe intact.

11. Registered cold/warm rooms, freezers, refrigerators:

[ ] a. No food, beverage storage.

[ ] b. All radioactive material samples labeled.

C. **Radiation Level Survey**:

[ ] 1. Record laboratory background (BKG) radiation level _____ mR/hr.

[ ] 2. Bench-top levels ≤ 0.5 mR/hr in front of shields.

[ ] 3. Floor levels ≤ BKG.

4. Waste containers:

[ ] a. Floor models ≤ 200 mR/hr on contact, ≤ 2 mR/hr at 3 ft.

[ ] b. Bench-top models ≤ 1 mR/hr on contact.

[ ] 5. Sink basins and drains ≤ BKG.

[ ] 6. Non-radioactive waste containers ≤ BKG.

[ ] 7. Equipment (eg. centrifuges, ring stands, water baths, etc.) ≤ 0.5 mR/hr on contact.

D. **Comments**: Indicate item number and comments.

_____

_____

_____

_____

_____

E. **Person Performing Survey**:

_____ _____

(Signature) (Date)

10-95-29

4 November 1994

Package Check-in and Delivery Procedure

I. Introduction

A. This document describes requirements for all radioactive material receipt and delivery for the Massachusetts Institute of Technology, Cambridge campus, and the Whitehead Institute and Genome Center.

B. Packages containing radioactive material are received Monday through Friday from 8 a.m. to 5 p.m. at the following locations only:

MIT Building 20 Receiving
18 Vassar St.
Cambridge MA 02139

Whitehead Institute Receiving
9 Cambridge Center
Cambridge MA 02142

Whitehead Institute-Genome Center
One Kendall Square, Building 300
Cambridge, MA 02139

C. Special delivery requests must be arranged with the Radiation Protection Office. Security will not sign for any package delivery attempt after the posted hours.

II. General Package Receipt and Delivery Practices

A. Receiving will notify the Radiation Protection Office upon receipt of radioactive shipments.

B. Packages are checked in by an RPO Technician, monitored for radiation levels, wipe tested for surface contamination, inspected for damage, and delivered if acceptable.

1. Federal regulations (10 CFR 20.1906) require that packages be monitored within three hours of receipt if received during normal work hours.

2. More limiting, the broad scope licenses state that these surveillances should be completed within one

hour of package receipt.

C. Only those packages which meet radiation monitoring and wipe test requirements will be delivered to the appropriate end-user.

D. The RPO Technician will report any discrepancies in labelling, packaging, radiation monitoring and/or contamination levels to the RPO staff member responsible for packages for immediate attention. Should this staff member be unavailable, contact the staff member for the recipient's laboratory.

E. Any time that radioactive material is not delivered to the user, it must be determined if special handling like cold storage is required for material integrity and make arrangements for such.

F. All records must be complete. Use of "ditto" marks, arrows, or other notations in lieu of actual data is unacceptable. If data is not applicable or not available, use the abbreviation "NA".

III. Relevant Transportation Regulations

A. Package Labeling

1.	No Label	Excepted Quantity for activity $\leq$ 0.5 mrem/hour @ surface
2.	White I Label	$\leq$ 0.5 mrem/hour @ surface Background Dose Rate @ 1 meter
3.	Yellow II Label	> 0.5 - 50 mrem/hour @ surface $\leq$ 1.0 mrem/hour @ 1 meter
4.	Yellow III Label	> 50 - 200 mrem/hour @ surface > 1 - 10 mrem/hour @ 1 meter

B. Excepted quantities of radioactive material are defined by the Department of Transportation Hazardous Materials Regulations of 49 CFR 100-177 and 178-179. They are formally called limited quantities.

1. Limited quantities are excepted from some packaging and labeling requirements.

2. A limited quantity equals 10^{-4} times the activity level for a particular nuclide in Table A-2 in 10 CFR 71 if it is a liquid, and 10^{-3} times the 10 CFR 71 activity level in Table A-2 for a solid.

3. The limited quantities for selected radionuclides will be posted where radioactive materials are checked-in.

C. The transport index (TI) is the dose rate at 1 meter rounded up to the first decimal place. The TI is indicated on Yellow II and Yellow III package labels.

IV. Responsibilities

A. RPO Secretary

1. Take package Purchase Order Number information from Receiving and enter on form *RP-08: Information for Checking-In Shipments of Radioactive Material* (see Appendix 1).

2. Look up the Purchase Order Number in either the MIT or Whitehead Order Book.

   a. Write the purchase order number on the form. Add the initials s.o. if the purchase order is a standing order.

   b. Add the appropriate end-user's name on *RP-08* form under "Ordered By" heading.

   c. Under the "Material Ordered" heading, write down "Nuclide" and "mCi" ordered on *RP-08* form.

   d. Under the "Comments" column, record the room number for delivery and other comments useful to the check-in and delivery technician.

3. Give form *RP-08* to the check-in and delivery technician.

4. Upon return of form *RP-08* from the check-in and delivery technician, enter completed information in dBase III Plus.

   a. MIT orders are filed in dbase\data\MITORDER.dbf

   b. Whitehead and Genome orders are filed in dbase\data\WIORDER.dbf.

B. RPO Technician

1. Pick up the radioactive material packages from Receiving.

2. Using the partially completed *RP-08* form obtained from the RPO secretary:

   a. Write down the actual "Nuclide" and "mCi" of radioactive material received under "Material Received" columns of *RP-08* form. The actual nuclide and activity is that which is recorded on the package's shipping papers.

   b. If information regarding "Material Ordered" and "Material Received" differ, contact an RPO staff member to determine appropriate response.

   c. Note that radionuclides with short half-lives like ^{32}P may be received with activities greater than those ordered. This is a practice of the isotope suppliers to account for decay.

      (1) A short half-life is defined as less than 90 days for this function.

      (2) A 10-20% greater activity for short half-life materials is generally acceptable.

      (3) When the activity delivered exceeds 150% of ordered value for short half-life materials or 110% for long half-life materials, contact the RPO staff member responsible for packages for disposition.

3. Return completed *RP-08* form to the RPO Secretary daily and attached to the completed form *RP-016: Record of Delivery of Radioactive Packages*. This is the only method of maintaining up to date Standing Orders.

4. Perform radiation monitoring and wipe tests for each package in accordance with Appendix 2.

5. Record the radiation monitoring and wipe test results on form *RP-012: Record of Checking-In and Delivery of Radioactive Material* (see Appendix 1).

6. Keep and maintain *RP-012* forms in the log book in room 20C-028 for MIT, in the Shipping and Receiving Room for Whitehead Institute, and the Shipping and Receiving Room for the Genome Center.

7. Attach form *RP-017: Procedure for Opening Packages Containing Radioactive Material* (see Appendix 1) to each package prior to delivery.

8. Deliver packages which meet radiation monitoring and wipe test requirements only to the designated end-user or to a co-worker.

   a. The co-worker must be a registered radiation worker.

   b. Packages are not to be left with a secretary, unless authorized by the RPO staff member responsible for packages.

9. Delivery documentation.

   a. Obtain the signature and printed name of the package recipient on form *RP-016: Record of Delivery of Radioactive Packages*. (see Appendix 1).

   b. In addition to the recipient's signature and printed name, record the purchase order number, lab number, nuclide, activity, and date of delivery for each package delivered.

10. It is the responsibility of the RPO check-in and delivery technician to maintain all applicable forms.

C. End-User

1. Only those individuals who are registered by the Radiation Protection Office are authorized to work with radioactive materials.

2. End-users are instructed to:

   a. Monitor the inside of each radioactive shipping package for possible contamination.

   b. Deface or remove all radioactive labelling prior to disposal of the package or packing materials.

3. Styrofoam containers used in the packaging of radioactive materials can be recycled.

   a. Procedures are posted at the various recycling locations as specified on form *RP-017: Procedure for Opening Packages*

Containing Radioactive Material (an orange sticker) which is attached to each package delivered by the Radiation Protection Office.

b. Please refer to the **Styrofoam Recycling Program** for additional information.

Appendix 1

Form RP 08

Form RP-012

Form RP-016

Form RP-017

Form RP-318

10 CFR 71, Packaging and Transportation of Radioactive Material

RP-08
Rev. 10/94

Date_____

M.I.T. RADIATION PROTECTION OFFICE
Information for Checking-in Radioactive Material

Purchase Order Number	Ordered By	Material Ordered		Material Received		Comments relative to check-in
		Nuclide	Amount	Nuclide	Amount	

Form submitted to RPO secretary:

_____ _____
signature date

Form received by RPO secretary:

_____ _____
signature date

RP-212
Rev. 7/95

M.I.T. RADIATION PROTECTION OFFICE
Check-In Record of Radioactive Material

P.O. #	ORDERED BY	LAB NO.	NUC-LIDE	mCi	SURFACE mR/HOUR	1 METER mR/HOUR	LABEL TYPE	WIPE TESTS dpm/ $100cm^2$	CHECKED BY	DATE	COMMENTS **

* Notify the appropriate staff member if: (a) wipe test results exceed 2000 dpm/100 cm^2, (b) external radiation levels exceed 50 mrem/hr, or (c) radiation levels at 1 meter exceed 1 mrem/hr. Wipe test MDA = 1000 dpm/100 cm^2.

** Note discrepancies in labelling, packaging, or radiation and contamination levels.

RP-016
4/91

M.I.T. RADIATION PROTECTION OFFICE
Record of Delivery of Radioactive Packages

Purchase Order #	Ordered By	Material Received		Printed Name	Date	Purchase Order #	Ordered By	Material Received		Printed Name	Date
	Lab. #	Nuclide	mCi	Signature			Lab. #	Nuclide	mCi	Signature	

M.I.T. RADIATION PROTECTION OFFICE

PROCEDURES FOR OPENING PACKAGES CONTAINING RADIOACTIVE MATERIAL

1. OPEN ONLY IN A REGISTERED RADIATION LAB

2. ASSUME INSIDE MATERIALS ARE CONTAMINATED UNTIL PROVEN FREE OF CONTAMINATION WITH A SURVEY METER AND/OR WIPE TESTING

3. NOTIFY RPO IF:

   a) CONTAMINATION OR LEAKAGE IS DETECTED.
   b) UNEXPECTED DOSE RATES ARE MEASURED.
   c) THERE IS A DISCREPANCY BETWEEN MATERIAL RECEIVED AND ORDERED.

4. REMOVE OR DEFACE "CAUTION - RADIOACTIVE MATERIAL" STATEMENT AND RADIATION WARNING SYMBOL FROM PACKAGES BEFORE DISPOSAL.

RP-318
Rev 10/94

SEALED SOURCE DELIVERY LOG

DATE	ORDERED BY	NUCLIDE	ACTIVITY	AUTHORIZATION	ROOM #	WIPE-TEST RESULTS	COMMENTS

Procedure for handling deliveries of sealed sources:

1. The technician checking-in packages will determine if a given shipment contains sealed sources. In general, sealed sources will be different radionuclides than the usual unsealed sources. In case of doubt, contact a staff member.

2. All package check-in requirements for radioactive material receipts must be met for sealed sources as well.

3. In addition:

   a. Open the package and obtain a wipe from the nearest accessible surface---not the active surface---of the source. Have the counting room technician count the wipe for alpha and/or beta-gamma radioactivity. The counting room technician will provide the wipe test results for form RP-318.

   b. Fill out form RP-318 for each source received.

   c. For each day that one or more sealed sources are received, a separate form RP-318 is required.

   c. Deliver the completed form RP-318 to the staff member responsible for sealed sources.

4. Deliver the package to the person that ordered the sealed source in the same manner as other radioactive material packages.

Appendix 2

Procedure for Radiation Monitoring and Wipe Testing

I. Package Monitoring

A. General Requirements

1. Packages are to be monitored with a calibrated Geiger-Mueller (GM) detector on contact with each surface as well as at a distance of one meter.

a. The one meter dose rate verifies the transport index (TI).

b. The GM detector measurements on the package surface are to be taken through the side wall of the detector, not the detector window to conform with detector calibration geometry.

2. Package Labeling Requirements

a.No Label	Excepted Quantity for activity ≤ 0.5 mrem/hour @ surface
b.White I Label	≤ 0.5 mrem/hour @ surface Bkgd Dose Rate @ 1 meter
c.Yellow II Label	> 5 - 50 mrem/hour @ surface ≤ 1.0 mrem/hour @ 1 meter
d.Yellow III Label	> 50 - 200 mrem/hour @ surface > 1 - 10 mrem/hour @ 1 meter

3. The receipt of sealed sources requires additional action as described in Section III below.

B. Radiation levels

1. Survey the entire package exterior for the highest dose rate and record it on *RP-012*. If no package dose rate above background is detected, record it as "< 0.05 mR/hr".

2. Where the highest dose rate was measured on the package, take a dose rate 1 meter away and record that on *RP-012*. If the 1 meter dose rate is at background, record it as "< 0.05 mR/hr".

3. Compare the dose rates at the package surface and at 1 meter to the package labeling requirements in Part I.A.2. above. If there are discrepancies, proceed to section II below.

C. Wipe tests

1. Perform wipe tests on all packages using standard **two** inch wipes looking for evidence of removable radioactive

contamination.

2. Measure the wipe for activity.

   a. Survey all wipes with the GM detector holding the wipe approximately **1 cm** away from the detector.

   b. Wipe tests for packages containing $\geq$ 2 mCi ^{3}H or $\geq$ 7 mCi of ^{125}I should be sent to the Counting Room as soon as possible for liquid scintillation counting.

3. Record the surface contamination levels.

   a. Since between 100 and 300 cm^2 may be wiped and survey results are reported in dpm/100 cm^2, correct the results for the area wiped.

   b. If no activity above background is measured, record the results as "< MDA".

   c. The limit for removable contamination is 22 dpm/cm^2 (10^{-5} $\mu Ci/cm^2$). The activity on the wipe divided by the cm^2 of surface area wiped yields the surface contamination value. For example, if a wipe of 300 cm^2 surface area is counted and found to have 1000 dpm, the calculated contamination value equals about 4 dpm/cm^2.

II. Documentation

A. From the material packing list or shipping papers, record "PO #", "END-USER/LAB #", "NUCLIDE", and "ACTIVITY" on *RP-012*.

B. Record the "SURFACE" and "1 METER" dose rates under the "EXPOSURE RATE" column on *RP-012*.

C. Record the dpm/100 cm^2 for "WIPE TESTS".

D. Enter the initials of the person checking the package in under "CHECKED BY", and add the "DATE" of this evolution.

E. The "COMMENTS" section is for discrepancies in labeling, packaging, or radiation and contamination levels.

III. Sealed Source Receipts

A. Sealed sources are received in the same fashion as other radioactive materials.

B. In addition, sealed source packages are opened by RPO and wipe tested for leakage.

C. Receipt and leakage testing for sealed source receipt is documented on form RP-318.

D. The completed RP-318 form is turned into the RPO staff member responsible for sealed sources.

IV. Package Discrepancies

A. In the event wipe test results show above background radioactivity levels:

1. Place the package in a plastic bag.

2. Place the covered package in the calibration room.

3. Immediately notify the RPO staff member responsible for packages for proper follow-up.

4. If the package is packed in dry ice to maintain material temperature requirements, place it in the RPO walk-in freezer.

B. In the event of excessive radiation levels:

1. Place the package in the calibration room.

2. Appropriately shield the package.

3. Immediately notify the RPO staff member responsible for packages.

C. In the event a package requiring radioactive material labeling is not properly labeled, immediately notify the RPO staff member responsible for packages.

D. In the event a package appears damaged upon receipt:

1. See if the delivery vehicle is still at Receiving and, if so, hold it for surveillance.

2. Isolate the package from other materials and personnel.

3. Contact the RPO staff member responsible for packages for further response.

Procedure for handling deliveries of sealed sources:

1. The technician checking-in packages will determine if a given shipment contains sealed sources. In general, sealed sources will be different radionuclides than the usual unsealed sources. In case of doubt, contact a staff member.

2. All package check-in requirements for radioactive material receipts must be met for sealed sources as well.

3. In addition:

   a. Open the package and obtain a wipe from the nearest accessible surface---not the active surface---of the source. Have the counting room technician count the wipe for alpha and/or beta-gamma radioactivity. The counting room technician will provide the wipe test results for form RP-318.

   b. Fill out form RP-318 for each source received.

   c. For each day that one or more sealed sources are received, a separate form RP-318 is required.

   c. Deliver the completed form RP-318 to Don Haes.

4. Deliver the package to the person that ordered the sealed source in the same manner as other radioactive materia' packages.

M.I.T. MEDICAL DEPARTMENT

GUIDELINES FOR HANDLING OF A PATIENT WHO IS CONTAMINATED WITH RADIOACTIVE MATERIAL OR HAS BEEN EXPOSED TO IONIZING RADIATION

* *

NOTIFICATION: AS SOON AS PRACTICABLE, NOTIFY EACH OF THE FOLLOWING: 1) THE ON-CALL PHYSICIAN OR SURGEON; 2) A STAFF MEMBER OF THE RADIATION PROTECTION OFFICE (X-2180, 2360).

TYPE I: MINOR INJURY

Description: A contaminated patient, with minor injury who comes to E23 or to the Inpatient Unit.

PROCEDURE GUIDELINES

1. Escort patient to Decontamination Room, E23-123.
2. Put on surgical gown and gloves.
3. Give preliminary treatment to injury and apply waterproof dressing.
4. Ask patient about contamination: a) Radioisotope? b) Amount of radioisotope being handled when contamination occurred?
5. Use Survey Meter* to measure patient's outer clothing, hair, and exposed skin surfaces for radioactive contamination.
6. If patient's outer clothing is contaminated, have him remove it and put it in plastic bags.
7. a) If patient's hands or forearms are contaminated, instruct patient to wash thoroughly and, if needed, use procedures described in the Hand-Decontamination Kit.
   b) If other parts of the body are contaminated, instruct patient to shower (in the Decontamination Room).
8. Provide patient with surgical gown, or his own clothing if not contaminated.
9. Proceed with treatment of the injury.
10. Use Survey *Meter to measure for residual contamination on skin surfaces. Record results.
11. Before releasing patient, discuss situation with a staff member of the Radiation Protection Office. He will arrange, as needed, additional measurements, decontamination, removal of contaminated disposable items, and documentation of the incident for radiation protection records.

*Note: Omit the survey if contamination is Tritium, because the Survey Meter does not detect Tritium contamination.

TYPE II: MODERATE INJURY

Description: A contaminated patient with extent of injury such that immediate transport to a general hospital is not necessary, but admittance to the M.I.T. Inpatient Unit is indicated. The patient should be brought directly to the Inpatient Unit, Building E23.

PROCEDURE GUIDELINES

1. Proceed with indicated medical treatment doing whatever is practicable to control the spread of contamination as per following:
   a) Keep attendant personnel in room at minimum number necessary.
   b) Wear surgical gown and gloves, and also wear booties if practicable.
   c) Station someone at the treatment room doorway to relay messages, control entry, make radioactive contamination check with survey * meter of outgoing persons, etc.
   d) As soon as practicable, question patient about type of contamination, and use survey * meter to measure patient for contamination on clothing and/or skin. If contamination is found or suspected, decontaminate patient by:
      1) Removal of contaminated clothing
      2) Washing of contaminated skin surfaces
   e) Segregate contaminated materials and store in plastic bags. Wash water can be discharged into sink.
   f) After treatment and decontamination, survey* patient for residual contamination. Record results.
   g) If patient is still contaminated, confine to private room until further decontamination is practicable.

2. Survey* attendant personnel for possible contamination. Decontaminate as needed.

3. Discuss situation with a staff member of the Radiation Protection Office. He will arrange, as needed, additional measurements, decontamination items, and documentation of the incident for radiation protection records.

*Note: Omit the survey if contamination is Tritium, because the Survey Meter does not detect Tritium contamination.

TYPE III: SEVERE INJURY AND/OR WHOLE BODY RADIATION EXPOSURE EXCEEDING 25 REM.

Description: A contaminated patient with injury and/or radiation exposure such that the patient will be transported directly to a general hospital.

PROCEDURE GUIDELINES

1. CAMPUS POLICE will transport the patient to the Emergency Ward of the M.G.H. or other designated hospital.
2. While waiting for Campus Patrol to arrive at the scene:

   a) Give first-aid as necessary.
   b) *Survey patient's outer clothing for contamination. If contaminated, remove or cut off clothing if possible to do so without aggravating injury.
   c) Cover patient with blanket, sheet, or lab coat and secure it in place.
   d) If patient is contaminated, attach sign to outer cover stating "Radioactive Contamination". (Specify isotope, if known).

3. Advance notification of Emergency Ward: Campus Police or the Medical Department will notify the hospital of the impending arrival of the patient, stating specifically whether radioactive contamination or radiation overexposure is involved.

   Telephone numbers of Emergency Wards:
   M.G.H. 726-2000

4. Notify a staff member of the Radiation Protection Office
   a) During normal work-hours: Extension 2180, 2360, 5374
   b) Other times:
   Notify the E.M.S. On-Call person, using the schedule-list posted at the Inpatient Unit.

*Note: Omit the survey if contamination is Tritium, because the Survey Meter does not detect Tritium contamination.

March, 1983

CONTAMINATION MEASUREMENT PROCEDURE

I. To verify that the instrument is operating properly:
   a) Turn the range-selector to "bat" (battery). The needle should deflect into the "bat ok" region.
   b) Turn the range-selector to the "X1" position.
   c) Hold the end window Geiger-Mueller (G.M.) probe against the test source located on the side of the instrument case. The needle should deflect to a reading of 0.35 to 0.5 mr/hr.

II. Measurement procedure:
   a) Start measurements with the range-selector set at the X0.1 position. Scan the surface to be measured with the end window G.M. probe (do not touch probe to possibly contaminated surfaces).
   b) If the needle deflects off-scale, turn the range-selector to the next highest range and try to obtain an on-scale reading. Repeat until an on-scale reading is obtained.
   c) Record the measurement results.

U.S. NUCLEAR REGULATORY COMMISSION

July 1981

REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

REGULATORY GUIDE 8.29
(Task OH 902-4)

INSTRUCTION CONCERNING RISKS FROM OCCUPATIONAL RADIATION EXPOSURE

A. INTRODUCTION

Section 19.12 of 10 CFR Part 19, "Notices, Instructions and Reports to Workers; Inspections," requires that all persons working in or frequenting any portion of a restricted area be instructed in the health protection problems associated with exposure to radioactive materials or radiation. This guide describes the instruction that should be provided to the worker concerning biological risks from occupational radiation exposure. Additional guides are being or will be developed to address other aspects of radiation protection training.

B. DISCUSSION

It is generally accepted by the scientific community that exposure to ionizing radiation can cause biological effects that are harmful to the exposed organism. These effects are classified into three categories:

Somatic Effects: Effects occurring in the exposed person that, in turn, may be divided into two classes:

Prompt effects that are observable soon after a large or acute dose (e.g., 100 rems[1] or more to the whole body in a few hours), and

Delayed effects such as cancer that may occur years after exposure to radiation.

Genetic Effects:[2] Abnormalities that may occur in the future children of exposed individuals and in subsequent generations.

Teratogenic Effects: Effects that may be observed in children who were exposed during the fetal and embryonic stages of development.

Concerns about these biological effects have resulted in controls on doses to individual workers and in efforts to control the collective dose (person-rems) to the worker population.

NRC-licensed activities result in a significant fraction of the total occupational radiation exposure in the United States. Regulatory action has recently focused more attention on maintaining occupational radiation exposure at levels that are as low as is reasonably achievable (ALARA). Radiation protection training for all workers who may be exposed to ionizing radiation is an essential component of any program designed to maintain exposure levels ALARA. A clear understanding of what is presently known about the biological risks associated with exposure to radiation will result in more effective radiation protection training and should generate more interest on the part of the worker in minimizing both individual and collective doses. In addition, radiation workers have the right to whatever information on radiation risk is available to enable them to make informed decisions regarding the acceptance of these risks. It is intended that workers who receive this instruction develop a healthy respect for the risks involved rather than excessive fear or indifference.

At the relatively low levels of occupational radiation exposure in the United States, it is difficult to demonstrate a relationship between exposure and effect. There is considerable uncertainty and controversy regarding estimates of radiation risk. In the appendix to this guide, a range of risk estimates is provided (see Table 1). Information on radiation risk has been included from such sources as the 1980 National Academy of Sciences' Report of the Committee on the Biological Effects of Ionizing Radiation (BEIR-80), the International Commission on Radiological Protection (ICRP) Publication 27 entitled "Problems in Developing an Index of Harm," the 1979 report of the science work group of the Interagency Task Force on the Health Effects of Ionizing Radiation, the 1977 report of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR report), and numerous published articles (see the bibliography to the appendix).

[1] In the International System of Units (SI), the rem is replaced by the sievert. 100 rems is equal to 1 sievert (Sv).

[2] Genetic effects exceeding normal incidence have not been observed in any of the studies of exposed humans.

C. REGULATORY POSITION

Strong management support is considered essential to an adequate radiation protection training program. Instruction to workers performed in compliance with §19.12 of 10 CFR Part 19 should be given prior to assignment to work in a restricted area and periodically thereafter. In providing instruction concerning health protection problems associated with exposure to radiation, all workers, including those in supervisory roles, should be given specific instruction on the risk of biological effects resulting from exposure to radiation.

The instruction should be presented both orally and in printed form to all affected workers and supervisors. It should include the information provided in the appendix to this guide.[3] The information should be discussed during training sessions. Each individual should be given an opportunity to ask questions and should be asked to acknowledge in writing that the instruction has been received and understood.

[3]Copies of the appendix to this guide are available at the current Government Printing Office price, which may be obtained by writing to the U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, Attention: Publications Sales Manager. This appendix is not copyrighted, and Commission approval is not required to reproduce it.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants regarding the NRC staff's plans for using this regulatory guide.

Except in those cases in which an applicant or licensee proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the methods described in this guide will be used in the evaluation of the training program for all individuals working in or frequenting any portion of a restricted area and for all supervisory personnel after December 15, 1981.

If an applicant or licensee wishes to use the material provided in this guide on or before December 15, 1981, the pertinent portions of the application or the licensee's performance will be evaluated on the basis of this guide.

U.S. NUCLEAR REGULATORY COMMISSION

APPENDIX TO REGULATORY GUIDE 8.29

INSTRUCTION CONCERNING RISKS FROM OCCUPATIONAL RADIATION EXPOSURE

This instructional material is intended to provide the user with the best available information concerning what is currently known about the health risks from exposure to ionizing radiation.[1] A question and answer format has been used. The questions were developed by the NRC staff in consultation with workers, union representatives, and licensee representatives experienced in radiation protection training. Risk estimates have been compiled from numerous sources generally recognized as reliable. A bibliography is included for the user interested in further study.

The biological effects that are known to occur after exposure to high doses (hundreds of rems[2]) of radiation are discussed early in the document; discussions of the estimated risks from the low occupational dose (<5 rems per year) follow. It is intended that this information will help develop an attitude of healthy respect for the risks associated with radiation, rather than unnecessary fear or lack of concern. Additional guidance is being or will be developed concerning other topics in radiation protection training.

• • • • • • • •

1. What is meant by risk?

Risk can be defined in general as the probability (chance) of injury, illness, or death resulting from some activity. However, the perception of risk is affected by how the individual views its probability and its severity. The intent of this document is to provide estimates of and explain the basis for possible risk of injury, illness, or death resulting from occupational radiation exposure. (See Questions 9 and 10 for estimates of radiation risk and comparisons with other types of risk.)

2. What are the possible health effects of exposure to radiation?

Some of the health effects that exposure to radiation may cause are cancer (including leukemia), birth defects in the future children of exposed parents, and cataracts.[3] These effects (with the exception of genetic effects) have been observed in studies of medical radiologists, uranium miners, radium workers, and radiotherapy patients who have received large doses of radiation. Studies of people exposed to radiation from atomic weapons have also provided data on radiation effects. In addition, radiation effects studies with laboratory animals have provided a large body of data on radiation-induced health effects, including genetic effects.

The observations and studies mentioned above, however, involve levels of radiation exposure that are much higher (hundreds of rems) than those permitted occupationally today (<5 rems per year). Although studies have not shown a cause-effect relationship between health effects and current levels of occupational radiation exposure, it is prudent to assume that some health effects do occur at the lower exposure levels.

3. What is meant by prompt effects, delayed effects, and genetic effects?

a. Prompt effects are observable shortly after receiving a very large dose in a short period of time. For example, a whole-body[4] dose of 450 rems (90 times the annual dose limit for routine occupational exposure) in an hour to an average adult will cause vomiting and diarrhea within a few hours; loss of hair, fever, and weight loss within a few weeks; and about a 50 percent chance of death within 60 days without medical treatment.

b. Delayed effects such as cancer may occur years after exposure to radiation.

c. Genetic effects can occur when there is radiation damage to the genetic material. These effects may show up as birth defects or other conditions in the future children of the exposed individual and succeeding generations, as demonstrated in animal experiments. However, excess genetic effects clearly caused by radiation have not been observed in human populations exposed to radiation. It has been observed, however, that radiation can change the genes in cells of the human body. Thus, the possibility exists that genetic effects can be caused in humans by low doses even though no direct evidence exists as yet.

4. In worker protection, which effects are of most concern to the NRC?

The main concern to the NRC is the delayed incidence of cancer. The chance of delayed cancer is believed to depend

[1] Ionizing radiation consists of energy or small particles such as gamma, beta, or alpha radiation emitted from radioactive materials which, when absorbed by living tissue, can cause chemical and physical damage.

[2] The rem is the unit of measure for radiation dose and relates to the biological effect of the absorbed radiation.

[3] Cataracts differ from other radiation effects in that a certain level of dose to the lens of the eye (~200 rems) is required before they are observed.

[4] It is important to distinguish between whole-body and partial-body exposure. 100 rems to the whole body will have more effect than 100 to a hand. For example, exposure of a hand would affect a small fraction of the bone marrow and a limited portion of the skin.

on how much radiation exposure a person gets; therefore, every reasonable effort should be made to keep exposures low.

Immediate or prompt effects are very unlikely since large exposures would normally occur only if there were a serious radiation accident. Accident rates in the radiation industry have been low, and only a few accidents have resulted in exposures exceeding the legal limits. The probability of serious genetic effects in the future children of workers is estimated in the BEIR[5] report, based on animal studies, at less than one-third that of delayed cancer (5-65 genetic effects per million rems compared to 160-450 cancer cases). A clearer understanding of the cause-effect relationship between radiation and human genetic effects will not be possible until additional research studies are completed.

5. *What is the difference between acute and chronic exposure?*

Acute radiation exposure, which causes prompt effects and may also cause delayed effects, usually refers to a large dose of radiation received in a short period of time; for example, 450 rems received within a few hours or less. The effects of acute exposures are well known from studies of radiotherapy patients, some of whom received whole-body doses; atomic bomb victims; and the few accidents that have occurred in the early days of atomic weapons and reactor development, industrial radiography, and nuclear fuel processing. There have been few occupational incidents that have resulted in large exposures. NRC data indicate that, on the average, 1 accidental overexposure in which any acute symptoms are observed occurs each year. Most of these occur in industrial radiography and involve exposures of the hands rather than the whole body.

Chronic exposure, which may cause delayed effects but not prompt effects, refers to small doses received repeatedly over long time periods; for example, 20-100 mrem (a mrem is one-thousandth of a rem) per week every week for several years. Concern with occupational radiation risk is primarily focused on chronic exposure to low levels of radiation over long time periods.

6. *How does radiation cause cancer?*

How radiation causes cancer is not well understood. It is impossible to tell whether a given cancer was caused by radiation or by some other of the many apparent causes. However, most diseases are caused by the interaction of several factors. General physical condition, inherited traits, age, sex, and exposure to other cancer-causing agents such as cigarette smoke are a few possible contributing factors. One theory is that radiation can damage chromosomes in a cell, and the cell is then directed along abnormal growth patterns. Another is that radiation reduces the body's normal resistance to existing viruses which can then multiply and damage cells. A third is that radiation activates an existing virus in the body which then attacks normal cells causing them to grow rapidly.

What is known is that, in groups of highly exposed people, a higher than normal incidence of cancer is observed. Higher than normal rates of cancer can also be produced in laboratory animals by high levels of radiation. An increased incidence of cancer has not been demonstrated at radiation levels below the NRC limits.

7. *If I receive a radiation dose, does that mean I am certain to get cancer?*

Not at all. Everyone gets a radiation dose every day (see Question 25), but most people do not get cancer. Even with doses of radiation far above legal limits, most individuals will experience no delayed consequences. There is evidence that some radiation damage can be repaired. The danger from radiation is much like the danger from cigarette smoke. Only a fraction of the people who breathe cigarette smoke get lung cancer, but there is good evidence that smoking increases a person's chances of getting lung cancer. Similarly, there is evidence that the larger the radiation dose, the larger the increase in a person's chances of getting cancer.

Radiation is like most substances that cause cancer in that the effects can be seen clearly only at high doses. Estimates of the risks of cancer at low levels of exposure are derived from data available for exposures at high dose levels and high dose rates. Generally, for radiation protection purposes these estimates are made using the linear model (Curve 1 in Figure 1). We have data on health effects at high doses as shown by the solid line in Figure 1. Below about 100 rems, studies have not been able to accurately measure the risk, primarily because of the small numbers of exposed people and because the effect is small compared to differences in the normal incidence from year to year and place to place. Most scientists believe that there is some degree of risk no matter how small the dose (Curves 1 and 2). Some scientists believe that the risk drops off to zero at some low dose (Curve 3), the threshold effect. A few believe that risk levels off so that even very small doses imply a significant risk (Curve 4). The majority of scientists today endorse either the linear model (Curve 1) or the linear-quadratic model (Curve 2). The NRC endorses the linear model (Curve 1), which shows the number of effects decreasing as the dose decreases, for radiation protection purposes.

It is prudent to assume that smaller doses have some chance of causing cancer. This is as true for natural cancer-causers such as sunlight and natural radiation as it is for those that are man made such as cigarette smoke, smog, and man-made radiation. As even very small doses may entail some small risk, it follows that no dose should be taken without a reason. Thus, a principle of radiation protection is to do more than merely meet the allowed regulatory

[5] The National Academy of Sciences established a committee on the Biological Effects of Ionizing Radiation (BEIR) whose 1980 report on the effects on populations of exposure to low levels of ionizing radiation provides much of the background for this guide.

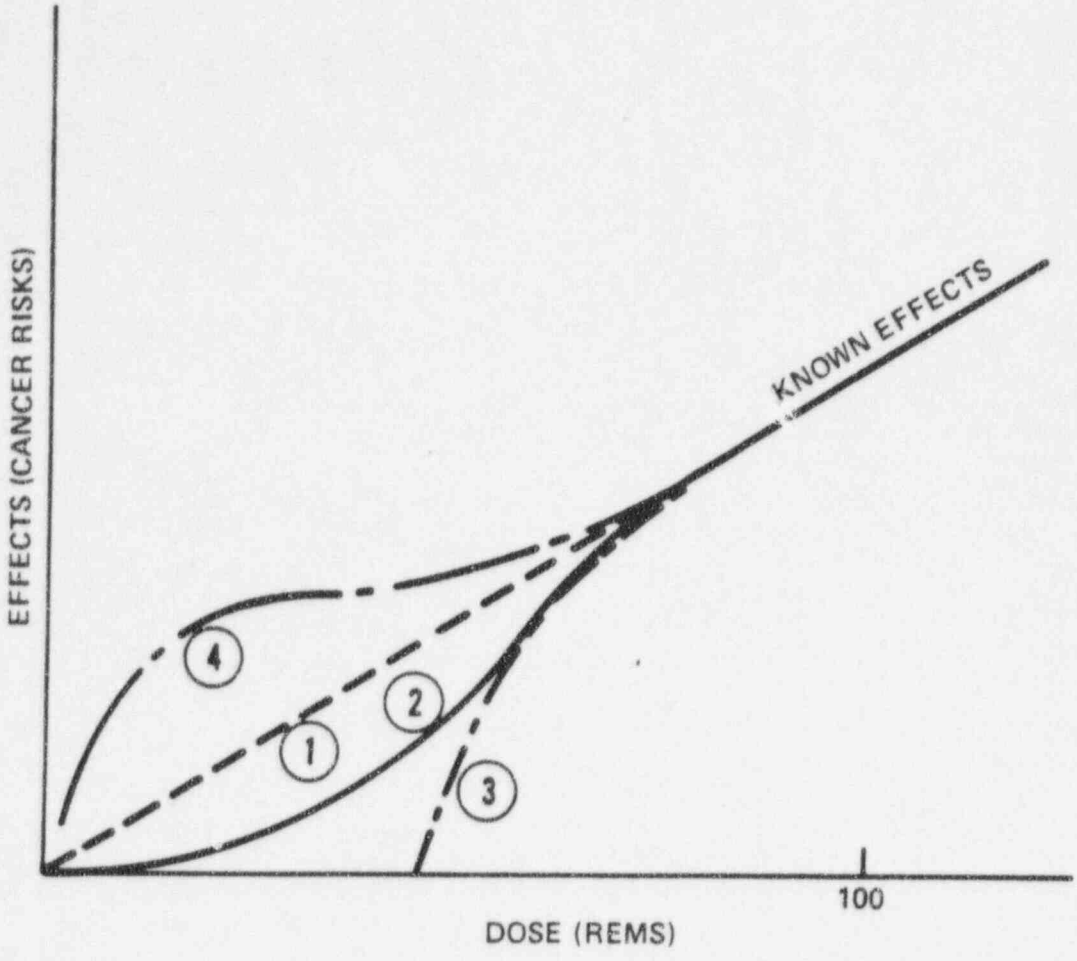


Figure 1. Some proposed models for how the effects of radiation vary with doses at low levels.

limits; doses should be kept as low as is reasonably achievable (ALARA).

We don't know exactly what the chances are of getting cancer from a low-level radiation dose, but we can make estimates based on extensive scientific knowledge. The estimates of radiation risks are at least as reliable as estimates for the effects from any chemical hazard. Being exposed to typical occupational radiation doses is taking a chance, but that chance is reasonably well understood.

It is important to understand the probability factors here. A similar question would be: If you select one card from a full deck, will you get the ace of spades? This question cannot be answered with a simple yes or no. The best answer is that your chances are 1 in 52. However, if 1000 people each select one card from full decks, we can predict that about 20 of them will get an ace of spades. Each person will have 1 chance in 52 of drawing the ace of spades, but there is no way that we can predict which persons will get the right card. The issue is further complicated by the fact that in 1 drawing by 1000 people, we might get only 15 successes and in another perhaps 25 correct cards in 1000 draws. We can say that if you receive a radiation dose, you will have increased your chances of eventually developing cancer. It is assumed that the more radiation exposure you get, the more you increase your chances of cancer.

Not all workers incur the same level of risk. The radiation risk incurred by a worker depends on the amount of dose received. Under the linear model explained above, a worker who receives 5 rems in a year incurs 10 times as much risk as another worker (the same age) who receives only 0.5 rem. The risk depends not only on the amount of dose, but also on the age of the worker at the time the dose is received. This age difference is due, in part, to the fact that a young worker has more time to live than an older worker, and the risk is believed to depend on the number of years of life following the dose. The more years left, the larger the risk. It should be clear that, even within the regulatory dose limits, the risk may vary a great deal from one worker to another. Fortunately, only a very few workers receive doses near 5 rems per year; as pointed out in the answer to Question 19, the average annual dose for all radiation workers is less than 0.5 rem.

A reasonable comparison involves exposure to the sun's rays. Frequent short exposures provide time for the skin to repair. An acute exposure to the sun can result in painful burning, and excessive exposure has been shown to cause skin cancer. However, whether exposure to the sun's rays is short term or spread over time, some of the injury is not repaired and may eventually result in skin cancer.

The effect upon a group of workers occupationally exposed to radiation may be an increased incidence of cancer over and above the number of cancers that would normally be expected in that group. Each exposed individual has an increased probability of incurring subsequent cancer. We can say that if 10,000 workers each receive an additional 1 rem in a year, that group is more likely to have a larger incidence of cancer than 10,000 people who do not receive the additional radiation. An estimate of the increased probability of cancer from low radiation doses delivered to large groups is one measure of occupational risk and is discussed in Question 9.

8. *What groups of expert scientists have studied the risk from exposure to radiation?*

In 1956, the National Academy of Sciences established advisory committees to consider radiation risks. The first of these was the Advisory Committee on the Biological Effects of Atomic Radiations (BEAR) and more recently it was renamed the Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR). These committees have periodically reviewed the extensive research being done on the health effects of ionizing radiation and have published estimates of the risk of cancer from exposure to radiation (1972 and 1980 BEIR reports). The International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurement (NCRP) are two other groups of scientists who have studied radiation effects and published risk estimates (ICRP Publication 26, 1977). These two groups have no government affiliation. In addition, the United Nations established an independent study group that published an extensive report in 1977, including estimates of cancer risk from ionizing radiation (UNSCEAR, 1977).

Several individual research groups or scientists such as Alice Stewart, E.S. Gilbert, T.F. Mancuso, T.W. Anderson, to name a few, have published studies concerning low-level radiation effects. The bibliography to this appendix includes several articles for the reader who wishes to do further study. The BEIR-80 report includes analysis of the work of many independent researchers.

9. *What are the estimates of the risk of cancer from radiation exposure?*

The cancer risk estimates (developed by the organizations identified in Question 8) are presented in Table 1.

In an effort to explain the significance of these estimates, we will use an approximate average of 300 excess cancer cases per million people, each exposed to 1 rem of ionizing radiation. If in a group of 10,000 workers each receives 1 rem, we could estimate that three would develop cancer because of that exposure, although the actual number could be more or less than three.

TABLE 1

Estimates of Excess Cancer Incidence from Exposure to Low-Level Radiation

Source	Number of Additional[a] Cancers Estimated to Occur in 1 Million People After Exposure of Each to 1 Rem of Radiation
BEIR, 1980	160-450[b]
ICRP, 1977	200
UNSCEAR, 1977	150-350

[a] Additional means above the normal incidence of cancer.

[b] All three groups estimated premature deaths from radiation-induced cancers. The American Cancer Society has recently stated that only about one-half of all cancer cases are fatal. Thus, to estimate incidence of cancer, the published numbers were multiplied by 2. Note that the three groups are in close agreement on the risk of radiation-induced cancer.

The American Cancer Society has reported that approximately 25 percent of all adults in the 20- to 65-year age bracket will develop cancer at some time from all possible causes such as smoking, food, alcohol, drugs, air pollutants, and natural background radiation. Thus in any group of 10,000 workers not exposed to radiation on the job, we can expect about 2,500 to develop cancer. If this entire group of 10,000 workers were to receive an occupational radiation dose of 1 rem each, we could estimate that three additional cases might occur which would give a total of about 2,503. This means that a 1-rem dose to each of 10,000 workers might increase the cancer rate from 25 percent to 25.03 percent, an increase of about 3 hundredths of one percent.

As an individual, if your cumulative occupational radiation dose is 1 rem, your chances of eventually developing cancer during your entire lifetime may have increased from 25 percent to 25.03 percent. If your lifetime occupational dose is 10 rems, we could estimate a 25.3 percent chance of developing cancer. Using a simple linear model, a lifetime dose of 100 rems may have increased your chances of cancer from 25 to 28 percent.

The normal chance of developing cancer if you receive no occupational radiation dose is about equal to your chance of getting any spade on a single draw from a full deck of playing cards, which is one chance out of four. The additional chance of developing cancer from an occupational exposure of 1 rem is less than your chances of drawing an ace from a full deck of cards three times in a row.

Since cancer resulting from exposure to radiation usually occurs 5 to 25 years after the exposure and since not all cancers are fatal, another useful measure of risk is years of

life expectancy lost on the average from a radiation-induced cancer. It has been estimated in several studies that the average loss of life expectancy from exposure to radiation is about 1 day per rem of exposure. In other words, a person exposed to 1 rem of radiation may, on the average, lose 1 day of life. The words "on the average" are important, however, because the person who gets cancer from radiation may lose several years of life expectancy while his coworkers suffer no loss. The ICRP estimated that the average number of years of life lost from fatal industrial accidents is 30 while the average number of years of life lost from a fatal radiation-induced cancer is 10. The shorter loss of life expectancy is due to the delayed onset of cancer.

It is important to realize that these risk numbers are only estimates. Many difficulties are involved in designing research studies that can accurately measure the small increases in cancer cases due to low exposures to radiation as compared to the normal rate of cancer. There is still uncertainty and a great deal of controversy with regard to estimates of radiation risk. The numbers used here result from studies involving high doses and high dose rates, and they may not apply to doses at the lower occupational levels of exposure. The NRC and other agencies both in the United States and abroad are continuing extensive long-range research programs on radiation risk.

Some members of the National Academy of Sciences BEIR Advisory Committee and others feel that risk estimates in Table 1 are higher than would actually occur and represent an upper limit on the risk. Other scientists believe that the estimates are low and that the risk could be higher. However, these estimates are considered by the NRC staff to be the best available that the worker can use to make an informed decision concerning acceptance of the risks associated with exposure to radiation. A worker who decides to accept this risk should make every effort to keep exposure to radiation ALARA to avoid unnecessary risk. The worker, after all, has the first line responsibility for protecting himself from radiation hazards.

10. How can we compare radiation risk to other kinds of health risks?

Perhaps the most useful unit for comparison among health risks is the average number of days of life expectancy lost per unit of exposure to each particular health risk. Estimates are calculated by looking at a large number of persons, recording the age when death occurs from apparent causes, and estimating the number of days of life lost as a result of these early deaths. The total number of days of life lost is then averaged over the total group observed.

Several studies have compared the projected loss of life expectancy resulting from exposure to radiation with other health risks. Some representative numbers are presented in Table 2.

These estimates indicate that the health risks from occupational radiation exposure are smaller than the risks associated with many other events or activities we encounter and accept in normal day-to-day activities.

TABLE 2

Estimated Loss of Life Expectancy from Health Risks[a]

Health Risk	Estimates of Days of Life Expectancy Lost, Average
Smoking 20 cigarettes/day	2370 (6.5 years)
Overweight (by 20%)	985 (2.7 years)
All accidents combined	435 (1.2 years)
Auto accidents	200
Alcohol consumption (U.S. average)	130
Home accidents	95
Drowning	41
Natural background radiation, calculated	8
Medical diagnostic x-rays (U.S. average), calculated	6
All catastrophes (earthquake, etc.)	3.5
1 rem occupational radiation dose, calculated (industry average for the higher-dose job categories is 0.65 rem/yr)	1
1 rem/yr for 30 years, calculated	30

[a]Adapted from Cohen and Lee, "A Catalogue of Risks," *Health Physics*, Vol. 36, June 1979.

A second useful comparison is to look at estimates of the average number of days of life expectancy lost from exposure to radiation and from common industrial accidents at radiation-related facilities and to compare this number with days lost from other occupational accidents. Table 3 shows average days of life expectancy lost as a result of fatal work-related accidents. Note that the data for occupations other than radiation related do not include death risks from other possible hazards such as exposure to toxic chemicals, dusts, or unusual temperatures. Note also that the unlikely occupational exposure at 5 rems per year for 50 years, the maximum allowable risk level, may result in a risk comparable to the average risks in mining and heavy construction.

Industrial accident rates in the nuclear industry and related occupational areas have been relatively low during the entire history of the industry (see Table 4). This is believed to be due to the early and continuing emphasis on tight safety controls. The relative safety of various occupational areas can be seen by comparing the probability of death by accident per 10,000 workers over a 40-year working lifetime. These figures do not include death from possible causes such as exposure to toxic chemicals or radiation.

11. Can a worker become sterile or impotent from occupational radiation exposure?

Observation of radiation therapy patients who receive localized exposures, usually spread over a few weeks, has

TABLE 3

Estimated Loss of Life Expectancy from Industrial Hazards[a]

Industry Type	Estimates of Days of Life Expectancy Lost, Average
All industry	74
Trade	30
Manufacturing	43
Service	47
Government	55
Transportation and utilities	164
Agriculture	277
Construction	302
Mining and quarrying	328
Radiation accidents, death from exposure	<1
Radiation dose of 0.65 rem/yr (industry average) for 30 years, calculated	20
Radiation dose of 5 rems/yr for 50 years	250
Industrial accidents at nuclear facilities (nonradiation)	58

[a]Adapted from Cohen and Lee, "A Catalogue of Risk," *Health Physics*, Vol. 36, June 1979; and World Health Organization, *Health Implications of Nuclear Power Production*, December 1975.

TABLE 4

Probability of Accidental Death by Type of Occupation[a]

Occupation	Number of Accidental Deaths for 10,000 Workers for 40 Years
Mining	252
Construction	228
Agriculture	216
Transportation and public utilities	116
All industries	56
Government	44
Nuclear industry (1975 data excluding construction)	40
Manufacturing	36
Services	28
Wholesale and trade	24

[a]Adapted from National Safety Council, *Accident Facts*, 1979; and Atomic Energy Commission, *Operational Accidents and Radiation Exposure Experience*, WASH-1192, 1975.

shown that a dose of 500-800 rems to the gonads can produce permanent sterility in males or females (an acute whole-body dose of this magnitude would probably result in death within 60 days). An acute dose of 20 rems to the testes can result in a measurable but temporary reduction in sperm count. Such high exposures on the job could result only from serious and unlikely radiation accidents. Although high doses of radiation can affect fertility, they have no effect on the ability to function sexually. Likewise, exposure to permitted occupational levels of radiation has no observed effect on fertility and also has no effect on the ability to function sexually.

12. What are the NRC external radiation dose limits?

Federal regulations currently limit occupational external whole-body radiation dose to 1¼ rems in any calendar quarter or specified 3-month period. However, when there is documented evidence that a worker's previous occupational dose is low enough, a licensee may permit a dose of up to 3 rems per quarter or 12 rems per year. The accumulated dose may not exceed 5(N - 18) rems[6] where N is the person's age in years, i.e., the lifetime occupational dose may not exceed an average of 5 rems for each year above the age of 18.

An additional whole-body dose of approximately 5 rems per year is permitted from internal exposure. (See Question 28.)

13. What is meant by ALARA?

In addition to providing an upper limit on a person's permissible radiation exposure, the NRC also requires that its licensees maintain occupational exposures as far below the limit as is reasonably achievable (ALARA). This means that every activity at a nuclear facility involving exposure to radiation should be planned so as to minimize unnecessary exposure to individual workers and also to the worker population. A job that involves exposure to radiation should be scheduled only when it is clear that the benefit justifies the risks assumed. All design, construction, and operating procedures should be reviewed with the objective of reducing unnecessary exposures.

14. Has the ALARA concept been applied if, instead of reaching dose limits during the first week of a quarter, the worker's dose is spread out over the whole quarter?

No. For radiation protection purposes, the risk of cancer from low doses is assumed to be proportional to the amount of exposure, not the rate at which it is received. Thus it is assumed that spreading the dose out over time or over larger numbers of people does not reduce the overall risk. The ALARA concept has been followed only when the individual and collective doses are reduced by reducing the time of exposure or decreasing radiation levels in the

[6]The NRC has published a proposed rule change for public comment that would eliminate the 5(N-18) formula. This proposal is currently under consideration by a task force reviewing all of 10 CFR Part 20. Recent EPA guidance recommends eliminating the 5(N-18) formula. If adopted, the maximum allowed annual dose will be 5 rems rather than 12.

individual and collective doses are reduced by reducing the time of exposure or decreasing radiation levels in the working environment.

15. What is meant by collective dose and why should it be maintained ALARA?

Nuclear industry activities expose an increasing number of people to occupational radiation in addition to the radiation doses they receive from natural background radiation and medical radiation exposures. The collective occupational dose (person-rems) is the sum of all occupational radiation exposure received by all the workers in an entire worker population. For example, if 100 workers each receive 2 rems, the individual dose is 2 rems and the collective dose is 200 person-rems. The total additional risk of cancer and genetic effects in an exposed population is assumed to depend on the collective dose.

It should be noted that, from the viewpoint of risk to a total population, it is the collective dose that must be controlled. For a given collective dose, the number of health effects is assumed to be the same even if a larger number of people share the dose. Therefore, spreading the dose out may reduce the individual risk, but not that of the population.

Efforts should be made to maintain the collective dose ALARA so as not to unnecessarily increase the overall population incidence of cancer and genetic effects.

16. Is the use of extra workers a good way to reduce risks?

There is a "yes" answer to this question and a "no" answer. For a given job involving exposure to radiation, the more people who share the work, the lower the average dose to an individual. The lower the dose, the lower the risk. So, for you as an individual, the answer is "yes."

But how about the risk to the entire group of workers? Under assumptions used by the NRC for purposes of protection, the risk of cancer depends on the total amount of radiation energy absorbed by human tissue, not on the number of people to whom this tissue belongs. Therefore, if 30 workers are used to do a job instead of 10, and if both groups get the same collective dose (person-rems), the total cancer risk is the same, and nothing was gained for the group by using 30 workers. From this viewpoint the answer is "no." The risk was not reduced but simply spread around among a larger number of persons.

Unfortunately, spreading the risk around often results in a larger collective dose for the job. Workers are exposed as they approach a job, while they are getting oriented to do the job, and as they withdraw from the job. The dose received during these actions is called nonproductive. If several crew changes are required, the nonproductive dose can become very large. Thus it can be seen that the use of extra workers may actually increase the total occupational dose and the resulting collective risks.

The use of extra workers to comply with NRC dose limits is not the way to reduce the risk of radiation-induced cancer for the worker population. At best, the total risk remains the same, and it may even be increased. The only way to reduce the risk is to reduce the collective dose; that can be done only by reducing the radiation levels, the working times, or both.

17. Why doesn't the NRC impose collective dose limits?

Compliance with individual dose limits can be achieved simply by using extra workers. However, compliance with a collective dose limit (such as 100 person-rems per year for a licensee) would require reduction of radiation levels, working times, or both. But there are many problems associated with setting appropriate collective dose limits.

For example, we might consider applying a single collective dose limit to all licensees. The selection of such a collective dose limit would be almost impossible because of the wide variations in collective doses among licensees. A power reactor could reasonably be expected to have an average annual collective dose of several hundred person-rems. However, a small industrial radiography licensee could very well have a collective dose of only a few person-rems in a year.

Even choosing a collective dose limit for a group of similar licensees would be almost as difficult. Radiography licensees as a group had an average collective dose in 1977 of 9 person-rems. However, the smallest collective dose for a radiography licensee was less than 1 person-rem, and the largest was 401 person-rems.

Setting a reasonable collective dose limit for each individual licensee would also be very difficult. It would require a record of all past collective doses on which to base such limits. Setting an annual collective dose limit would then amount to an attempt to predict a reasonable collective dose for each future year. In order to do this, it would be necessary to be able to predict changes in each licensed activity that would increase or decrease the collective dose. In addition, annual collective doses vary significantly from year to year according to the kind and amount of maintenance required, which cannot generally be predicted in advance. Following all such changes and revising limits up and down would be very difficult if not impossible. However, these efforts would be necessary if a collective dose limit were to be reasonable and help minimize doses and risks.

18. How are radiation dose limits established?

The NRC establishes occupational radiation dose limits based on guidance to Federal agencies from the Environmental Protection Agency (EPA) and, in addition, considers NCRP and ICRP recommendations. Scientific reviews of research data on biological effects such as the BEIR report are also considered.

For example, recent EPA guidance recommended that the annual whole-body dose limit be established at 5 rems per year and indicated that exposure, year after year, to 5 rems would involve a risk to a worker comparable to the average risks incurred by workers in the higher risk jobs

such as mining. In fact, few workers ever reach such a limit, much less year after year, and the risks associated with actual exposures are considered by the EPA to be comparable to the safer job categories. A 5-rem-per-year limit would allow occasional high dose jobs to be done without excessive risk.

19. What are the typical radiation doses received by workers?

The NRC requires that certain categories of licensees report data on annual worker doses and doses for all workers who leave employment with licensees. Data were received on the occupational doses in 1977 of approximately 100,000 workers in power reactors, industrial radiography, fuel processing and fabrication facilities, and manufacturing and distribution facilities. Of this total group, 85 percent received an annual dose of less than 1 rem; 95 percent received less than 2 rems; fewer than 1 percent exceeded 5 rems in 1 year. The average annual dose of those workers who were monitored and had measurable exposures was about 0.65 rem. A study completed by the EPA, using 1975 exposure data for 1,260,000 workers, indicated that the average annual dose for all workers who received a measurable dose was 0.34 rem.

Table 5 lists average occupational exposures for workers (persons who had measurable exposure above background levels) in various occupations, based on the 1975 data.

TABLE 5

U.S. Occupational Exposure Estimates[a]

Occupational Subgroup	Average Whole-Body Dose (millirems)	Collective Dose (person-rems)
Medicine	320	51,400
Industrial Radiography	580	5,700
Source Manufacturing	630	2,500
Power Reactors	760	21,400
Fuel Fabrication and Reprocessing	560	3,100
Uranium Enrichment	70	400
Nuclear Waste Disposal	920	100
Uranium Mills	380	760
Department of Energy Facilities	300	11,800
Department of Defense Facilities	180	10,100
Educational Institutions	206	1,500
Transportation	200	2,300

[a]Adapted from Cook and Nelson, *Occupational Exposures to Ionizing Radiation in the United States: A Comprehensive Summary for 1975*, Draft, Environmental Protection Agency.

20. What happens if a worker exceeds the quarterly exposure limit?

Radiation protection limits, such as 3 rems in 3 months, are not absolute limits below which it is safe and above which there is danger. Exceeding a limit does not imply that you have suffered an injury. A good comparison is with the highway speed limit, which is selected to limit accident risk and still allow you to get somewhere. If you drive at 75 mph, you increase your risk of an auto accident to levels that are not considered acceptable by the people who set speed limits, even though you may not actually have an accident. If a worker's radiation dose repeatedly exceeds 3 rems in a quarter, the risk of health effects could eventually increase to a level that is not considered acceptable to the NRC. Exceeding an NRC protection limit does not mean that any adverse health effects are going to occur. It does mean that a licensee's safety program has failed in some respect and that the NRC and the licensee should investigate to make sure the problems are corrected.

If an overexposure occurs, the regulations prohibit any additional occupational exposure to that person during the remainder of the calendar quarter in which the overexposure occurred. The licensee is required to file an overexposure report to the NRC and may possibly be subject to a fine, just as you are subject to a traffic fine for exceeding the speed limit. In both cases, the fines and, in some serious or repetitive cases, suspension of license are intended to encourage efforts to operate within the limits. The safest limits would be 0 mph and 0 rem per quarter. But then we wouldn't get anywhere.

21. Why do some facilities establish administrative limits that are below the NRC limits?

There are two reasons. First, the NRC regulations state that licensees should keep exposures to radiation ALARA. By requiring specific approval for worker doses in excess of set levels, more careful risk-benefit analysis can be made as each additional increment of dose is approved for a worker. Secondly, a facility administrative limit that is set lower than the quarterly NRC limit provides a safety margin designed to help the licensee avoid overexposures.

22. Several scientists have suggested that NRC limits are too high and should be lowered. What are the arguments for lowering the limits?

In general, those critical of present dose limits say that the individual risk is higher than is estimated by the BEIR Committee, the ICRP, and UNSCEAR. Based on studies of low-level exposures to large groups, some researchers have concluded that a given dose of radiation may be more likely to cause biological effects than previously thought. Some of these studies are listed in the bibliography (Mancuso, Archer) and the BEIR-80 report includes a section analyzing the findings of these and other studies. Scientific opinion differs on the validity of the research methods used and the methods of statistical analysis. The problem is that the expected additional incidence of radiation-caused effects such as cancer is difficult to detect in comparison with the much larger normal incidence. It cannot be shown without question that these effects were more frequent in the exposed study group than in the unexposed group used for comparison, or that the observed effects were caused

by radiation. The BEIR committee concluded that claims of higher risk had "no substance."

The NRC staff continually reviews the results of research on radiation risks. With respect to large-scale studies of radiation-induced health effects in human populations exposed to low-level ionizing radiation, the NRC and EPA have recently concluded that there is no one population group available for which such a study could be expected to provide a more meaningful estimate of the low-level radiation risk. This is due, in large part, to the observed and estimated low incidence of radiation health effects from low doses. However, the results of ongoing studies, such as that on nuclear shipyard workers, will be carefully reviewed and the development of a radiation-worker registry is being considered as a possible data base for future studies.

23. What are the reasons for not lowering the NRC dose limits?

Assuming that the 5-rem-per-year limit is adopted, there are three reasons:

a. Health risks are already low.

The estimated health risks associated with current average occupational radiation doses (e.g., 0.5 rem/yr for 50 years) are comparable to or less than risk levels in other occupational areas considered to be among the safest. If a person were exposed to the maximum of 5 rems per year for 50 years, which virtually never occurs, he or she might incur a risk comparable to the average risks in mining and heavy construction. An occasional 5-rem annual dose might be necessary to allow some jobs to be done without a significant increase in the collective dose. If the dose limits were lowered significantly, the number of people required to complete many jobs would increase. The collective dose would then increase since more individuals would be receiving nonproductive exposure while entering and leaving the work area and preparing for the job. The total number of health effects might go up as the collective dose increased.

b. The current regulations are considered sound.

The regulatory standards for dose limits are based on the recommendations of the Federal Radiation Council. At the time these standards were developed, about 1960, it was considered unlikely that exposure to these levels during a working lifetime would result in clinical evidence of injury or disease different from that occurring in the unexposed population. The scientific data base for the standards consisted primarily of human experience (x-ray exposures to medical practitioners and patients, ingestion of radium by watch dial painters, early effects observed in Japanese atomic bomb survivors, radon exposures of uranium miners, occupational radiation accidents) involving very large doses delivered at high dose rates. The data base also included the results of a large number of animal experiments involving high doses and dose rates. The animal experiments were particularly useful in the evaluation of genetic effects. The observed effects were related to low-level radiation according to the linear model explained in Question 7. Based on this approach, the regulations in 10 CFR Part 20, "Standards for Protection Against Radiation," also state that licensees should maintain all radiation exposures, and releases of radioactive materials in effluents, as low as is reasonably achievable. More recent scientific reviews of the large body of experimental data, such as the BEIR-80 and the recent EPA guidance, continue to support the view that use of a 5-rem-per-year limit is acceptable in practice. Experience has shown that, under this limit, the average dose to workers is near 0.5 rem/yr with very few workers consistently approaching the limit.

c. There is little to gain.

Reducing the dose limits, for example, to 0.5 rem/yr has been analyzed by the NRC staff. An estimated 2.6 million person-rems could be saved from 1980 through the year 2000 by nuclear power plant licensees if compliance with the new limit were achieved by lowering the radiation levels, working times, or both, rather than by using extra workers. It is estimated that something like $23 billion would be spent toward this purpose. Spending $23 billion to save 2.6 million person-rems would amount to spending $30 to $90 million to prevent each potential radiation-induced premature cancer death. Society considers this cost unacceptably high for individual protection.

24. Are there any areas of concern about radiation risks that might result in changing the NRC dose limits?

Yes. Three areas of concern to the NRC staff are specifically identified below:

a. An independent study by Rossi and Mays and other biological research have indicated that a given dose of neutron radiation may be more likely to cause biological effects than was previously thought. Other recent studies cast doubt on the issue. The NCRP is currently studying the data related to the neutron radiation question and is expected to make recommendations as to whether neutron dose limits should be changed. Although the scientific community has not yet come to agreement on this question, workers should be advised of the possibility of higher risk when entering areas where exposure to neutrons will occur.

b. It has been known for some time that rapidly growing living tissue is more sensitive to injury from radiation than tissue in which the cells are not reproducing rapidly. Thus the embryo or fetus is more sensitive to radiation injury than an adult. The NCRP recommended in Report No. 39 that special precautions be taken when an occupationally exposed woman could be pregnant in order to protect the embryo or fetus. In 1975, the NRC issued Regulatory Guide 8.13, "Instruction Concerning Prenatal Radiation Exposure," in which it is recommended that licensees instruct all workers concerning this special risk. The guide recommends that all workers be advised that the NCRP recommended that the maximum permissible dose to the embryo or fetus from occupational exposure of the mother should not exceed 0.5 rem for the full 9-month pregnancy period. In addition, the guide suggests options

available to the female employee who chooses not to expose her embryo or fetus to this additional risk.

The United States Department of Health and Human Services is similarly concerned about prenatal exposure from medical x-rays. In 1979 they published proposed guidelines for physicians concerning abdominal x-rays for possibly pregnant women. The guidelines in effect encourage the x-ray staff to make efforts to determine whether a female patient is pregnant and to defer x-rays if possible until after the child is born.

c. Also of special interest is the indication that female workers are subject to more risk of cancer incidence than male workers. In terms of all types of cancer except leukemia, the BEIR-80 analysis indicates that female workers have a risk of developing radiation-induced cancer that is approximately one and one-half times that for males. This increased risk is primarily due to the incidence of breast and thyroid cancer in women. These types of cancer, however, have a high cure rate. Thus the difference between men and women in cancer mortality is not great. Incidence of radiation-induced leukemia is about the same for both sexes. Female workers should be aware of this difference in the risks of radiation-induced cancer in deciding whether or not to seek work involving exposure to radiation.

25. *How much radiation does the average person who does not work in the nuclear industry receive?*

We are all exposed from the moment of conception to ionizing radiation from several sources. Our environment, and even the human body, contains naturally occurring radioactive materials that contribute some of the background radiation we receive. Cosmic radiation originating in space and in the sun contributes additional exposure. The use of x-rays and radioactive materials in medicine and dentistry adds considerably to our population exposure.

Table 6 shows estimated average individual exposure in millirems from natural background and other sources.

TABLE 6

U.S. General Population Exposure Estimates (1978)[a]

Source	Average Individual Dose (mrem/yr)
Natural background (average in U.S.)	100
Release of radioactive material in natural gas, mining, milling, etc.	5
Medical (whole-body equivalent)	≯0
Nuclear weapons (primarily fallout)	5-8
Nuclear energy	0.28
Consumer products	0.03
Total	∿200 mrem/yr

[a]Adapted from a report by the Interagency Task Force on the Health Effects of Ionizing Radiation pubished by the Department of Health, Education, and Welfare.

Thus, the average individual in the general population receives about 0.2 rem of radiation exposure each year from sources that are a part of our natural and man-made environment. By the age of 20 years, an individual has accumulated about 4 rems. The most likely target for reduction of population exposure is medical uses.

26. *Why aren't medical exposures considered as part of a worker's allowed dose?*

Equal doses of medical and occupational radiation have equal risks.[7] Medical exposure to radiation should be justified for reasons quite different, however, from those applicable to occupational exposure. A physician prescribing an x-ray should be convinced that the benefit to the patient of the resulting medical information justifies the risk associated with the radiation. Each worker must decide on the acceptance of occupational radiation risk just as each worker must decide on the acceptability of any other occupational hazard.

For another point of view, consider a worker who receives a dose of 2 rems from a series of x-rays or a radioactive medicine in connection with an injury or illness. This dose and the implied risk should be justified on medical grounds. If the worker had also received a dose of 2 rems on the job, the combined dose of 4 rems would not incapacitate the worker. A dose of 4 rems is not especially dangerous and is not large compared to the cumulative lifetime dose. Resfricting the worker from additional job exposure during the remainder of the quarter would have no effect one way or the other on the risk from the 2 rems already received from medical exposure. If the individual worker accepts the risks associated with the x-rays on the basis of the medical benefits and the risks associated with job-related exposure on the basis of employment benefits, it would be unfair to restrict the individual from employment in radiation areas for the remainder of the quarter.

Some therapeutic medical doses such as those received from cobalt-60 treatment can range as high as 6000 rems to a small part of the body, spread over a period of several weeks or months.

27. *What is meant by internal exposure?*

The total radiation dose to the worker is the external dose (measured by the film badge and reported as "whole-body dose") plus the dose from internal emitters. The monitoring of the additional internal dose is difficult. Because there is the possibility of internal doses occurring, a good air-monitoring program should be established when warranted.

The uptake of radioactive materials by workers is generally due to breathing contaminated air. Radioactive materials may be present as fine dust or gases in the workplace atmosphere. The surfaces of equipment and workbenches

[7]It is likely that a significant portion of reported medical x-ray exposure is to parts of the body only. An exposure of 100 mrem to the whole body is more significant than a 100-mrem chest x-ray.

may be contaminated. Radioactive materials may enter the body by being breathed in, taken in with food or drink, or being absorbed through the skin, particularly if the skin is broken.

After entering the body, the radioactive material will migrate to particular organs or particular parts of the body depending on the biochemistry of the material. For example, uranium will tend to deposit in the bones where it will remain for a long time. It is slowly eliminated from the body, mostly by way of the kidneys. Radium will also tend to deposit in the bones. Radioactive iodine will seek out the thyroid glands (located in the neck) and deposit there.

The dose from these internal emitters cannot be measured either by the film badge or by other ordinary dosimeters carried by the worker. This means that the internal radiation dose must be separately monitored using other detection methods.

Internal exposure can be estimated by measuring the radiation emitted from the body or by measuring the radioactive materials contained in biological samples such as urine or feces. Dose estimates can also be made if one knows how much radioactive material is in the air and the length of time during which the air was breathed.

28. How are the limits for internal exposure set?

Standards have been established for the maximum permissible amount of each radionuclide that may be accumulated in the critical organs[8] of the worker's body.

Calculations are made to determine the quantity of radioactive material that has been taken into the body and the total dose that would result. Then, based on limits established for particular body organs similar to 1¼ rems in a calendar quarter for whole-body exposure, the regulations specify maximum permissible concentrations of radioactive material in the air to which a worker can be exposed for 40 hours per week over 13 weeks or 1 calendar quarter. The regulations also require that efforts be made to keep internal exposure ALARA.

Internal exposure is controlled by limiting the release of radioactive material into the air and by carefully monitoring the work area for airborne radioactivity and surface contamination. Protective clothing and respiratory (breathing) protection should be used whenever the possibility of contact with loose radioactive material cannot be prevented.

29. Is the dose a person received from internal exposure added to that received from external exposure?

Exposure to radiation that results from radioactive materials taken into the body is measured, recorded, and reported to the worker separately from external dose. The internal dose to the whole body or to specific organs does not at this time count against the 3-rem-per-calendar-quarter limit. ICRP recommends that the internal and external doses should be appropriately added. This recommendation is currently under study by the staffs of the NRC, the EPA, and the Occupational Safety and Health Administration (OSHA).

30. How is a worker's external radiation dose determined?

A worker may wear three types of radiation-measuring devices. A self-reading pocket dosimeter records the exposure to incident radiation and can be read out immediately upon finishing a job involving external exposure to radiation. A film badge or TLD badge records radiation dose, either by the amount of darkening of the film or by storing energy in the TLD crystal. Both these devices require processing to determine the dose but are considered more reliable than the pocket dosimeter. A worker's official report of dose received is normally based on film or TLD badge readings, which provide a cumulative total and are more accurate.

31. What are my options if I decide not to accept the risks associated with occupational radiation exposure?

If the risks from exposure to radiation that may be expected to occur during your work are unacceptable to you, you could request a transfer to a job that does not involve exposure to radiation. However, the risks associated with exposure to radiation that workers, on the average, actually receive are considered acceptable, compared to other occupational risks, by virtually all the scientific groups that have studied them. Your employer is probably not obligated to guarantee you a transfer if you decide not to accept an assignment requiring exposure to radiation.

You also have the option of seeking other employment in a nonradiation occupation. However, the studies that have compared occupational risks in the nuclear industry to those in other job areas indicate that nuclear work is relatively safe. Thus, you will not necessarily find significantly lower risks in another job.

A third option would be to practice the most effective work procedures so as to keep your exposure ALARA. Be aware that reducing time of exposure, maintaining distance from radiation sources, and using shielding can all lower your exposure. Plan radiation jobs carefully to increase efficiency while in the radiation area. Learn the most effective methods of using protective clothing to avoid contamination. Discuss your job with the radiation protection personnel who can suggest additional ways to reduce your exposure.

32. Where can I get additional information on radiation risk?

The following list suggests sources of useful information on radiation risk:

a. Your Employer

The radiation protection or health physics office in the facility where you are employed.

[8] Critical organ refers to those parts of the body vulnerable to radiation damage such as bone, lungs, thyroid, and other systems where certain radioactive materials will concentrate if taken into the body.

b. Nuclear Regulatory Commission

Regional Offices

King of Prussia, PA 19406	215-337-5000
Atlanta, GA 30303	404-221-4503
Glen Ellyn, IL 60137	312-932-2500
Arlington, TX 76012	817-334-2841
Walnut Creek, CA 94596	415-943-3700

Headquarters

Occupational Radiation Protection Branch
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Telephone: 301-443-5970

c. Department of Health and Human Services

Office of the Director
Bureau of Radiological Health (HFX-1)
Department of Health and Human Services
5600 Fishers Lane
Rockville, MD 20857

Telephone: 301-443-4690

d. Environmental Protection Agency

Office of Radiation Programs
U.S. Environmental Protection Agency
401 M Street, SW
Washington, D.C. 20460

Telephone: 703-557-9710

BIBLIOGRAPHY

American Cancer Society, *1979 Cancer Facts and Figures*, 1978.

Anderson, T.W., "Radiation Exposure of Hanford Workers: A Critique of the Mancuso, Stewart, and Kneale Report," *Health Physics*, Vol. 35, December 1978.

Archer, V.E., "Effects of Low-Level Radiation: A Critical Review," *Nuclear Safety*, Vol. 21, No. 1, January-February 1978.

Atomic Energy Commission, *Operational Accidents and Radiation Exposure Experience*, WASH-1192, Fall 1975.

Barnett, M.H., *The Biological Effects of Ionizing Radiation: An Overview*, Department of Health, Education, and Welfare Publication (FDA) 77-8004, October 1976.

Cohen, B.L., and Lee, I.S., "A Catalog of Risks," *Health Physics*, Vol. 36, June 1979.

Cook, J., and Nelson, D., *Occupational Exposures to Ionizing Radiation in the United States: A Comprehensive Summary for 1975*, EPA 520/4-80-001, Environmental Protection Agency.

Department of Health, Education, and Welfare, *Biologic Effects of Ionizing Radiation*, Report of the Science Work Group of the Interagency Task Force on Radiation, June 1979.

Dreyer, N.A., et al., *The Feasibility of Epidemiologic Investigations of the Health Effects of Low-Level Ionizing Radiation*, NUREG/CR-1728, Nuclear Regulatory Commission, November 1980.

Gilbert, E.S., "Assessment of Risks from Occupational Exposure to Ionizing Radiation," in *Energy and Health Proceedings of the Conference on Energy and Health*, June 26-30, 1978, SIAM Publication, Philadelphia, 1979.

Gofman, J.W., "The Question of Radiation Causation of Cancer in Hanford Workers," *Health Physics*, Vol. 37, November 1979.

Gotchy, R.L., "Estimation of Life Shortening Resulting from Radiogenic Cancer per Rem of Absorbed Dose," *Health Physics*, Vol. 35, October 1978.

Hall, E.J., *Radiation and Life*, Pergamon Press, 1976.

International Commission on Radiological Protection, *Problems Involved in Developing an Index of Harm, Annals of the ICRP*, ICRP Publication 27, Pergamon Press, May 1977.

International Commission on Radiological Protection, *Radiation Protection*, Recommendations of the International Commission on Radiological Protection, ICRP Publication 26, Pergamon Press, January 1977.

Kelsey, C.A., "Comparison of Relative Risk from Radiation Exposure and Other Common Hazards," *Health Physics*, Vol. 35, August 1978.

Lapp, R.E., *The Radiation Controversy*, Reddy Communications, Inc., Greenwich, Connecticut, 1979.

Lapp, R.E., *A Worker's Guide to Radiation*, Atomic Industrial Forum, August 1979.

Linos, A., et al., "Low Dose Radiation and Leukemia, Mayo Clinic and Foundation, Rochester, Minn.," *New England Journal of Medicine 1980*; Vol. 302, pp. 1101-1105.

Mancuso, T.F., Stewart, A., and Kneale, G., "Radiation Exposures of Hanford Workers Dying from Cancer and Other Causes," *Health Physics*, Vol. 33, November 1977.

Muller, R., "Natural Radiation Background vs. Radiation from Nuclear Power Plants," *Journal of Environmental Sciences*, August 1972.

Najarian, T., and Colton, T., "Mortality from Leukemia and Cancer in Shipyard Nuclear Workers," *Lancet*, I: May 1978.

National Academy of Sciences, *The Effects on Populations of Exposure to Low Levels of Ionizing Radiation*, Report of the Committee on the Biological Effects of Ionizing Radiation (BEIR), 1980.

Rossi and Mays, "Leukemia Risk from Neutrons," *Health Physics*, Vol. 34, pp. 353-360, 1978.

Schottenfeld, D., and Haas, J., "Carcinogens in the Workplace," *CA-A Cancer Journal for Clinicians*, Vol. 29, No. 3, May-June 1979.

United Nations Scientific Committee on the Effects of Atomic Radiation, 1977, *Sources and Effects of Ionizing Radiation*, Report to the General Assembly, UN Publication No. E.77.IX.I, 1977.

Upton, Arthur C., "Radiation from Nuclear Power Exaggerated," *New England Journal of Medicine*, Vol. 302, pp. 1205-1206, May 22, 1980.

World Health Organization, *Health Implications of Nuclear Power Production*, Report of a Working Group, December 1975.

VALUE/IMPACT STATEMENT

1. PROPOSED ACTION

1.1 Description

All NRC licensees are required to provide appropriate radiation protection training for all permanent and transient personnel who work in restricted areas (§ 19.12 of 10 CFR Part 19). A clear and reasonable assessment of the biological risks associated with occupational radiation exposure is essential to effective radiation protection training. The proposed action is to provide instructional material in a suitable form describing and estimating the risks from exposure to radiation. The instructional material will be suitable for use in licensee training programs and will represent an acceptable method of complying with part of the existing training requirements.

1.2 Need for Proposed Action

One common element of those occupational areas encompassed by NRC licensing activity is worker exposure to ionizing radiation and the biological risks from exposure. Union representatives have expressed a dissatisfaction with the way in which these risks have been explained to the worker by the licensee. In addition, they feel the NRC has a responsibility to make its position on the controversial issue of radiation risk clear to the worker and the public. A meeting of NRC staff and union representatives was held on November 28, 1978, during which this matter was discussed. A transcript of the meeting is available from the Public Document Room.

The Environmental Protection Agency (EPA) has published recommendations concerning radiation protection for public comment and, in conjunction with other government agencies, will be holding public hearings on radiation risk and dose limits. This guide reflects current and proposed EPA guidance and will be helpful to workers and worker groups interested in understanding current discussion on the issues of risk and dose limits.

1.3 Value/Impact of Proposed Action

1.3.1 NRC Operations

Instructional material on radiation risk written at a level and scope understandable to the worker should contribute to increased confidence, on the part of the worker, in the NRC in general. A better understanding of the risk should elicit more worker cooperation with NRC-enforced safety programs. Impacts of the development of instructional material on risk include task completion manpower cost, estimated to be 0.2 person-year, and printing costs of approximately $400.00.

1.3.2 Other Government Agencies

Agreement States whose licensing regulations include radiation protection training requirements may benefit from the availability of an NRC guide on radiation risk suitable for inclusion in those training programs. The guide was reviewed and distributed to agreement states by the Office of State Programs. Comments have been received from the EPA and the Bureau of Radiological Health.

1.3.3 Industry

Providing a reasonable and understandable statement on worker risk should facilitate industry efforts to provide effective safety training and to better achieve as low as is reasonably achievable (ALARA) objectives. Minimal impact is expected in the form of additional cost of training programs since training requirements already exist. Comments from unions and industry in the development of instructional material on risk were encouraged. Numerous public comment letters were received from industry and three meetings were held with worker groups to review the draft guide.

1.3.4 Workers

The proposed action should improve worker protection in that reasonable understanding of radiation risk is essential to the development of safe working practices. The staff believes that an objective discussion of radiation risk may in fact reduce "over concern" and also eliminate "under concern" on the part of some workers. If improved training results in a wider recognition and respect for radiation as an industrial hazard, more attention will be given to protective procedures and a reduction in individual and collective dose should result.

1.3.5 Public

Nuclear workers are also members of the public and are generally residents of the area where facilities are located. Having a better-informed public should result in a wider range of participation in local decisionmaking concerning nuclear development. Improved training implies the added benefit of increased plant safety, thereby decreasing the probability of accidents that could involve the public.

1.3.6 Decision on Proposed Action

The NRC should develop and provide instructional material concerning risk from occupational radiation exposure.

2. TECHNICAL APPROACH

The technical approach proposed is to develop instructional material concerning risks to the worker from occupational radiation exposure and to publish the material in a form that will receive the widest dissemination among NRC-licensed facilities. An alternative is to publish the findings of the proposed hearing on dose limits and assume the relevant information will filter down to the worker. It is

the feeling of the staff that a direct approach is required here.

3. PROCEDURAL APPROACH

The proposed action, to publish training material concerning risks from occupational radiation exposure, the use of which would be recommended to all licensees, could be accomplished by several alternative methods. These include an NRC regulation requiring that specific training materials be used, a regulatory guide based on the existing §19.12 that would provide an acceptable method for training on ris; an ANSI standard on training that could be adopted by a regulatory guide, and a NUREG report or a branch position paper.

3.1 Value/Impact of Procedural Alternatives

An *NRC regulation* establishes general legal requirements, is costly and time consuming to prepare, and is not an appropriate vehicle for the specific and narrow objective proposed here. A regulation would be difficult to modify as new information on radiation risk is developed. One advantage is that a regulation legally requires compliance. In general, this approach is not considered cost effective in view of the objectives of the proposed action.

ANSI standards are generally intended as highly technical and advanced treatments of specialized areas of concern to industry. A comprehensive technical review of risks from radiation would be of value but would not be suitable as instructional material at an introductory level for worker radiation protection training. Completion of an ANSI standard and an endorsing regulatory guide would require several years and would be too costly. This approach is not considered cost effective in view of the proposed objectives.

A *NUREG document* would be an appropriate vehicle for a comprehensive discussion of radiation risk beyond the scope of what is proposed here. A regulatory position, however, is not established through publication of a NUREG report. Since this proposal includes establishing an acceptable method for compliance with elements of required training programs, a NUREG report is not suitable.

Branch position statements are intended as interim measures to be used when an immediate response is required. They are usually superseded when a more permanent mode of guidance is developed.

A *regulatory guide* can be prepared at reasonable cost within a reasonable time period. The staff does not consider that revision of any existing regulatory guides could provide the instructional material intended here. Regulatory guides on training requirements are being developed but are specific to types of licensees such as Regulatory Guide 8.27, "Radiation Protection Training for Personnel at Light-Water-Cooled Nuclear Power Plants." The action proposed here has broad application to all licensees, as does Regulatory Guide 8.13, "Instruction Concerning Prenatal Radiation Exposure."

3.2 Decision on Procedural Approach

The staff concludes that a regulatory guide similar to Regulatory Guide 8.13 on the subject of worker instruction concerning risks from occupational radiation exposure should be published at this time.

4. STATUTORY CONSIDERATIONS

4.1 NRC Regulatory Authority

Section 19.12 of 10 CFR Part 19 establishes a legal requirement that all NRC licensees provide radiation protection training to personnel and that the training be commensurate with the potential risks from radiation exposure encountered by those personnel. The NRC is thus authorized to provide criteria for acceptable levels of training and to inspect for compliance with training requirements.

4.2 Need for NEPA Statement

The action proposed here is to publish an instructional document on risks. This will occur after, and be in addition to, any major NRC action on retaining or modifying existing dose limits, based on planned public hearings. Since at that time it would not constitute a major addition or change and would entail no effect on the environment, an environmental impact statement is not considered necessary.

5. RELATIONSHIP TO OTHER EXISTING OR PROPOSED REGULATIONS OR POLICIES

Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants," requires a commitment to appropriate radiation protection training. When next revised, it should include reference to this proposed action as an acceptable element of a licensee's training program.

This proposed guide is consistent with Regulatory Guide 8.8, "Information Relevant to Ensuring That Occupational Exposures at Nuclear Power Stations Will Be As Low As Is Reasonably Achievable." When next revised, Regulatory Guide 8.8 should include cross-reference to this proposed action.

This proposed action directly supplements Regulatory Guide 8.27 and will supplement and be referenced in other planned guides on training at other types of licensed facilities, e.g., uranium fuel fabrication plants, uranium mills, medical institutions.

6. SUMMARY AND CONCLUSIONS

In summary, it is proposed that this regulatory guide be prepared and issued for the purpose of providing instructional material concerning assessment of risk from occupational radiation exposure.

Revision 2
December 1987

U.S. NUCLEAR REGULATORY COMMISSION

REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

REGULATORY GUIDE 8.13
(Task OP 031-4)

INSTRUCTION CONCERNING PRENATAL RADIATION EXPOSURE

A. INTRODUCTION

Section 19.12, "Instructions to Workers," of 10 CFR Part 19, "Notices, Instructions, and Reports to Workers; Inspections," requires that all individuals working in or frequenting any portion of a restricted area[1] be instructed in the health protection problems associated with exposure to radioactive materials or radiation, in precautions or procedures to minimize exposure, and in the regulations that they are expected to observe. The present 10 CFR Part 20, "Standards for Protection Against Radiation," has no special limit for exposure of the embryo/fetus.[2] This guide describes the instructions an employer should provide to workers and supervisors concerning biological risks to the embryo/fetus exposed to radiation, a dose limit for the embryo/fetus that is under consideration, and suggestions for reducing radiation exposure.

This regulatory guide takes into consideration a proposed revision to 10 CFR Part 20, which incorporates the radiation protection guidance for the embryo/fetus approved by the President in January 1987 (Ref. 1). This revision to Part 20 was issued in January 1986 for comment as a proposed rule. Comments on the guide as it pertains to the proposed Part 20 are encouraged. If the new Part 20 is codified, this regulatory guide will be revised to conform to the new regulation and will incorporate appropriate public comments.

Any information collection activities mentioned in this regulatory guide are contained as requirements in 10 CFR Parts 19 or 20, which provide the regulatory basis for this guide. The information collection requirements in 10 CFR Parts 19 and 20 have been cleared under OMB Clearance Nos. 3150-0044 and 3150-0014, respectively.

B. DISCUSSION

It has been known since 1906 that cells that are dividing very rapidly and are undifferentiated in their structure and function are generally more sensitive to radiation. In the embryo stage, cells meet both these criteria and thus would be expected to be highly sensitive to radiation. Furthermore, there is direct evidence that the embryo/fetus is radiosensitive. There is also evidence that it is especially sensitive to certain radiation effects during certain periods after conception, particularly during the first 2 to 3 months after conception when a woman may not be aware that she is pregnant.

Section 20.104 of 10 CFR Part 20 places different radiation dose limits on workers who are minors than on adult workers. Workers under the age of 18 are limited to one-tenth of the adult radiation dose limits. However, the present NRC regulations do not establish dose limits specifically for the embryo/fetus.

The NRC's present limit on the radiation dose that can be received on the job is 1,250 millirems per quarter (3 months).[3] Working minors (those under 18) are limited to a dose equal to one-tenth that of adults, 125 millirems per quarter. (See § 20.101 of 10 CFR Part 20.)

Because of the sensitivity of the unborn child, the National Council on Radiation Protection and Measurements (NCRP) has recommended that the dose equivalent

[1] Restricted area means any area that has controlled access to protect individuals from being exposed to radiation and radioactive materials.

[2] In conformity with the proposed revision to 10 CFR Part 20, the term "embryo/fetus" is used throughout this document to represent all stages of pregnancy.

[3] The limit is 3,000 millirems per quarter if the worker's occupational dose history is known and the average dose does not exceed 5,000 millirems per year.

8801200276 APP

to the unborn child from occupational exposure of the expectant mother be limited to 500 millirems for the entire pregnancy (Ref. 2). The 1987 Presidential guidance (Ref. 1) specifies an effective dose equivalent limit of 500 millirems to the unborn child if the pregnancy has been declared by the mother, the guidance also recommends that substantial variations in the rate of exposure be avoided. The NRC (in § 20.208 of its proposed revision to Part 20) has proposed adoption of the above limits on dose and rate of exposure.

In 1971, the NCRP commented on the occupational exposure of fertile women (Ref. 2) and suggested that fertile women should be employed only where the annual dose would be unlikely to exceed 2 or 3 rems and would be accumulated at a more or less steady rate. In 1977, the ICRP recommended that, when pregnancy has been diagnosed, the woman work only where it is unlikely that the annual dose would exceed 0.30 of the dose-equivalent limit of 5 rems (Ref. 3). In other words, the ICRP has recommended that pregnant women not work where the annual dose might exceed 1.5 rem.

C. REGULATORY POSITION

Instructions on radiation risks should be provided to workers, including supervisors, in accordance with § 19.12 of 10 CFR Part 19 before they are allowed to work in a restricted area. In providing instructions on radiation risks, employers should include specific instructions about the risks of radiation exposure to the embryo/fetus.

The instructions should be presented both orally and in printed form, and the instructions should include, as a minimum, the information provided in Appendix A (Instructor's Guide) to this guide. Individuals should be given the opportunity to ask questions and in turn should be questioned to determine whether they understand the instructions. An acceptable method of ensuring that the information is understood is to give a simple written test covering the material included in Appendix B (Pregnant Worker's Guide). This approach should highlight for instructors those parts of the instructions that cause difficulties and thereby lead to appropriate modifications in the instructional curriculum.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC staff's plans for using this regulatory guide.

Except in those cases in which an applicant or licensee proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the NRC will use the material described in this guide to evaluate the instructional program presented to individuals, including supervisors, working in or frequenting any portion of a restricted area.

APPENDIX A

INSTRUCTOR'S GUIDE

EFFECTS ON THE EMBRYO/FETUS OF EXPOSURE TO RADIATION AND OTHER ENVIRONMENTAL HAZARDS

In order to decide whether to continue working while exposed to ionizing radiation during her pregnancy, a woman should understand the potential effects on an embryo/fetus, including those that may be produced by various environmental risks such as smoking and drinking. This will allow her to compare these risks with those produced by exposure to ionizing radiation.

Table 1 provides information on the potential effects resulting from exposure of an embryo/fetus to radiation and nonradiation risks. The second column gives the rate at which the effect is produced by natural causes in terms of the number per thousand cases. The fourth column gives the number of additional effects per thousand cases believed to be produced by exposure to the specified amount of the risk factor.

The following section discusses the studies from which the information in Table 1 was derived. The results of exposure of the embryo/fetus to the risk factors and the dependence on the amount of the exposure are explained.

1. RADIATION RISKS

1.1 Childhood Cancer

Numerous studies of radiation-induced childhood cancer have been performed, but a number of them are controversial. The National Academy of Science (NAS) BEIR report reevaluated the data from these studies and even reanalyzed the results. Some of the strongest support for a causal relationship is provided by twin data from the Oxford survey (Ref. 4). For maternal radiation doses of 1,000 millirems, the excess number of deaths (above those occurring from natural causes) was found to be 0.6 death per thousand children (Ref. 4).

1.2 Mental Retardation and Abnormal Smallness of the Head (Microcephaly)

Studies of Japanese children who were exposed while in the womb to the atomic bomb radiation at Hiroshima and Nagasaki have shown evidence of both small head size and mental retardation. Most of the children were exposed to radiation doses in the range of 1 to 50 rads. The importance of the most recent study lies in the fact that investigators were able to show that the gestational age (age of the embryo/fetus after conception) at the time the children were exposed was a critical factor (Ref. 7). The approximate risk of small head size as a function of gestational age is shown in Table 1. For a radiation dose of 1,000 millirems at 4 to 7 weeks after conception, the excess cases of small head size was 5 per thousand; at 8 to 11 weeks, it was 9 per thousand (Ref. 7).

In another study, the highest risk of mental retardation occurred during the 8 to 15 week period after conception (Ref. 8). A recent EPA study (Ref. 16) has calculated that excess cases of mental retardation per live birth lie between 0.5 and 4 per thousand per rad.

1.3 Genetic Effects

Radiation-induced genetic effects have not been observed to date in humans. The largest source of material for genetic studies involves the survivors of Hiroshima and Nagasaki, but the 77,000 births that occurred among the survivors showed no evidence of genetic effects. For doses received by the pregnant worker in the course of employment considered in this guide, the dose received by the embryo/fetus apparently would have a negligible effect on descendants (Refs. 17 and 18).

2. NONRADIATION RISKS

2.1 Occupation

A recent study (Ref. 9) involving the birth records of 130,000 children in the State of Washington indicates that the risk of death to the unborn child is related to the occupation of the mother. Workers in the metal industry, the chemical industry, medical technology, the wood industry, the textile industry, and farms exhibited stillbirths or spontaneous abortions at a rate of 90 per thousand above that of workers in the control group, which consisted of workers in several other industries.

2.2 Alcohol

It has been recognized since ancient times that alcohol consumption had an effect on the unborn child. Carthaginian law forbade the consumption of wine on the wedding night so that a defective child might not be conceived. Recent studies have indicated that small amounts of alcohol consumption have only the minor effect of reducing the birth weight slightly, but when consumption increases to 2 to 4 drinks per day, a pattern of abnormalities called the fetal alcohol syndrome (FAS) begins to appear (Ref. 11). This syndrome consists of reduced growth in the unborn child, faulty brain function, and abnormal facial features. There is a syndrome that has the same symptoms as full-blown FAS that occurs in children born to mothers who have not consumed alcohol. This naturally occurring syndrome occurs in about 1 to 2 cases per thousand (Ref. 10).

TABLE 1

EFFECTS OF RISK FACTORS ON PREGNANCY OUTCOME

Effect	Number Occurring from Natural Causes	Risk Factor	Excess Occurrences from Risk Factor
		RADIATION RISKS	
		Childhood Cancer	
Cancer death in children	1.4 per thousand (Ref. 5)	Radiation dose of 1000 millirems received before birth	0.6 per thousand (Ref. 4)
		Abnormalities	
		Radiation dose of 1000 millirads received during specific periods after conception:	
Small head size	40 per thousand (Ref. 6)	4-7 weeks after conception	5 per thousand (Ref. 7)
Small head size	40 per thousand (Ref. 6)	8-11 weeks after conception	9 per thousand (Ref. 7)
Mental retardation	4 per thousand (Ref. 8)	Radiation dose of 1000 millirads received 8 to 15 weeks after conception	4 per thousand (Ref. 8)
		NONRADIATION RISKS	
		Occupation	
Stillbirth or spontaneous abortion	200 per thousand (Ref. 9)	Work in high-risk occupations (see text)	90 per thousand (Ref. 9)
		Alcohol Consumption (see text)	
Fetal alcohol syndrome	1 to 2 per thousand (Ref. 10)	2-4 drinks per day	100 per thousand (Ref. 11)
Fetal alcohol syndrome	1 to 2 per thousand (Ref. 10)	More than 4 drinks per day	200 per thousand (Ref. 11)
Fetal alcohol syndrome	1 to 2 per thousand (Ref. 10)	Chronic alcoholic (more than 10 drinks per day)	350 per thousand (Ref. 12)
Perinatal infant death (around the time of birth)	23 per thousand (Refs. 13, 14)	Chronic alcoholic (more than 10 drinks per day)	170 per thousand (Ref. 15)
		Smoking	
Perinatal infant death	23 per thousand (Refs. 13, 14)	Less than 1 pack per day	5 per thousand (Ref. 13)
Perinatal infant death	23 per thousand (Refs. 13, 14)	One pack or more per day	10 per thousand (Ref. 13)

For mothers who consume 2 to 4 drinks per day, the excess occurrences number about 100 per thousand; and for those who consume more than 4 drinks per day, excess occurrences number 200 per thousand. The most sensitive period for this effect of alcohol appears to be the first few weeks after conception, before the mother-to-be realizes she is pregnant (Refs. 10 and 11). Also, 17% or 170 per thousand of the embryo/fetuses of chronic alcoholics develop FAS and die before birth (Ref. 15). FAS was first identified in 1973 in the United States where less than full-blown effects of the syndrome are now referred to as fetal alcohol effects (FAE) (Ref. 12).

2.3 Smoking

Smoking during pregnancy causes reduced birth weights in babies amounting to 5 to 9 ounces on the average. In addition, there is an increased risk of 5 infant deaths per thousand for mothers who smoke less than one pack per day and 10 infant deaths per thousand for mothers who smoke one or more packs per day (Ref. 13).

2.4 Miscellaneous

Numerous other risks affect the embryo/fetus, only a few of which are touched upon here. Most people are familiar with the drug thalidomide (a sedative given to some pregnant women), which causes children to be born with missing limbs, and the more recent use of the drug diethylstilbestrol (DES), a synthetic estrogen given to some women to treat menstrual disorders, which produced vaginal cancers in the daughters born to women who took the drug. Living at high altitudes also gives rise to an increase in the number of low-birth-weight children born, while an increase in Down's Syndrome (mongolism) occurs in children born to mothers who are over 35 years of age. The rapid growth in the use of ultrasound in recent years has sparked an ongoing investigation into the risks of using ultrasound for diagnostic procedures (Ref. 19).

APPENDIX B

PREGNANT WORKER'S GUIDE

POSSIBLE HEALTH RISKS TO CHILDREN OF WOMEN WHO ARE EXPOSED TO RADIATION DURING PREGNANCY

During pregnancy, you should be aware of things in your surroundings or in your style of life that could affect your unborn child. For those of you who work in or visit areas designated as Restricted Areas (where access is controlled to protect individuals from being exposed to radiation and radioactive materials), it is desirable that you understand the biological risks of radiation to your unborn child.

Everyone is exposed daily to various kinds of radiation: heat, light, ultraviolet, microwave, ionizing, and so on. For the purposes of this guide, only ionizing radiation (such as x-rays, gamma rays, neutrons, and other high-speed atomic particles) is considered. Actually, everything is radioactive and all human activities involve exposure to radiation. People are exposed to different amounts of natural "background" ionizing radiation depending on where they live. Radon gas in homes is a problem of growing concern. Background radiation comes from three sources:

	Average Annual Dose
Terrestrial - radiation from soil and rocks	50 millirem
Cosmic - radiation from outer space	50 millirem
Radioactivity normally found within the human body	25 millirem
	125 millirem*
Dosage range (geographic and other factors)	75 to 5,000 millirem

The first two of these sources expose the body from the outside, and the last one exposes it from the inside. The average person is thus exposed to a total dose of about 125 millirems per year from natural background radiation.

In addition to exposure from normal background radiation, medical procedures may contribute to the dose people receive. The following table lists the average dose received by the bone marrow (the blood-forming cells) from different medical applications.

X-Ray Procedure	Average Dose*
Normal chest examination	10 millirem
Normal dental examination	10 millirem
Rib cage examination	140 millirem
Gall bladder examination	170 millirem
Barium enema examination	500 millirem
Pelvic examination	600 millirem

*Variations by a factor of 2 (above and below) are not unusual.

*Radiation doses in this document are described in two different units. The rad is a measure of the amount of energy absorbed in a certain amount of material (100 ergs per gram). Equal amounts of energy absorbed from different types of radiation may lead to different biological effects. The rem is a unit that reflects the biological damage done to the body. The millirad and millirem refer to 1/1000 of a rad and a rem, respectively.

NRC POSITION

NRC regulations and guidance are based on the conservative assumption that any amount of radiation, no matter how small, can have a harmful effect on an adult, child, or unborn child. This assumption is said to be conservative because there are no data showing ill effects from small doses. the National Academy of Sciences recently expressed "uncertainty as to whether a dose of, say, 1 rad would have any effect at all." Although it is known that the unborn child is more sensitive to radiation than adults, particularly during certain stages of development, the NRC has not established a special dose limit for protection of the unborn child. Such a limit could result in job discrimination for women of child-bearing age and perhaps in the invasion of privacy (if pregnancy tests were required) if a separate regulatory dose limit were specified for the unborn child. Therefore the NRC has taken the position that special protection of the unborn child should be *voluntary* and should be based on decisions made by workers and employers who are well informed about the risks involved.

For the NRC position to be effective, it is important that both the employee and the employer understand the risk to the unborn child from radiation received as a result of the occupational exposure of the mother. This document tries to explain the risk as clearly as possible and to compare it with other risks to the unborn child during pregnancy. It is hoped this will help pregnant employees balance the risk to the unborn child against the benefits of employment to decide if the risk is worth taking. This document also discusses methods of keeping the dose, and therefore the risk, to the unborn child as low as is reasonably achievable.

RADIATION DOSE LIMITS

The NRC's present limit on the radiation dose that can be received on the job is 1,250 millirems per quarter (3 months).* Working minors (those under 18) are limited to a dose equal to one-tenth that of adults, 125 millirems per quarter. (See § 20.101 of 10 CFR Part 20.)

Because of the sensitivity of the unborn child, the National Council on Radiation Protection and Measurements (NCRP) has recommended that the dose equivalent to the unborn child from occupational exposure of the expectant mother be limited to 500 millirems for the entire pregnancy (Ref. 2). The 1987 Presidential guidance (Ref. 1) specifies an effective dose equivalent limit of 500 millirems to the unborn child if the pregnancy has been declared by the mother; the guidance also recommends that substantial variations in the rate of exposure be avoided. The NRC (in § 20.208 of its proposed revision to Part 20) has proposed adoption of the above limits on dose and rate of exposure.

ADVICE FOR EMPLOYEE AND EMPLOYER

Although the risks to the unborn child are small under normal working conditions, it is still advisable to limit the radiation dose from occupational exposure to no more than 500 millirems for the total pregnancy. Employee and employer should work together to decide the best method for accomplishing this goal. Some methods that might be used include reducing the time spent in radiation areas, wearing some shielding over the abdominal area, and keeping an extra distance from radiation sources when possible. The employer or health physicist will be able to estimate the probable dose to the unborn child during the normal nine-month pregnancy period and to inform the employee of the amount. If the predicted dose exceeds 500 millirems, the employee and employer should work out schedules or procedures to limit the dose to the 500-millirem recommended limit.

It is important that the employee inform the employer of her condition as soon as she realizes she is pregnant if the dose to the unborn child is to be minimized.

INTERNAL HAZARDS

This document has been directed primarily toward a discussion of radiation doses received from sources outside the body. Workers should also be aware that there is a risk of radioactive material entering the body in workplaces where unsealed radioactive material is used. Nuclear medicine clinics, laboratories, and certain manufacturers use radioactive material in bulk form, often as a liquid or a gas. A list of the commonly used materials and safety precautions for each is beyond the scope of this document, but certain general precautions might include the following:

1. Do not smoke, eat, drink, or apply cosmetics around radioactive material.
2. Do not pipette solutions by mouth.
3. Use disposable gloves while handling radioactive material when feasible.
4. Wash hands after working around radioactive material.
5. Wear lab coats or other protective clothing whenever there is a possibility of spills.

Remember that the employer is required to have demonstrated that it will have safe procedures and practices before the NRC issues it a license to use radioactive material. Workers are urged to follow established procedures and consult the employer's radiation safety officer or health physicist whenever problems or questions arise.

*The limit is 3,000 millirems per quarter if the worker's occupational dose history is known and the average dose does not exceed 5,000 millirems per year.

REFERENCES

1. "Federal Radiation Protection Guidance for Occupational Exposure," *Federal Register*, p. 2822, January 27, 1987.

2. National Council on Radiation Protection and Measurements, "Basic Radiation Protection Criteria," NCRP Report No. 39, 1971.

3. International Commission on Radiological Protection, "Recommendations of the International Commission on Radiological Protection," ICRP Publication No. 26, Vol. 1, No. 3, 1977.

4. National Academy of Sciences, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation (BEIR III)," National Academy Press, Washington, DC, 1980.

5. J. L. Young and R. W. Miller, "Incidence of Malignant Tumors in U.S. Children," *Journal of Pediatrics*, pp. 254-258, 1975.

6. W. J. Blot, "Growth and Development Following Prenatal and Childhood Exposure to Atomic Radiation," *Journal of Radiation Research* (Supplement), pp. 82-85, 1975.

7. R. W. Miller and J. J. Mulvihill, "Small Head Size After Atomic Radiation," *Teratology*, Vol. 14, pp. 355-358, 1976.

8. M. Otake and W. J. Schull, "In Utero Exposure to A-bomb Radiation and Mental Retardation, a Reassessment," *The British Journal of Radiology*, Vol. 57, pp. 409-414, 1984.

9. T. L. Vaughan et al., "Fetal Death and Maternal Occupation," *Journal of Occupational Medicine*, Vol. 26, No. 9, pp. 676-678, 1984.

10. J. W. Hanson, A. P. Streissguth, and D. W. Smith, "The Effects of Moderate Alcohol Consumption During Pregnancy on Fetal Growth and Morphogenesis," *Journal of Pediatrics*, Vol. 92, pp. 457-460, 1978.

11. D. W. Smith, "Alcohol Effects on the Fetus," *Progress in Clinical and Biological Research*, Vol. 36, pp. 73-82, 1980.

12. L. B. Robe, "Alcohol and Pregnancy," The American Medical Association, Box 10946, Chicago, 1984.

13. M. B. Meyer and J. A. Tonascia, "Maternal Smoking, Pregnancy Complications, and Perinatal Mortality," *American Journal of Obstetrics and Gynecology*, Vol. 128, No. 5, pp. 494-502, 1977.

14. R. H. Mole, "Radiation Effects on Pre-Natal Development and Their Radiological Significance," *The British Journal of Radiology*, Vol. 52, No. 614, pp. 89-101, February 1979.

15. D. A. Roe, *Alcohol and the Diet*, AVI Publishing Company Inc., Westport, Connecticut, 1979.

16. Environmental Protection Agency, "Radionuclides," Background Information Document EPA 520/1-84-022-1, pp. 8-56 - 8-63.

17. G. W. Beebe, "The Atomic Bomb Survivors and the Problem of Low-Dose Radiation Effects," *American Journal of Epidemiology*, Vol. 114, No. 6, pp. 761-783, 1981.

18. W. J. Blot et al., "Reproductive Potential of Males Exposed in Utero or Prepubertally to Atomic Radiation," in *Atomic Bomb Casualty Commission Technicel Report* TR-39-72, Radiation Effects Research Foundation, Hiroshima, Japan, 1972.

19. National Council on Radiation Protection and Measurements, "Protection in Nuclear Medicine and Ultrasound Diagnostic Procedures in Children," NCRP Report No. 73, 1983.

VALUE/IMPACT STATEMENT

A draft value/impact statement was published with the proposed Revision 2 to Regulatory Guide 8.13 (Task OP 031-4) when the draft guide was published for public comment in August 1981. No changes were necessary, so a separate value/impact statement for the final guide has not been prepared. A copy of the draft value/impact statement is available for inspection and copying for a fee at the Commission's Public Document Room at 1717 H Street NW., Washington, DC, under Task OP 031-4.

*U.S. G.P.O. 1987-202-292:60318