designed to do that but, again, it is just a hope, is it not? Anyway, I agree with that; I do not have any particular reason not to - I am just being a little sceptical. The final part of that question was: Does the history of reactor operations suggest that the main problem with these risk assessments is that they lead to unrealistic estimates of probabilities? Certainly. I would probably replace 'unrealistic' by 'unbelievable'. If you take the statement I referred to by the Minister from the Ukraine about Chernobyl, saying this in February when in May the accident happened, do you call that unrealistic or unbelievable? I do not believe the bottom line figures, and that certainly makes my point on that question clear. As to the question that the approach has not anticipated the accidents that have taken place, that is one of the major reasons - most of the accidents that have occurred are manifestly outside the domain of the analysis. Finally, as to whether they lead to uncertainties in the consequences, again it is not something we have discussed at any length this morning, but there are many more uncertainties in the consequences, I think, than we are led to believe by some of the papers that have been presented to you. Obviously to do analyses, people fix on consequences, but then you face this problem of giving the impression that it is all cut and dried and that we know what is going to happen, whereas in other circles you can read enormous discussion about how little anybody knows. For example, they still do not know if there was a hydrogen explosion in the Three Mile Island accident - that is a debated question.

ACTING CHAIRMAN - At one stage in my career I did a bit of industrial advocacy and my memory of industrial accidents of all kinds - accidents that happen - is that the main factor is human error.

Mr Speed - Yes.

ACTING CHAIRMAN - It does not matter what the accident is - leave reactors out of it - like walking along the street, motor cars, factories or anything. Do we not have the human error in the situation and is that not impossible in terms of calculating probability?

Mr Speed - Yes, very much. That would be the single most important reason why I think these analyses do not lead to figures that can be believed. Of course, that does not mean that we should not think about the sorts of human responses that might occur in a given situation to try to prevent disastrous consequences, and that is what one hopes the people in the reactor business are doing. I guess it would be nice if we had enough information about naval reactors to do exactly that in the present context.

ACTING CHAIRMAN - I refer you now to page 3 so that you can follow the consequence of actions. The arguments in the submission relate largely to the probability of an accident occurring. The consequences of an accident are presumably independent of its probability. Can you explain the relevance of your arguments to describing the consequences of an accident? Can you explain the significance of your statement, in paragraph 17, that there is an enormous variety of uncertainties associated with release phenomena from the reactor vessel? What evidence is there for this statement? It gets longer as it goes.

Mr Speed - In paragraph 17, I refer to paragraph 16, which in turn refers to the study, so basically my information about these uncertainties is from that study. If you like, that is the evidence which summarises 16 probabilistic risk assessments of different reactors.

I will just mention a few: The magnitude of release of the large number of radionuclides, how much of iodine, radium, thorium and all, which is certainly an area where there is enormous uncertainty; the physical and chemical nature of the released species, whether they are in aerosol form or whether they are in liquid form; the release timing, at what stage of the action they come out; their duration, over what period are they released; the thermal properties, what is their temperature and how fast they are shooting out. All of these things are associated with the course of an accident, about which we have very little knowledge. So to make assumptions like 'X per cent of the iodine in the core will be released and that is it', is reflecting the genuine lack of knowledge as to what will actually happen when the core is melting. These are documented very fully in that reference I have given. That responds to that part.

The second question was: Given the uncertainties that exist, is it possible to take a worse case? I think I have already said that I do not find that appealing because there is a whole spectrum of accidents and somewhere you are going to be trading off an accident which might occur but which you feel is rather unlikely to, against contingency plans which you could but would rather not set into place. I will go for the worst case. Unless you feel you can thoroughly protect against the worst case, there is still the problem: Is it really the worst case? That assumes that you really understand what is going on. I think the thrust of my argument is that there is so much uncertainty that we cannot even be sure what the worst case is. I guess, in general, if you think you can protect against the worst case, that is obviously the one to go for.

ACTING CHAIRMAN - We will have to conclude. I would like to thank you on behalf of the Committee. If you have felt that some of our devil's advocate probing was rather sharp, forgive us, because in the end when we present our report it will be probed, not only in Australia but throughout the world. What you have

helped us to do and what we need to do all the time is to open our minds as widely as we can. Your paper has helped us in that regard. I do not want you to think that we are, ourselves, in any containment vessel. We are not. In fact you have helped us in breach of containment. I would like to thank you very much indeed.

Committee adjourned at 9.46 a.m.

(Evidence, p. 577)

SENATE STANDING CTEE ON FOREIGN AFFAIRS & DEFENCE 27 Mar 1987

CHAIRMAN - Professor Davis, I now invite you to speak on the document circulated to the Committee and at the conclusion of your remarks I shall invite members of the Committee to submit questions to you.

Prof. Davis - Thank you very much. The nuclear policy program with which I am affiliated has as its goal the clarification of scientific and technical issues insofar as they relate to nuclear policy decision. We do consulting work for State and local governments, for the Federal Government in the United States, for foreign governments and for environmental organisations.

The report which I have submitted to the Committee here was done under commission to an environmental organisation, Greenpeace International. This report analyses quantitatively what I consider to be the most credible risks of having warship visits to Australian ports. The major risks are, firstly, the increased probability of nuclear targeting in the event of a thermonuclear exchange. Secondly, the risk of accidental dispersion of the plutonium contained in a nuclear warhead in the event of a ship fire. Thirdly, the risk of a nuclear propulsion reactor melt-down which would distribute some of the radionuclides in the core into the surrounding metropolitan regions.

The consequences of the first accident, namely targeting in the event of a nuclear war, are difficult to imagine and so also are the probabilities. Consequently I have omitted a detailed analysis of that possibility. I was interested to note that the Department of Defence in this country has recently acknowledged that the presence of spy bases is conferring upon Australia the risk of thermonuclear targeting. I was surprised to note the absence of warships from that assessment because, in my view, the presence of warships in Australian ports has the same impact. But inasmuch as the probabilities and consequences are difficult to estimate, I have omitted a detailed analysis of that possibility.

With respect to a nuclear weapon accident and also a naval propulsion reactor accident, the consequences of either accident would be very much the same, namely a cloud of radioactive materials would be produced at the accident site. This cloud would then be transported by prevailing winds in a downwind direction in the form of a radioactive plume. People in the path of the plume would be exposed to the radioactivity via a number of biological pathways. In addition, radionuclides would fall out of the cloud and deposit on to the ground, in what is commonly known as fallout.

I have utilised conventional methodology of the Nuclear Regulatory Commission in the United States to assess these accidents and to determine their quantitative impacts. I would stress that my methodology is nothing new, nothing revolutionary, nothing innovative; it is exactly the same methodology that is used to regulate the commercial nuclear industry in the United States. As such, the methodology is accepted even by people within the industry. According to the results of this methodology, the consequences of the accidents that I have analysed, even under relatively conservative assumptions - that is to say, assumptions that understate the potential impact - would be up to 10,000 casualties in the city of Sydney. My analysis suggests that from a nuclear weapons accident there would be no immediate casualties, no prompt casualties, rather, the casualties would take the form of latent cancers induced in the population in the two to 10 years after the accident itself. These casualties also assume evacuation of the city within 24 hours. Should the city continue to be inhabited then the number of casualties would increase significantly.

Perhaps the most astonishing consequence of such an accident, at least to me, was not the number of casualties but rather the economic impact of such an accident. The accident would contaminate more than 100 square kilometres of urban area at levels that would exceed federal limits in the United States by up to one million times. Consequently, the affected areas would have to be evacuated unless truly astronomical casualties were to be incurred, and decontaminated prior to rehabitation of the city.

These findings suggest the need for effective emergency response plans. I would note that the policy of accepting visits from United States warships has never been evaluated in terms of these prospective costs, at least as far as I can tell. Therefore, they suggest the need for a re-evaluation of costs and benefits of this policy. If the policy were to be continued then more than effective evacuation plans are required. The

Government Accounting Office of the United States Congress recently produced a report stating that emergency preparedness plans cannot operate effectively unless they are periodically rehearsed. So, if in fact warship visits continue, these findings suggest the need for a periodic rehearsal of emergency evacuation plans.

Finally, in 1986 the Government Accounting Office released a study entitled 'Financial Consequences of a Nuclear Power Plant Accident'. This document is cited in my submission to the Committee. According to this document the cost of cleaning up after a major nuclear incident would range from $US0.3 billion up to $US150 billion. This economic consequence is probably beyond the capacity of even a Commonwealth government to absorb and it emphasises to me the need for detailed liability and indemnity arrangements in advance. I have, since I have been in Australia, looked into some of these issues, namely, the emergency response evacuation preparations and also the issue of indemnity and liability. I think that my findings with respect to the former emergency evacuation plans are reasonably confirmed in the recent Lucas Heights incident. There a relatively minor accident was met with substantial confusion in terms of emergency response plans.

It is my understanding that residents were not notified and that fire-fighters, when they arrived at the scene, could not gain access to the building that was on fire. I think this represents a relatively benign probe of the emergency response plans and the problems involved in such plans, especially if they are not rehearsed periodically.

With respect to liability and indemnity, since I have been in Australia I have worked very hard to learn all I can about what arrangements actually exist. As far as I can tell, these arrangements are summarised in the United States General Statement of Assurances under which these visits are apparently conducted. I have obtained a copy of this document. It is a restricted document but we have nonetheless obtained a copy. I would first of all say that this document does not mention nuclear weapons accidents even though these are described as credible accidents by the US military and US military authorities do plan for such accidents.

The second point to be made with respect to the US General Statement of Assurances is that it says that all claims for liability will be settled through diplomatic channels in accord with customary international procedure in these matters. The notion of diplomatic channels means that such claims would be subject to negotiation rather than being a traditional legal claim. With respect to customary international procedure, a legal scholar at the University of Hawaii advises me that, in relation to radioactive contamination that would result following a warship incident, there is no customary procedure. Therefore, all of the information which I have been able to gather suggests that indeed the original recommendation of clarification of liability and indemnity issues could be made even stronger now. Thank you for the opportunity to summarise my report.

CHAIRMAN - Thank you. As I said this morning, the Committee will be looking at emergency services, but it is the reference accident that interests me most at the moment. The emergency services would have to be geared to what the reference accident

is. In your calculations on the effect of a nuclear reactor accident, your accidental model assumes a breach of the reactor containment. Australian safety plans are based on a less severe accident in which there is no breach of containment. The more severe accident has been rejected because it is recorded as too improbable. Could you tell me the probabilities of your accident or your scenario and how you came to them?

Prof. Davis - Yes. I would be happy to. It is true that at the time the reference accident was developed, in 1976, that could have been considered the most credible accident that might have occurred. However, in the intervening decade, nuclear scientists have given a lot of consideration to the theoretical aspects of accidents and, in addition, we have now an empirical accident history that we can lean upon. With respect to the theoretical aspects, nuclear scientists now believe that an uncontained accident is substantially more probable than it was given credit for in the past decade. For reference to this point I would refer you to what is probably the most recent authoritative publication on the matter. A large panel of physicists and engineers, members of the American Physical Society, produced a very detailed re-evaluation of nuclear accidents in 1985. It is listed on page 91 of my report, under Wilson et al, 'Report to the American Physical Society of the Study Group on Radionuclide Release from Severe Accidents at Nuclear Power Plants'. In this document there is a lengthy discussion on the possibility of uncontained versus contained accidents. As may be judged from the document itself, the people who wrote it are of the opinion that uncontained accidents have been given far less attention than they deserve. I would emphasise that this report was written before the Chernobyl accident in the Soviet Union, which was, of course, by far the worst nuclear accident that has been experienced by human society and which was an uncontained nuclear accident - that is to say, the core inventory was released from the containment structure directly into the environment.

Senator Sir JOHN CARRICK - In the course of your opening remarks you said that a nuclear power-plant reactor on a vessel in Sydney Harbour would cause 10,000 casualties. Are you aware that all nuclear-powered ships are prohibited from entering Sydney Harbour, so it cannot happen? There are no berths and in fact, by government edict, no nuclear-powered ships come to Sydney Harbour.

Prof. Davis - That is at odds with my information, which is that there are three approved berths for nuclear-powered ships.

Senator HAMER - Your information is false.

Senator Sir JOHN CARRICK - Your information is totally wrong.

Prof. Davis - So there is no longer an anchorage at either Taronga Zoo or Hobbs Point?

Senator Sir JOHN CARRICK - It is possible for you to get information from here which will show you the state of the berths.

Prof. Davis - If, indeed, nuclear-powered vessels do not enter that port, then the analysis would----

Senator Sir JOHN CARRICK - Then you would withdraw your comments?

Prof. Davis - No, not at all. Then my comments would simply apply to any other city within which these vessels are berthed.

Senator Sir JOHN CARRICK - You would withdraw your comments about Sydney and you would, I take it, look at the berths to see whether there were any berths close to a city which could have the same impact.

Prof. Davis - I do not see any reason to withdraw comments that are accurate. The analysis of the nuclear power accident that I have done is fully accurate. If in fact nuclear-powered vessels enter that harbour, the harbour is subject to the type of accident that I have given you.

Senator Sir JOHN CARRICK - You would withdraw your comments about Sydney, if indeed you accept----

Prof. Davis - No, sir, I would not withdraw my comments. This is an analysis of a hypothetical accident scenario which is entirely accurate.

Senator Sir JOHN CARRICK - You did not insert the word 'hypothetical'.

Prof. Davis - If vessels did not visit the harbour, then of course the accident could not take place there. The same is true of nuclear weapons accidents. If nuclear capable vessels did not visit there, neither would that kind of accident be possible, but I should think that is self-evident.

Senator HAMER - I was going to get on to this nuclear weapons matter because there have been some rather odd remarks made in your paper. The first one I would like to deal with is a remark you made in the context of increased risks to the population from a global nuclear war, presumably. You made the flat statement: 'Naval vessels are targeted for destruction in the event of nuclear war'. What is your basis for that statement?

Prof. Davis - Nobody can know for sure----

Senator HAMER - It is a flat statement; I wonder what your basis for it was.

Prof. Davis - No one can know for sure what the targeting strategy of the Soviet Union is. It is all a matter of speculation, even within US----

Senator HAMER - That is not what you say; you say they 'are' targeted.

Prof. Davis - Even within US military circles. However, the assumption is made in the United States that all nuclear capable vessels are indeed targeted by submarines which are alleged to trail them. It is also assumed in the United States by the defence planning agencies that every----

Senator HAMER - Have you any evidence for that statement?

Prof. Davis - I would be happy to try to provide it for you.

Senator HAMER - I would be very happy to see it because I do not believe it.

Prof. Davis - You do not believe that nuclear capable vessels are targeted?

Senator HAMER - It is remotely possible. I want to pursue this because there are deductions drawn which I find rather bizarre. You go on to say that 'hence' their presence in Australian ports renders the corresponding port city vulnerable to nuclear attack. It is your contention, presumably, that in the event of a surprise nuclear attack, a nuclear Pearl Harbor, all ports in which American ships, whether capable of strategic retaliation or not, would themselves be targeted. Is that your assumption?

Prof. Davis - No.

Senator HAMER - That is what you say.

Prof. Davis - No, it is not what I say and it is not what I mean.

Senator HAMER - Whatever you mean, what you say is that 'hence' their presence in Australian ports renders the corresponding port city vulnerable to nuclear attack. What does that mean?

Prof. Davis - That means that if a nuclear capable ship were stationed at Garden Island approximately one and a half kilometres from Government House, that Government House and down-town Sydney would be destroyed by a nuclear blast at Garden Island.

Senator Sir JOHN CARRICK - Why use that hypothesis when we have just told you that that is impossible? Why use a hypothesis that is based upon an absolute impossibility? There will not be any station there.

Senator HAMER - I think he said 'nuclear capable'. I think we can dispose of this fairly quickly----

CHAIRMAN - There is one point I would like to bring up. I draw Professor Davis's and your attention to it. When representatives of the Defence Department came before us I made it quite clear to them that our term of reference was dealing with the emergency facilities and that the question of whether the ships are here or not here is entirely a political question. We accept the fact that they here just now, otherwise we would argue on forever about whether they should be here or not. We are sticking to the term of reference, that is, the probabilities of a nuclear accident aboard a nuclear-powered vessel or a nuclear-armed vessel.

Prof. Davis - That is precisely why I did not belabour that example in my text. There was only----

Senator HAMER - I was only worrying about the flat statements made on what is a matter of speculation - I think very improbable speculation, personally, though there may be different views on this.

Senator Sir JOHN CARRICK - What are your views on the theory of the nuclear winter? Do you support the general theory that, if there were a major nuclear exchange in the world, world-wide there would be some form of nuclear winter?

Prof. Davis - Inasmuch as we have just been advised by your good colleague that speculation is not desirable, I think I would desist from discussing that.

Senator Sir JOHN CARRICK - Unless I have that, I cannot ask you my next question nor can I relate to your paper. Let me----

Prof. Davis - What is your next question?

Senator Sir JOHN CARRICK - Why cannot you answer me? I ask you, as a biologist, whether you believe----

Prof. Davis - Is a nuclear winter within the terms of reference of this inquiry?

CHAIRMAN - It a nuclear winter could come from a reactor accident or a weapons accident, yes, you could include it. You would be drawing a very long bow indeed, and I think the probabilities there are on your side.

Senator Sir JOHN CARRICK - Do you conceive at all that it is possible that there would be an attack on an allied nuclear vessel in any harbour or any sea-way around Australia unless there were at the same time concurrently a world-wide nuclear conflict? Do you see Australia being an isolated nuclear target at all?

Prof. Davis - An isolated nuclear target, all by itself without other thermonuclear exchange?

Senator Sir JOHN CARRICK - Yes, that is right, and without the world going up. Can you see an attack on an American ship or an allied ship anywhere not being part of a total nuclear exchange?

Prof. Davis - Our President, Ronald Reagan, has discussed the possibility of theatre nuclear wars.

Senator Sir JOHN CARRICK - That is not what I asked you. I am asking what you think.

Prof. Davis - Inasmuch as our President and our Defence agencies are planning for theatre nuclear wars in Europe and potentially elsewhere in the world, I would bow to their wisdom and say yes.

Senator Sir JOHN CARRICK - There is no theatre nuclear war in an Australian harbour. I am asking you if there is an allied vessel anywhere in association with Australia which in your context becomes a nuclear target as such. Can it become a nuclear target in terms of a theatre nuclear war or will there not be a world war?

Prof. Davis - I do not know the answer to that.

Senator Sir JOHN CARRICK - Do you not need to know the answer to that? You have made an assertion. I put it to you that the fact of the matter is that what your assertion really underlies is that if you do not have them there, you will not have targets and you will not get into this messy nuclear war.

Prof. Davis - I do believe that the presence of installations on Australian soil that are part of the American strategic war fighting capability renders Australia subject to nuclear attack and your own Defence Department apparently believes the same thing.

Senator Sir JOHN CARRICK - Then would you please answer me on the question that I asked you about a nuclear winter, because it is very important to know whether in fact the attack on Australia's soil aggravates or not what could be a cosmic holocaust anyhow. If you got a nuclear winter and everybody was engaged, and Australia was engaged in ANZUS anyhow, in this situation, however horrible an attack on a ship in our port, the world would be in an enormous holocaust anyhow. So I asked you about the nuclear winter. Do you believe in the theory of the nuclear winter? Please - you must have a view.

Prof. Davis - To tell you the truth, scientists try to avoid belief in theories. What they prefer to do is to examine them and then, ideally, test them. This is a theory which we all----

Senator Sir JOHN CARRICK - Scientists like Sagan?

Prof. Davis - The nuclear winter theory is the subject of substantial debate right now. There is insufficient empirical observation to assess its probability. There are experiments going on right now in the United States involving the observation of large smoke plumes and these will hopefully clarify this possibility. Right now we do not really know what the impact of a massive global thermonuclear exchange would be.

Senator Sir JOHN CARRICK - I take it that you can conceive, because your paper says so, that there could be an isolated attack on an allied warship in Sydney harbour.

Prof. Davis - I repeat what I said before, that that is not my conception, that is United States defence planning policy - theatre nuclear wars.

Senator Sir JOHN CARRICK - Theatre nuclear war is in a theatre of war. Do you see any port in Australia being a theatre?

Prof. Davis - The Pacific is considered a theatre, yes.

Senator Sir JOHN CARRICK - I put it to you, Professor, that the discussion has been about the European theatre of war; that theatre nuclear weapons have been a discussion about Western Europe.

Prof. Davis - Are you saying that there is no planning for Pacific nuclear theatre war?

Senator Sir JOHN CARRICK - A nuclear theatre?

Prof. Davis - Yes, sir.

Senator Sir JOHN CARRICK - I know of none of a limited theatre of war at all. I know of none, and if you have some I would be grateful if you would let us have the papers.

CHAIRMAN - We are getting away from the terms of reference here.

Senator HAMER - The second postulated accident was the accidental incineration of a nuclear weapon. Before we discuss the consequences, we have to assess the probability. Would you run through the assumptions you made when you thought it was a probable accident firstly, on the state the nuclear weapon is in in the magazine and the circumstances under which this fire arises?

Prof. Davis - I would be glad to. As you are very well aware, the disposition of nuclear weapons aboard ships is classified information and indeed the United States Navy will not deny or confirm their presence. So neither the Australian Government nor I can be specific with respect to the disposition of weapons on board ships. We do not know what the situation is.

Senator HAMER - You must have made some assumptions when you were assessing the accident. What were they?

Prof. Davis - The assumptions that I have made and spelled out clearly in my report is that five kilograms of plutonium is dispersed by an accident.

Senator HAMER - No, I am not talking about that. I am talking about the state the nuclear weapon is in. How is this five kilograms dispersed?

Prof. Davis - By an accidental fire, the dispersal of energy for which is fossil fuel.

Senator HAMER - And how does this accident arise?

Prof. Davis - By an accidental fire aboard the ship which----

Senator HAMER - External to the magazine or inside the magazine?

Prof. Davis - I do not know where weapons are on ships. I do not even know if they are on ships, but presumably they are in some place on the ship and my assumption is that a fire reaches them.

Senator HAMER - This fire burns for three hours in a magazine?

Prof. Davis - I did not make any assumptions about where in a ship. My assumption is simply that five kilograms, one warhead, is dispersed by a fire and distributed across the metropolitan area.

Senator HAMER - Yes, I understand that, but I want to get some credible impression of how this came about.

Prof. Davis - Inasmuch as we do not have any information about that, because it is all classified, anything that I now say is bound to be speculative and I thought we wanted to avoid speculation.

Senator HAMER - Yes, except that you are postulating. We have seen newspaper reports of the horrendous consequences of this; it seems to me, quite frankly, absolutely inconceivable, but you have postulated that type of accident. I wonder on what assumptions you postulate this accident.

Prof. Davis - You might be interested to know that the United States military also postulates these accidents and has preparedness plans for them. If you like, I would be happy to read sections of reports from the United States military that document this and to enter them as evidence.

Senator HAMER - You mean shipboard fires burning five kilograms of plutonium?

Prof. Davis - No - dispersion of plutonium from fire involving nuclear weapons.

Senator HAMER - No, that is absolute nonsense. Weapons when they are in magazine storage are in a safe state. What you have to suggest is how the fire starts, what goes off in this magazine and why no one floods or sprays the magazine during this three-hour fire. It has to be some sort of credible accident otherwise it is not worth considering.

Prof. Davis - The fact that the United States military plans for such an accident would suggest to me and, presumably, to your Government that it is a credible accident.

Senator HAMER - All right. In what circumstance does it plan a shipboard fire?

Prof. Davis - It does not say.

Senator HAMER - No, I know it does not - it does not think it is going to happen.

Prof. Davis - Then why does it say that it plans for it?

Senator HAMER - Read the thing and I will tell you. I do not think I should be answering the questions, but I will tell you.

Prof. Davis - There are two documents that I think will be relevant: One is called 'CINPACFLT Instruction 6470.2C', and I have a copy which I would be pleased to enter into the evidence. The subject is: 'Medical Department Responsibility and Procedures in the Event of a Nuclear Weapons Incident/Accident'. One of the three references given to which this is relevant is the 'Naval Ships' Technical Manual', chapter 070. The purpose of this document is 'to promulgate policies and procedures for

Medical Department Personnel in the management of personnel casualties resulting from a nuclear weapons incident/accident'. I would submit that that, in itself, justifies the credibility of this accident - namely, the fact that the United States military is preparing for such accidents.

Senator HAMER - Just because it is preparing for some accident, you now cite specific consequences of a shipboard fire in a magazine in the stowed condition, resulting in the incineration over three hours of five kilograms of plutonium, as I understood your reference----

Prof. Davis - Do you have evidence that nuclear weapons are stowed in magazines aboard----

Senator HAMER - That is what I am asking for.

Prof. Davis - I think you should ask the United States Navy.

Senator HAMER - We have.

Prof. Davis - What did it say?

Senator HAMER - It has not answered yet. You have put forward a proposition which I frankly think is absolute rubbish, nevertheless I have tried to get you to justify on what basis you are making these assumptions. Certainly we will get the answer out of the United States Navy in due course, but what we want to know is on what basis you are making these assertions. I cannot find any basis at all.

Prof. Davis - In order to do a site-specific quantitative analysis of any accident scenario, you must start with a source term. On a typical nuclear weapons vessel there may be up to 100 warheads. I have taken one per cent of that inventory - one per cent of 100 warheads - imagined that it is dispersed accidentally in a shipboard fire, and evaluated the consequences of this.

Senator HAMER - I want to know how you think this may happen?

Prof. Davis - You mean how such a fire could result?

Senator HAMER - Yes, how such a fire could result in such consequences.

Prof. Davis - The answer to that would require access to the following information: Firstly, the frequency and duration of shipboard fires in the United States Navy; secondly, the proportion of these that occur in port; thirdly, the capacity of nuclear weapons to withstand thermal stress in the event of this kind of accident; et cetera.

Senator HAMER - Fourthly, you might like to ask when a fire last occurred in a magazine in a United States warship.

Prof. Davis - Are nuclear weapons stored in magazines aboard ships in harbour in Sydney?

Senator HAMER - They are when they are here - quite so. I happen to know that, but I do not think I should be telling you your evidence. I found the whole thing quite incredible and I do not think it is worth discussing any further.

Senator Sir JOHN CARRICK - Let us see if we can take it step by step. As I understand it, what you are predicating is a fire, not that there will be any nuclear explosion. In long term, after three hours, the ordinary conventional explosive that surrounds the plutonium would cause a conventional explosion and would put a particular plutonium in the air - plutonium oxide, and so on. Am I right in that? So in fact what you are saying is that there is the same risk, except for the distribution of the plutonium, as for every high-explosive weapon lying in every non-nuclear armed vessel in the world, because fire plus high explosives give you explosion. Surely, the very first thing that we need to know is the incidence of that. To understand Senator Hamer, and supposing that there is a risk, we have to make recommendations about protection from the risk. What evidence have we that fire on any vessel has caused the high explosives to blow up?

Prof. Davis - I would answer that question in two stages, if I may. The first would be to read again briefly from the document that I have just entered into evidence from the United States military which says: 'In the handling, storage and transportation of nuclear weapons there is a potential risk of an

explosion which is similar to that involved while handling conventional munitions'. So there is the statement of potential risk.

Senator Sir JOHN CARRICK - That is what I have just said, and now we have to measure the risk. It says that it is the same risk of explosion, except that it will disperse plutonium. So will you tell us what that risk of explosion is?

Prof. Davis - I would refer you to recommendation No. 5 on page 85 of my report, which says:

> If port visits by nuclear warships are contemplated for the future, Australian authorities should seek information from the governments of visiting ships that would enable independent calculation of the probability of the type of accidents modelled here.

As it also says clearly in the text, I have not assessed, and cannot assess, this probability because I lack the types of information which I just described to you. Consequently, the acceptance of visits by United States warships is tantamount to accepting an incalculable risk.

Senator Sir JOHN CARRICK - You can, in fact, calculate one thing - because we are both in agreement, as is that document - and that is that there is the same risk of fire, except for the plutonium, as in an ordinary vessel with high-explosive weapons on board. It must be available to you and to the rest of the world what that risk was and has been over the decades. When have fires set off high explosives on vessels?

Prof. Davis - Yes. The United States Navy would have that information.

Senator Sir JOHN CARRICK - Can you lead us to it?

Prof. Davis - Actually Australian ports that are visited by warships are subject to this risk and I would think that the most likely way of obtaining it would be for the Australian Government to ask the Navy for it. When I have asked the Navy for it it has not provided it.

Senator Sir JOHN CARRICK - Supposing that we say to you that the evidence before us so far is that there is almost no evidence of fires being caused on orthodox warships carrying orthodox HE explosives.

Senator HAMER - There have been fires but there have never been magazine explosions.

Senator Sir JOHN CARRICK - There have been fires but there have never been explosions from it. It is very important for us to know whether that is right or wrong.

Prof. Davis - I would say that you have access to information that is classified and that I do not have access to.

Senator Sir JOHN CARRICK - Supposing we are right, then it must minimise the risk.

Prof. Davis - Yes. One of the two ways of computing a risk of a nuclear accident - and I think the best way - is from empirical accident history. I have with me from the General Accounting Office a report which was released in February of this year and which states that the United States military acknowledges 630 incidents involving nuclear weapons and 32 accidents, 12 of which caused significant release of radionuclides and endangered the public.

Senator Sir JOHN CARRICK - Of 600-odd accidents how many were because the nut fell off the bolt and how many of them were related to nuclear matters?

Prof. Davis - Of the 630 incidents the occurrences involved relatively minor unanticipated events such as bent tail fins on a missile, flat tyres on a convoy, et cetera. The 32 accidents involving nuclear materials involved events that could potentially risk lives in the public. The 12 of those 32 that caused the release of radioactive materials did indeed present a risk to the public.

Senator HAMER - Did any of those occur on board ship?

Prof. Davis - Only two such accidents are alleged to have occurred on warships.

Senator HAMER - What were they?

Prof. Davis - One was the loss of an A4 aircraft with weapons aboard in the Pacific; it sank to the bottom. The other was a classified accident aboard a submarine. The submarine is not identified nor is the nature of the accident.

Senator Sir JOHN CARRICK - In probing I want to say to you that we are as interested not to get a distortion this way in the evidence as that way. In other words, we are looking for the objective truth - please accept that from us - and we are interested in not creating public melodrama or underestimating the threat. If we are pressing you, and it looks as though we are trying to minimise the incidents, do not think that that is just a course of action that we are pursuing for that reason. Please accept that.

Prof. Davis - I do. I understand.

Senator Sir JOHN CARRICK - In the end this document of ours has to stand the test right around the world.

Prof. Davis - Let me respond in kind, that I wish that I could answer your question with respect to the probability of a nuclear weapons accident but, as I state in my report, I cannot. All I can do is calculate the consequences of what I regard as a fairly minor accident or a moderate accident and I can do that very precisely. The risk is the equivalent of the consequences times the probability and in view of the large consequences the recommendation that I would make is that you, as members of the Australian Government elected to protect the public from such risks, assess the probability so that you can determine the risk.

Senator Sir JOHN CARRICK - We would be grateful for your help on that. We would like to see if you can get the dimension of your weapons risk. You would agree, I think, that there is no physical possibility, using physics as the word physical possibility, of a nuclear explosion occurring. In other words,

what we are not talking about is a nuclear explosion. You would agree, too, that what we are talking about is a fire or some method of dispersal of particulate plutonium. Is that right?

Prof. Davis - Yes.

Senator Sir JOHN CARRICK - That defines the size of the problem. Those who believe that a nuclear weapon anywhere is capable of explosion, unless armed and triggered and so on, would be misled. Is that right?

Prof. Davis - I would not say misled so much as uninformed because, in fact, the details of nuclear weaponry, as you well know, as well as their safety features, which I would presume are, and accept as being, extensive, are unknown. These are classified forms of information. The only kinds of reports that I have on these issues are the types that appear in newspapers and may not be what this Committee needs to know.

Senator Sir JOHN CARRICK - We understand your difficulty. We have difficulties also.

CHAIRMAN - I would like to pose the same question in a different way. You argue in your paper that the most likely accident scenario for a ship weapon is incineration. This is consistent with the submission of the Australian Department of Defence to the Committee that said:

> The worst credible weapons accident that could occur during a port call by a visiting warship is considered to be one that might follow a major fire in the vessel's magazine.

The Department went on to say, however, that it believed that the size of the zone affected would only be a few hundred metres radius and that this would probably be the only area that was unsafe. You can get that in the 'Hansard' at page 10, reporting the Committee inquiry which took place in December 1986. Your model weapon accident suggests much greater problems. Why does your accident have greater problems than the one that our Defence Department had envisaged?

SENATE STANDING CTEE ON FOREIGN AFFAIRS & DEFENCE 27 Mar 1987

Prof. Davis - Inasmuch as I do not know what the assumptions and quantitative basis for its analysis were - and I would have to know that in order to compare them - I cannot answer the question. We would have to know how much plutonium it presumed was released, what the dispersal energies were, the kinds of dispersal models it used, the dosimeter reading, et cetera. If I could see that then I could answer your question.

Senator HAMER - I think we might move on to the more serious one which is the reactor accident which has a definite chance of occurring. I think you must be aware of the Australian conditions of entry for nuclear-powered warships. You are aware, are you, that they are assessed against the standard accident model, that is, the reference accident? Are you aware of the difference between the model used and your model?

Prof. Davis - Yes.

Senator HAMER - There are quite serious differences. I am sure you would know of that. Do you think the differences reflect on the validity of the Australian assessments?

Prof. Davis - Yes.

Senator HAMER - Do you disagree with the reference accident as being the most serious?

Prof. Davis - Yes.

Senator HAMER - Is it because you would assess much greater leakage or much greater degradation of the containment vessel?

Prof. Davis - That is one of two primary differences. The other is that that Australian AEC analysis appears only to have concerned a single radionuclide, namely iodine - iodine 131 with a half-life of 8.05 days. In the Rasmussen report which is the alleged basis of Australian regulatory guides, some 52 radionuclides are recognised as contributing potentially significant health defects. I have determined quantitatively the relative impacts of those 52 and will tell you that iodine is relatively minor compared to some of the volatile oxides and other radionuclides which could and have been released in nuclear accidents.

Senator HAMER - You understand that we have to logically go through the likelihood of the occurrence and the scale of it and then its consequences. Therefore, could I concentrate first on the scale of the disaster. What is the cause in your model of the much greater breach of the containment system for the reactor? On what basis do you assume that is going to happen?

Prof. Davis - I make no specific assumption as to the cause of lack of containment. I simply assume lack of containment and calculate source terms on that basis.

Senator HAMER - Why do you assume lack of containment? There is containment there and I presume it has to be breached if there is going to be a serious leak. I think the model assumes a one and a half per cent leakage a day or something like that which is relatively slow. You assume a much faster leak. I wonder why?

Prof. Davis - The model used by the AEC as I have understood it from this morning's additional submissions actually imagines a greater release from a core into the reactor compartment than I do. It is a substantially greater release, a greater fractional release. Then they assume that that material remains trapped inside the hull of the vessel and leaks out only slowly through controlled pressure relief valves that are built into the ship. That is one possible scenario without question. But as I mentioned earlier, the American Physical Society, a collection of a large number of nuclear scientists with broad expertise, believes that the major problem with the Rasmussen report and, by implication, with the Australian analysis is that it underestimates the possibility of uncontained accidents. Indeed, the accident at Chernobyl was just such an accident. Therefore, I believe in line with this more current thinking on the issue that uncontained accidents deserve more attention than they have previously received both on theoretical grounds and also on empirical grounds. That was my reason for using a different reference----

Senator HAMER - You understand that we have had evidence that suggested that the idea of a serious breach of containment is not a credible accident. That is why I am interested in how this could occur. If it does occur it makes a big difference to the whole problem.

Prof. Davis - Any such evidence that you have had must involve classified information about submarine construction that I am not aware of. But certainly even the containment at Three Mile Island must have been substantially stronger than is possible on a submarine simply because you do not have that much room for additional weight on a submarine.

Senator HAMER - One of the differences put to us was the cooling effect and the fact that the ship is floating or possibly submerged in sea-water. That was cited as a big difference to the likelihood of penetrating the hull.

Prof. Davis - Is that the cooling effect of water outside the vessel affecting the reactor core on the inside?

Senator HAMER - It is on the probability of a penetration of the hull by a melt-down.

Prof. Davis - How would cooling the hull change the----

Senator HAMER - I am really asking the question, not answering it. That point was put to us.

Senator Sir JOHN CARRICK - It was put to us that if you had a partial melt-down you could stop it very easily by flooding because you have access to unlimited water.

Prof. Davis - By flooding the reactor chamber?

Senator Sir JOHN CARRICK - Yes.

Prof. Davis - As a general rule you do not want to put water on zirconium in the presence of heat because you evolve hydrogen which blows up.

Senator Sir JOHN CARRICK - But pressurised water reactors have a sump, as we were advised and as it has been demonstrated to us, from which you can draw and replace the fluid over the rods so that the rods are not bare.

Prof. Davis - Is that the primary coolant do you mean?

Senator Sir JOHN CARRICK - Yes.

Prof. Davis - So you are saying that in the event of a loss of coolant you can substitute sea-water for the coolant.

Senator Sir JOHN CARRICK - You can substitute water anyhow.

Prof. Davis - That is fine so long as the reactor core is not melted and exposed but if it is melted and exposed the last thing you want to do is put water on it because, as I mentioned, water and zirconium at high temperatures evolve hydrogen.

Senator Sir JOHN CARRICK - I understand that. But one anticipates that all this does not happen just like that.

Prof. Davis - On the contrary, a melt-down could happen in minutes in the absence of coolant. It could happen in minutes and a breach of containment could likewise happen in minutes.

Senator HAMER - Your assumption is that the containment in the submarine or on a surface ship is less strong than in a shore-based reactor?

Prof. Davis - Once again I have not made any such assumptions because they would be based upon speculation, inasmuch as the details of construction of a naval propulsion reactor and its hull are classified. In the absence of such information I have simply assumed an uncontained accident and then modelled the consequences of that using the NRC methodology.

Senator HAMER - You can help us as you seem to have considerable detail on the consequences of an uncontained accident, but you cannot help us on the probability of such an accident?

Prof. Davis - The only way I can help you is by analogy with the commercial industry, which I fully acknowledge is an inadequate basis. In order to accurately assess the probability of naval propulsion reactor accidents you need access to the empirical accident history of naval propulsion reactors.

Senator HAMER - That has got us on the same wave length then. We can turn perhaps to the consequence of the accident.

CHAIRMAN - The accident described involved a release of fissionable products to the atmosphere over four hours. How might such an accident occur and, in particular, does it assume that the containment is breached and, if so, how is it breached? I am still not clear. Do you envisage a steam explosion, or what? I cannot see how you envisage the chamber being breached.

Prof. Davis - Once again I have not been explicit in my report as to the specific accident scenario that could lead to an uncontained accident; there are dozens of them that could. Different ones have occurred in different reactors at different

times in the history of the industry. So rather than speculate on the details of classified reactors, I have simply assumed an uncontained accident of relatively moderate proportions and then analysed its consequences.

Senator Sir JOHN CARRICK - You have mentioned some 630 accidents and you have reduced it to a small number that had some radioactive consequences. Did any of these accidents occur in a port?

Prof. Davis - To my knowledge, no accidents that have been reported by the military have been reported to have happened in port.

Senator Sir JOHN CARRICK - You have mentioned that there was some release of radioactive material. At any stage was it a significant release, and did it have any measured effects on people, on the community?

Prof. Davis - Are you referring now to the 32 acknowledged nuclear accidents, including those 12 which caused releases?

Senator Sir JOHN CARRICK - I am asking about any accidents that have caused releases but I am not talking about Chernobyl.

Prof. Davis - Yes, there are a number of accidents which have been fully reported in the Press including the loss of nuclear weapons in Spain; the crashing of the B52 on to the ice in Greenland; a crash of a bomb ladened airforce plane at Edwards Airforce Base in California, et cetera.

Senator Sir JOHN CARRICK - Could you take them one by one. The first one, the Spanish one, I think was a dropping of a bomb, was it?

Prof. Davis - Yes, that is right.

Senator Sir JOHN CARRICK - The important thing about that, I suppose, was for both of us to identify that when they are dropped they do not go off. That is the first thing that we note on it. Secondly, what accurate evidence is there of damage to people?

Prof. Davis - There was a substantial dispersion of plutonium that required a costly gathering of soil and the shipping of it back to the United States. It is my understanding, although I am not fully versed in these details, that there is a continuing effort to extract compensation and continuing evidence of biological impacts in Spain.

Senator Sir JOHN CARRICK - I understand those things, but there is no hard proof. I am not trying to minimise it, I am trying to get facts for ourselves as to what did happen. Where have we got firm evidence of the release of radioactivity? We have Chernobyl, of course; we have got very clear evidence at Three Mile Island because that is very largely negative, is it not?

Prof. Davis - That was what?

Senator Sir JOHN CARRICK - Very largely negative in its external effect. It had no particular impact upon the community around.

Prof. Davis - It depends on how you define impact and whose reports you wish to believe.

Senator Sir JOHN CARRICK - Can you help us?

Prof. Davis - With respect to the impact of Three Mile Island?

Senator Sir JOHN CARRICK - Yes.

Prof. Davis - Yes, I can. Firstly I would emphasise that the containment structure in the Three Mile Island case weighs more than a military submarine. So we are talking about a structure that is much stronger than anything that could possibly be on a submarine.

For that reason I question the relevance of TMI as an analogy or a metaphor for a naval propulsion reactor, but in fact that accident was relatively well-contained compared to what might be possible. There was a relatively small release of iodine compared to the total core inventory. I am not certain what the release of other radionuclides was. In fact, I have never seen anything published on it, and I do not know why. Either they were not measured or they have simply not been accounted for.

Senator HAMER - One thing that has worried me a bit is that the Atomic Energy Commission's submission puts weight on iodine. You mentioned this a little earlier. You, I think, in your analysis ignore the other fissionable materials. You put in ruthenium 103 and tellurium 132 which, I think, you said gave a much greater contribution to the health problem than iodine. Could you explain that a little more? Is that generally accepted or is it a theory of yours? It is perhaps unfair to ask you why you differ from the Atomic Energy Commission.

Prof. Davis - No, I do not think it is unfair at all; it is a good question. I approached this problem freshly, without leaning terribly on what has been done in the past, or what has been stated in the past and I know that iodine is generally, even in the United States, considered to be the most troublesome radionuclide. That is the conventional wisdom. My approach to the problem was to take the 52 radionuclides listed in the Rasmussen report and to determine the percentage of health impact of each one of them for several different biological pathways - specifically, cloudshine, inhalation and groundshine. The way that I did this was to take the accepted dose conversion factor for each of these radionuclides and multiply it by the source term; that is to say, the total quantity of available radionuclides. In this way I could determine the contribution to health impact of each of the radionuclides and then express it as a percentage of the total impact. That is done on page 61 of my report for the three pathways that I considered.

You will notice that I ignored ingestion of radionuclides and I ignored resuspension. These are two pathways that are normally considered which I have ignored on the assumption that the city would be evacuated rapidly. As you will see on page 61, the percentage of contribution in each of the three pathways, as expressed in percentages, is relatively small for iodine. It is the third largest contributor to the cloudshine pathway, but with respect to the inhalation pathway it is about eighth or tenth and with respect to groundshine, it is fourth or fifth, in that neighbourhood. The significant feature of iodine is that it is taken up by a single gland, the thyroid, and it has a half-life of 8.05 days. The other radionuclides - caesium 137, for example - not only have a larger contribution for at least some of the pathways, namely inhalation, but in addition they persist for much longer. So if you integrate the consequences of an accident like this over time - I have not done this, but if you do this - then iodine becomes a relatively minor contributor to the overall health impact and to the overall economic impact.

Senator HAMER - In your assessment of health impact were you assuming that iodine tablets would be given out, or that no counter action would be taken? Presumably, if iodine tablets are given out, iodine becomes even less significant, relatively.

Prof. Davis - That is if you are considering thyroid doses, but all of my analyses are whole body doses. In fact, potassium iodate, the non-radioactive iodine, will compete with the radioactive iodine and minimise uptake by the thyroid for that single radionuclide. But inasmuch as it is a minor contributor to the overall health impact, the distribution of potassium iodate tablets would not have a significant mitigating effect on a nuclear accident.

Senator HAMER - Are there any other pills, such as the iodine pills, that can be taken to counter the whole body effects?

Prof. Davis - None that I know of.

Senator HAMER - All our premises are, as you know, based on distributing iodine tablets particularly to children. From what you are arguing, we are doing nothing about the more serious risks. Is there nothing that can be done, other than evacuation?

Prof. Davis - That is, in general, correct.

Senator HAMER - I did not want to question too much the assumption you made about the nature of the exercise; I am more interested, from what you have been saying, in your estimate of the consequences of the given accident rather than what caused it and how likely that is. I think in your assessment of the consequences you made no allowance for the possibility of the vessel being towed away and removed to a remote anchorage. Would that be correct? You assumed it stayed there for the full period.

Prof. Davis - Yes. I assumed that the vessel would stay there for the full four-hour duration of the release. That is correct.

Senator HAMER - The full four hours. It would be a job getting away in less than four hours anyway, I should think.

CHAIRMAN - The Navy gives us 24 hours.

Prof. Davis - An accident could last longer than that too. The problem there is that if you take a stricken vessel which is emitting radioactivity and begin to tow it, you are in essence distributing the radionuclides over a broader metropolitan area and, in certain senses, compounding the problem.

Senator HAMER - The value of the towing away was based on a much slower rate of emission than you are suggesting and certainly I do not think any vessel would be towed away in under four hours; it would be extremely slick work if it were.

Prof. Davis - The notification procedures could take that long.

Senator HAMER - You are suggesting contingency plans, including evacuation. Do you know of anywhere where anyone has exercised evacuation?

Prof. Davis - No, I do not.

Senator HAMER - But are you suggesting that we should?

Prof. Davis - I do not think that it would be socially realistic to practise evacuating a city like Sydney over the whole area that needs to be evacuated. I think that is unrealistic. What would be socially realistic is to exercise the communication lines that would be activated in the event of an accident, and also to inform the public explicitly what to do in the event of an accident, and that has been done elsewhere. There is a Government Accounting Office report in the United States that was published in 1979, in which the off-site consequences of nuclear reactor accidents and emergency planning were examined. In three of the 15 sites that were examined there were emergency evacuation plans in place, although in none of those places in the United States had they been exercised either. The recommendation of that GAO report was that rehearsal and exercise of those plans be undertaken because, in the absence of rehearsal, the plans could not be effective. This is not my conclusion; this is the conclusion of the General Accounting Office of the United States Government.

CHAIRMAN - The submissions from the Department of Defence and the Atomic Energy Commission state that United States naval operators are trained to the highest standard in the world. You cast doubts on this on page 14 of your submission, where you also state that independent assessment of naval reactors does not occur. What evidence do you have for these statements?

Prof. Davis - With respect to the competence or non-competence of naval propulsion reactor operators, I refer to an article in the 'Enlisted Times' by a man named Lipman, who was a former instructor at the naval propulsion reactor school, who quit the school and, in doing so, made charges of incompetence in teaching and cheating in exams, and so on and so forth. His complaints were later confirmed by other people at the school. I am not saying that that means that the training there is any worse or better than one can get any place else, but it would seem that there are problems in the naval propulsion program educational scheme. I also note in my report that in the Three Mile Island accident, which is acknowledged to have resulted from human error, five of the eight operators on duty at the time had been trained in the naval propulsion reactor school. Perhaps the technical training that one can obtain in that school is as good as one can get anywhere, but what can never be eliminated, as shown by virtually every nuclear accident that has taken place, is the human factor, the possibility of human error.

CHAIRMAN - How are arrangements concerning liability and indemnity in respect to nuclear accidents affected by the Price-Anderson Act, and does this apply to both reactor and weapons accidents?

Prof. Davis - To my knowledge, in the United States there are no arrangements whatever with respect to liability and indemnity in the event of a military accident in a port. I have tried to find out information, both from the United States Navy and from other places in the States, and, as best as I can determine, there are no such arrangements.

SENATE STANDING CTEE ON FOREIGN AFFAIRS & DEFENCE 27 Mar 1987

CHAIRMAN - What decontamination actions would be necessary, following an accident of the kind described, and what effect would they have in reducing the casualty figures?

Prof. Davis - The measures that would be required have never been developed. There is no history of radioactive contamination of a large urban area and one simply does not know how one would go about decontamination. I could speculate by describing the kinds of problems that would have to be faced in such an incident. For example, the air conditioning systems in skyscrapers would draw in contaminated air and distribute it within the insides of all buildings in which air conditioning systems had not been turned off. So one is talking about the removal of radioactive contamination from both the inside and outside of all structures within perhaps 100 square kilometres of a metropolitan area. There was a report published in 1986, again by the General Accounting Office of the United States Government, which estimated the cost of cleaning up after such an accident and, although the techniques for decontamination were not spelled out, the estimates of cost range from $US0.3 billion to $US150 billion. Those really have to be considered speculative figures, I think, because we do not know exactly how one would go about that decontamination, how long it would take, what we would do with waste materials, and so on.

The second part of your question was how decontamination would reduce casualties. Unless the city were evacuated shortly after such an accident, as soon as possible - I assume 24 hours is a realistic figure - the casualties would be much higher than those I have mentioned. I have, in my study, computed the casualties, assuming one week of additional habitation and also one year of additional habitation and those figures are presented in my report. They are substantially higher than those which I have orally described here. So I presume decontamination would be necessary. Unless that decontamination were carried out, people could not move back into the affected area without experiencing significant additional casualties, mainly from the resuspension and the ingestion pathways.

Senator HAMER - One of the difficulties we had - because this is a highly technical area and we cannot pretend to be experts - is the difficulty of comparing your work with what the Atomic Energy Commission has given us because you are assuming different accidents. If you accepted our reference accident, except for the issue of iodine and other particles, would you have any other serious disputes about the consequences of the reference accident, not your one? Are you and the Atomic Energy Commission in disagreement on that or substantially in agreement?

Prof. Davis - In order to answer your question properly, I would have to talk with AAEC officials and also see more details of the nature of their calculations. But I did see this morning the supplementary handout that they had given in which they described source term, that is to say, the fraction released from the core to the reactor compartment and that seems realistic to me. I did see some of the meteorological conditions that they have assumed, including the Pasquill F category, which is the most consequential, and that seems prudent to me. Certainly it seems that many of their assumptions are similar to mine. The two basic differences are, first of all, that they assume a contained accident and I have assumed a moderate uncontained one. Secondly, they examine only iodine and I examined the full range of radionuclides.

Senator HAMER - The first one, I think we agreed earlier, is not even going to help us very much, that is the probability of the accident. What we are interested in is the accident having occurred, we have got to decide whether the reference accident is right or the more serious one is prudent planning. Would I be right in saying that you are broadly in agreement on the consequences of the reference accident?

Prof. Davis - No, I would say that the reference accident, by the omission of other radionuclides, itself significantly underestimates the impact. The inclusion of those other radionuclides would, just as an off the hand estimate, increase the consequences by perhaps an order of magnitude or two - a factor of 10 or 100.

Senator HAMER - I see. I am not meaning to be offensive, but are you on your own in your emphasis on these other radionuclides or is that a fairly general emerging scientific opinion?

Prof. Davis - I have never seen regulatory plans based on anything except iodine by itself, although any nuclear scientist is fully aware that the other radionuclides have impacts. The dose conversion factors are published. In fact, they are reported in my appendix and as you can see, they are quite a bit higher for radionuclides other than iodine. The half-lives are well known and it is known that iodine is a relatively short-lived isotope. So why regulatory authorities have put so much emphasis on iodine all by itself I can only speculate. I think probably the accident at Windscale, now named Sellafield, in which much more iodine escaped than anybody had predicted, may have sensitised the nuclear community to the possibility that iodine would have more impact than previously discussed.

Senator HAMER - I want to get this quite clear because this is an obvious area we will have to probe, and I want to see what scale of emphasis it should be given. You would suggest that even accepting the reference accident, that is leakage rather than rupture of the containment was the one we should deal with,

assuming that is the conclusion reached, do you still think that the consequences are underestimated by a factor of something like 2? Is that a correct summary of what you just said?

Prof. Davis - A factor of 100 - two orders of magnitude.

Senator HAMER - Two orders of magnitude? One hundred times as serious?

Prof. Davis - Yes. The quantitative basis for that is on page 61 of my report, in which the contribution of iodine to cloudshine is 14.93 per cent. The contribution of iodine to the inhalation dose is 1.87 per cent and the contribution of iodine 131 to groundshine is 8.05 per cent - this assumes no decay. The inhalation dose and the groundshine dose are generally considered to be the biggest and iodine has the smallest contribution to those. Furthermore, the long-lived nature of the other radionuclides would exaggerate the difference between them and iodine even further. So the overall consequences could be at least 100 times greater, even of the reference accident.

Senator HAMER - I am trying to concentrate on the reference because it is the only thing we can really compare with at the moment. If you are right in this - I frankly have no way of knowing - this is a very marked change in the damage assessment. Is this being taken up in America by the nuclear regulatory agencies or are you a lone voice in the wilderness?

Prof. Davis - The impacts of other radionuclides are frequently examined. Caesium 137, for example, is known to be an especially difficult one because of its volatility.

Senator HAMER - The magnitude of difference in consequences is pretty major.

Prof. Davis - Yes, it would be.

Senator HAMER - Do you know if it is being taken up by any of the nuclear regulatory agencies? I am asking that because if we investigate this we would want such information as we can get on whether this is generally accepted because when scientists disagree it is very difficult for a committee of politicians to adjudicate.

Prof. Davis - I understand. I am afraid that I cannot answer you very specifically about to what degree the other radionuclides are taken into account in emergency planning documents in the United States. I could try to find that out; I am interested myself.

Senator HAMER - That would be of great interest to us, because, obviously, we have to pursue this allegation. Whether we accept your accident or not, the consequences are of such a different order of magnitude from what we have been told that they have to be investigated and any lead that you can give us as to where this has been assessed and both pro and contrary views would be helpful.

Prof. Davis - I will, both for my own interest and in the hope of furthering the work of this Committee, look into the question and communicate it to you.

CHAIRMAN - You estimate that strontium nuclides would contribute 19 per cent of the inhalation hazard. What physical mechanism did you assume for the leakage and dispersion of strontium into the atmosphere? Did you allow for greater hold-up in the containment of solid compared with the volatile materials and volatile compared with the gaseous materials?

Prof. Davis - Yes, I did. I assumed that fractional releases were 100 per cent for the noble gases, Xenon and krypton, 10 per cent for the volatile oxides and one per cent for all other radionuclides including strontium 90. The actual release at Chernobyl for strontium was 3 per cent.

CHAIRMAN - Regarding the reference to hydrogen on page 14 have you made any attempt to calculate the quantity which could be generated in a core-melt accident in order to check the feasibility of explosive mixtures of hydrogen and air occurring?

Prof. Davis - No, I have not. I do not feel the need to make such calculations myself to demonstrate the feasibility, inasmuch as precisely that occurred at Three Mile Island. Hydrogen was generated by the interaction of zirconium and steam. The formation of a hydrogen bubble forced the coolant down off the core which is what led to its disruption. The question of whether that hydrogen exploded or not is a controversial one. Some people say that it ignited but did not explode and it may well have been that the relative restriction of air supply limited the rapidity of the ignition so that it could not, in fact, be called an explosion. In any event these events did occur and that is by no means hypothetical.

CHAIRMAN - Could you explain why you have compared your estimated releases of radioactive material with the United States limits for routine discharges rather than that with the limits recommended for use in consideration of discharges following accidents - that is, the emergency reference levels of protective action guides?

Prof. Davis - That question is based upon a misinterpretation of the limits that I actually used. There are no routine limits of plutonium release, for example. The ground contamination limits that I used are limits for the unrestricted use by the public.

CHAIRMAN - Thank you very much for your appearance here and the trouble you have gone to with your submission.

Committee adjourned at 3.26 p.m.