SESSION 12

PANEL SESSION: PROPOSED SOURCE TERM REVISIONS - POTENTIAL IMPACT ON FUTURE NUCLEAR AIR CLEANING REQUIREMENTS

Wednesday: August 26, 1992
Moderator: R. R. Weidler

Panel Members: L. Soffer
H.E. Vanpelt
J.L. Kovach
M.L. Hyder
B. Schwartz

OPENING COMMENTS OF PANEL MODERATOR WEIDLER

We have an interesting and important topic for this panel session - Proposed Source Term Revisions and their Potential Impact on Future Nuclear Air Cleaning Requirements.

I am Ray Weidler of Duke Power Company. I work in the Engineering area of McGuire Nuclear Station in Charlotte, NC and I am also Vice-Chair of the ASME Committee on Nuclear Air and Gas Treatment. I will chair this panel session. My Co-Chair is Leonard Soffer of the US NRC and he will be providing summary remarks at the conclusion of today's session.

We will be hearing five (5) completely different perspectives this afternoon on revised source term implications for nuclear air cleaning from a most distinguished panel:
Mr. Leonard Soffer of the USNRC
Mr. Harry Vanpelt of Duke Power Company
Dr. Lou Kovach of NUCON
Dr. Lee Hyder of Westinghouse-Savannah River
and,
Mr. Barry Schwartz of Sargent and Lundy.

Each panelist will deliver a brief paper on their perspective of the revised source terms and then we will open the session to the audience for questions.

PANEL ON PROPOSED SOURCE TERM REVISIONS AND POTENTIAL IMPACT ON FUTURE NUCLEAR AIR CLEANING REQUIREMENTS

Introductory remarks of
Leonard Soffer
US Nuclear Regulatory Commission

The NRC's proposed revised reactor accident source term and some implications for nuclear air cleaning requirements was presented yesterday at this conference.

This source term is intended for licensing of future light water reactors, and will be implemented via a future revision to 10 CFR Part 50 to incorporate improved source term and other severe accident insights. It is not expected that this source term will be applied in siting future reactors, since a proposed change to 10 CFR Part 100 is expected to eliminate the use of dose calculations for assessing site suitability. Rather, the revised source term is expected to be used in evaluating the capability of the plant to deal with accidents. The revised source term will not be imposed upon existing plants, however they may voluntarily propose to use it. Such applications will be reviewed by the NRC. A more realistic understanding of fission products release into containment must also be combined with a realistic treatment of fission product removal and retention both by engineered safety features as well as by natural removal mechanisms. This area is also part of the NRC's effort to provide a revised understanding of accident source terms and is continuing at this time.

Potential impacts of the revised source term on nuclear air cleaning requirements arise from (1) revised insights on iodine chemical form, (2) the presence of other nuclides, in addition to iodine and the noble gases, (3) revised timing and duration of fission product releases, and (4) the release of non-radioactive aerosols.

Although detailed analyses have not be done at this time, major changes in nuclear air cleaning requirements are not envisioned as a result of the revised accident source term. It is important to recognize that present fission product removal and air cleaning systems, when evaluated realistically, can provide a high degree of mitigation and can be effective against many types of nuclides, whether in aerosol or elemental form. The concept of what constitutes an air cleaning system should be broadened to include other plant systems, as well. In-containment sources of water, for example, can reduce the loading on present filter systems and the combination can provide an enhanced capability to deal with large quantities of aerosols.

One unresolved question is the need for charcoal and elemental iodine retention in filter applications where the pH is controlled. Present filter systems are effective for aerosols as well as elemental iodine. It may be prudent to retain some capability to deal with elemental iodine; however, it may not be necessary to have filters with an elemental iodine removal efficiency as high as present designs. The potential benefits and impacts of reduced charcoal testing and surveillance requirements, assuming pH control, could provide useful insights in resolving this question and deserve further study.

A Utility Perspective on New Source Terms

Harry E Vanpelt

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The Utility industry may benefit from the revision of accident source terms used for licensing accident analysis provided procedures and requirements are modified to recognize the changes incorporated in the revised source terms.

The design requirements and operating procedures of accident mitigation systems may be tied more directly to response to radiological release concerns. Operation of containment spray and chemistry control may be better linked to radiological release concerns along with plant integrity. This will more directly tie public health and safety benefits to accident mitigation actions. Design and operation requirements of current systems are slanted to respond to very unlikely radiological conditions. Less emphasis will be necessary on immediate availability of HVAC cleanup systems. More concern for long term operation of accident mitigation systems such as annulus ventilation, and control room ventilation will result if new source terms are adopted. The testing requirements associated with these systems may be redirected to focus on their ability to respond to a continuing release of activity from the fuel and not on rapid response to the initial accident signals. The necessary maintenance of systems will be simplified since compensatory measures may be more readily taken which allow maintenance service while maintaining availability of the system components. Chemistry Requirements will be tied more closely to radiological release concerns. Sump Ph is guided primarily by hydrogen generation and metal corrosion concerns at present. Consideration of Ph in limiting Iodine release to the containment atmosphere will further emphasize proper control on this important parameter throughout severe accident response operations.

The importance of carbon filter systems is lessened when considering new source terms. The HEPA filters will now be of primary importance in determining filter effectiveness. This may allow the requirements for carbon bed efficiency to be relaxed to ease testing and maintenance problems. Testing requirements may be adjusted to reflect the concern for particulate removal primarily and for elemental and organic iodine removal at a lesser extent.

The utility industry will directly benefit from revised source terms if the revised accident analysis provides additional margin for optimization of core design for more fuel burnup and better fuel utilization during operation. The source term effect on post accident equipment qualification must also be considered. It is not clear that the revised source term will result in less conservative post accident dose rates to equipment in all cases.

Adoption of the new source terms by utilities will hinge primarily on the benefits in design requirements and operational improvements gained as a result new terms. If little change in actual operation and testing is seen as a result of the use of the revised source term it is not likely that utilities will see the need to adopt the Nureg. It appears that there are several potential safety and operational benefits associated with the use of new source terms but it will take the cooperation of regulators, component manufacturers and plant owners to properly realize these benefits. Efforts need to begin to relicense plants to take advantage of these benefits.

NOTES ON THE DRAFT NUREG REPORT ACCIDENT SOURCE TERMS FOR LIGHT-WATER NUCLEAR POWER PLANTS

J. L. Kovach
NUCON International, Inc.

The major air cleaning related accident source term changes in the NRC draft report relates to the chemical form of iodine in the containment. While the Regulatory Guides 1.3 and 1.4 assumptions of 91% elemental, 5% particulate and 4% organic forms were known for a long time to be unrealistic, the proposed assumptions of 2.85% elemental 97% particulate and 0.15% organic distribution is also questionable.

Unfortunately, it became typical of the source term studies to use data from carefully controlled laboratory experiments with pure chemicals and extrapolate by computers for a large system such as an LWR containment. However, as those who had seen the TMI-2 containment after the accident well realize, the water on the bottom of the containment was anything but deionized water.

While there is generic agreement that the great majority of the iodine in most accident sequences would by in particulate form - mainly as cesium iodide - the value of 0.15% for organic is questionable. To start with, the data from the TMI-2 analysis indicates only 1/3 of the iodine in elemental form and analysis of the adsorbents used (in the fuel handling building and auxiliary building air cleaning units), which were used in the early stages of accident indicated that the great majority of the removed and released ^{131}I form was organic and not elemental.

There is a large amount of organic material in the containment which is available for reaction with any iodine (whether elemental I_2 or HI). Additionally, recent data indicates that a very extensive reaction can take place between small aerosol particles and gaseous compounds.

While this reaction can have the benefit of additional scrubbing of all gaseous species which have relatively large molecular weight, it can also result in organic iodide generation by reaction between suspended aerosol particles and the low molecular weight organic compounds to result in organic iodides.

Both I_2 and HI are good reactants with various organic compounds to generate a family of organic iodides. An interesting experiment to remember is a South African study when a seemingly iodine concentration effect was observed on the removal efficiency of unimpregnated activated carbon. At high entry concentrations 99+ % removal efficiency was noticed, however, as the elemental iodine challenge concentration was decreased the unimpregnated carbon efficiency drastically decreased. When an impregnated carbon was substituted the apparent concentration effect disappeared. Further investigation showed that there was a constant organic compound concentration in the challenge air stream and as the total ^{131}I concentration decreased a larger and larger fraction was converted to organic iodides causing the apparent concentration effect with unimpregnated carbons which do not remove organic iodides.

There is no assurance that the tellurium iodine precursor will also be in a location where cesium is available for reaction with the iodine daughter products before reaction with organic compounds takes place.

While there may be little argument with the 97% aerosol form, particularly with containment sprays operating, it would be more realistic to state that the non-particulates will be in a family of unknown chemical forms, a majority of which could be organic.

The currently used impregnated carbons exhibit excellent elemental iodine, good methyl iodide (but in shallow beds not all organic iodide form) removal and fairly good efficiency for HI removal (at least those that are not acidic carbons) therefore, little or no technology change is required for currently used adsorbents.

The major change in the family of challenges facing nuclear air treatment systems is the very significant increase in the mass and type of particulate matter, most of which would be various forms of hygroscopic alkali cesium salts. Many of the currently used prefilters, moisture separators are not capable of protecting the HEPA filters from the large mass of aerosol and the philosophy of using "dust" filters as prefilters and non-stainless steel moisture separators needs to change. Where stainless steel knit moisture separators are used as a first component the structural and chemical integrity probably will be adequate. However, where structurally inadequate prefilters and glass fiber moisture separators are used as first components off-design performance and very fast deterioration can be expected.

Unfortunately, in the past and currently the least attention is being paid to these important components. Regardless of the test frequency and regulation on the downstream HEPA and impregnated carbon components, the air cleaning system will not work if prefilters and/or glass fiber moisture separators fail.

The nuclear air cleaning industry (including specifiers, suppliers and regulators) will have to review the adequacy of all components of both air cleaning systems and currently "prefilter protected" fan coolers to ensure that perceived non-critical components will not cause system failures.

There is an editorial comment also regarding the NRC current draft, indicating iodine fractions to two decimal points is presumptuous and does not reflect provable reliable knowledge on full size systems. Our knowledge and the variability of accident sequences does not permit the indication of such certainty.

Proposed Source Term Revisions- Potential Impact on Future Nuclear Air Cleaning Requirements

Application to DOE Production Reactor Operation

M. L. Hyder, Westinghouse Savannah River Company, Aiken, S. C.

Production reactors at the Savannah River Site (SRS), including the K Reactor now operating, are very different from commercial power reactors. They are heavy water cooled and moderated, and are operated below the boiling point. SRS fuel assemblies consist of long nested tubes made from aluminum-uranium alloy, clad in aluminum. (Figure 1)

SRS reactors were designed more than forty years ago, before the concept of a containment had been developed. Protection against radioactive releases is provided by the reactor confinement system, shown schematically in Figure 2. This system incorporates moisture separators, particulate filters, and carbon beds for iodine retention. It is always on line during reactor operation. All effluent air from the reactor building is passed through this air cleaning system to remove iodine and particulate radioactivity. Upgrades now in progress will bring this system into conformance with current air cleaning standards, while retaining the same types of air cleaning components. This system has been extensively described in a sequence of papers presented to this conference over the last thirty years.

It has been clear to us for a long time that the radioactive source term resulting from an accident in this reactor might be considerably different from that of commercial LWR's. Some of the differences in the design and operation of the reactors are shown in Figure 3. There are also differences between the K reactor building and typical LWR containment buildings, and the K reactor has the advantage of being centered in a very large site. The K reactor fuel will melt and relocate at temperatures that are very low compared to the corresponding processes in zircaloy-clad oxide fuels. The aluminum cladding and much of the fuel are molten at 660°C. Experimental measurements of the release of fission product isotopes from melting U/Al fuel have recently been summarized by Rusi Taleyarkhan at Oak Ridge.(1) Some important results are:

- Very little radioactivity is released below the melting point;
- Noble gases, iodine, considerable cesium, and some tellurium are released quickly upon melting;
- Unless some mechanism makes possible heating the fuel to much higher temperatures, other isotopes are of little concern.

After the development of the "TID" source term years ago, it was frequently used in the analysis of potential accidents at Savannah River. This was an easy approach, but more recently we have attempted to develop a spectrum of SRS-specific source terms that could be justified from the characteristics of the Savannah River reactors. This has been done, for example, in our probabilistic risk assessment (PRA). Figure 4 shows how the set of source terms for this PRA was derived.

Our new source terms do not have a big effect on the expected response of the air cleaning equipment in our confinement system. It was designed to retain very large releases of fission products. So long as the accident does not produce so much fine particulate as to overwhelm the filters, we expect the confinement system to retain 99% or more of particulates and iodine. (It will retain none of the noble gases or tritium.) The biggest difference in the new source terms is that substantial amounts of released iodine may be in particulate form, and will be retained on the HEPA filters rather than on carbon. This should hot be a problem for the operation of the system nor its effectiveness.

Perhaps the most important feature of the new NRC source term to us is that it is now reactor specific. One size no longer fits all. This provides an additional justification, if one were needed, for doing source term and confinement system analyses based on our best understanding of accident phenomena in our reactors: fission product releases, the effects of fission product release barriers, and the operation of engineered safety systems. As we have already been moving in this direction, this is very satisfying.

We would suggest that the new NRC guidance might include reactor- and site-specific policy wording. As we have found the local terrain and meteorology to be important in developing source terms, we would suggest that such site characteristics might well be incorporated into siting rulemaking.

Reference

1. R. P. Taleyarkhan, "Analysis and Modeling of Fission Product Release from Heated Uranium-Aluminum Plate-Type Reactor Fuels", presented at the International Topical Meeting on the Safety, Status, and Future of Non-Commercial Reactors and Irradiation Facilities, Boise, Idaho, Sept. 30-Oct. 4, 1990.

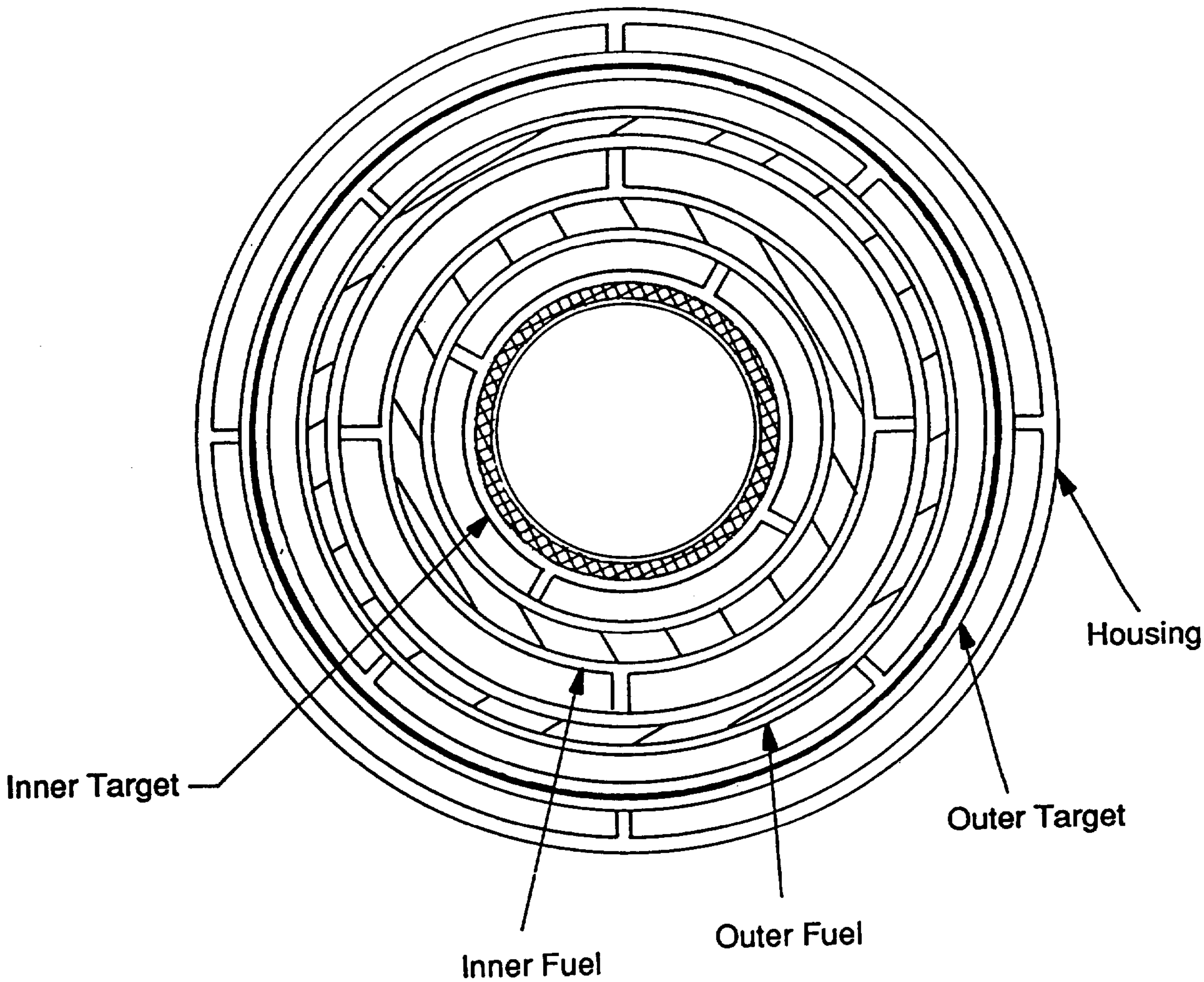
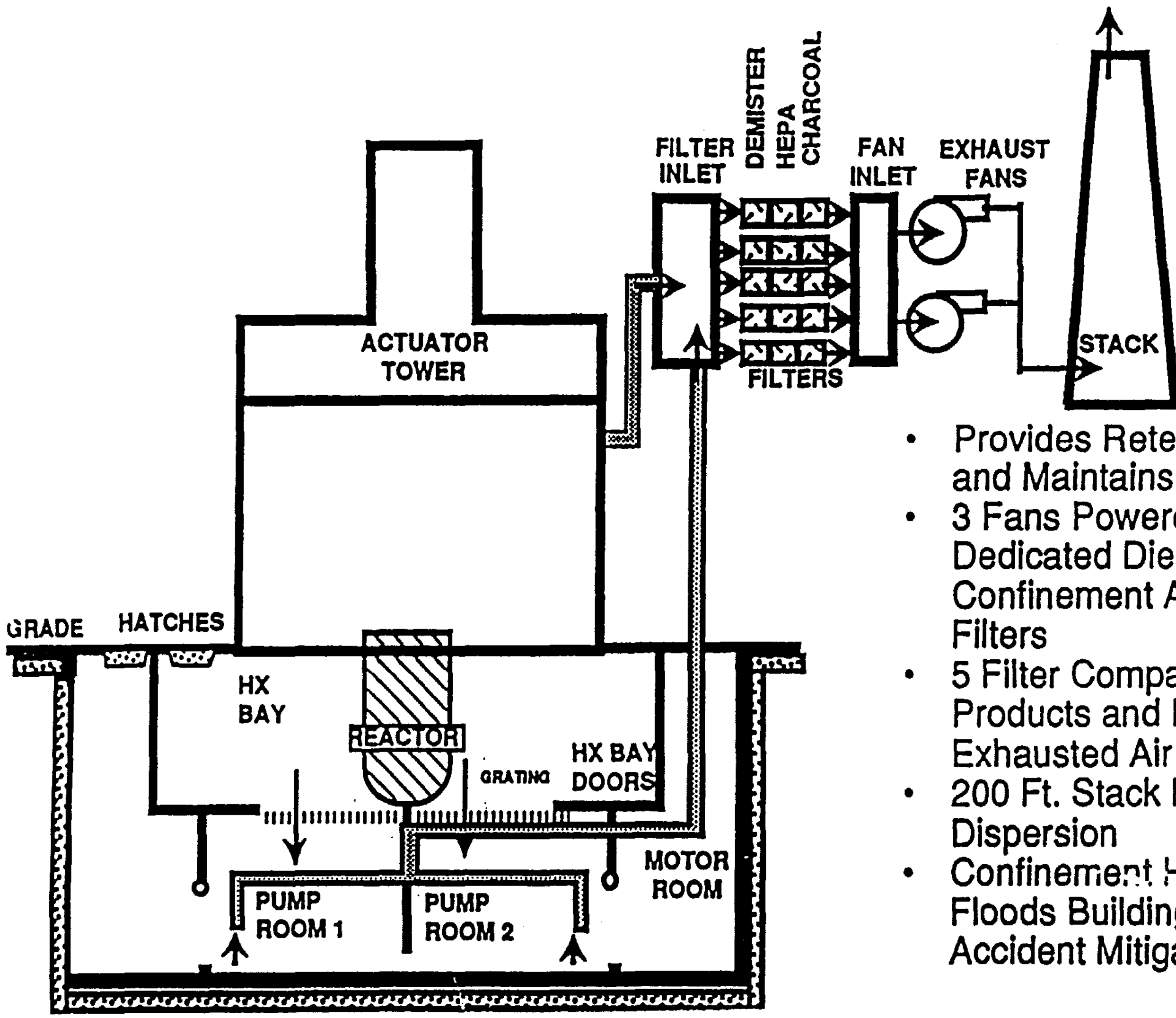


Figure 1. Typical Savannah River Fuel Assembly (Cross Section)

Figure 2

Reactor Building Barrier Airborne Activity Confinement System



- Provides Retention Of Fission Products and Maintains Integrity Of Confinement.
- 3 Fans Powered By Normal AC With Dedicated Diesel Backup Ensures Confinement Airflow Exhausted Through Filters
- 5 Filter Compartments Remove Fission Products and Particulates From Exhausted Air
- 200 Ft. Stack Height Enhances Dispersion
- Confinement Heat Removal System Floods Building Floor For Severe Accident Mitigation

Figure 3

Comparison of Key Features Between SRS HWR And Commercial PWR

Parameter	SRS K Reactor	PWR
Power (MWth)	≤ 720	3293
Primary/Secondary Cooling	D2O / H2O	H2O / H2O
Fuel - Cladding	U/Al - Al Alloy	UO_2 - Zircaloy
Fuel Centerline to Surface Temp. (deg C)	~80	590 - 288
Operating Pressure (psi)	5 (Blanket gas) 220 (@ Primary Water System Pumps)	2250
Reactor Spray System	Unbuffered	Buffered
Outer Fission Product Boundary	Confinement System	Containment

Figure 4

SRS PRA & Severe Accident Programs Have Led To NUREG-1150 Basis Source Term

- Accounts For Fuel & Cladding Behavior During Severe Accidents
- Includes Tritium In Source Term
- Defines Frequency-Magnitude Spectra Of Fission Product Release From SRS K Reactor During Severe Accident Scenarios
- Phases Are Markedly Different From Revised Source Term:

Revised Source Term

Commercial LWR	SRS K Reactor
Coolant Activity Release	Early Vessel Release
Gap Activity Release	Debris Heat-Up
Early In-Vessel Release	Vessel Failure
Ex-Vessel Release	Core-Concrete Interaction
Late In-Vessel Release	Delayed Release

- PRA Analysis "Walks" Scenario Through Release Phases, Applies Decontamination Factors And Determines Environmental Release

REVISED ACCIDENT SOURCE TERMS AND CONTROL ROOM HABITABILITY

Mini paper presented as part of
PANEL SESSION: PROPOSED SOURCE TERM REVISIONS -
POTENTIAL IMPACT ON FUTURE NUCLEAR AIR CLEANING REQUIREMENTS

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Abstract

In April 1992, the NRC staff presented to the Commissioners the draft NUREG "Revised Accident Source Terms for Light-Water Nuclear Power Plants." This document is the culmination of more than ten years of NRC-sponsored research and represents the first change in the NRC's position on source terms since TID-14844 was issued in 1962. The purpose of this paper is to investigate the impact of the revised source terms on the current approach to analyzing control room habitability as required by 10 CFR 50. Sample calculations are presented that identify aspects of the model requiring clarification before the implementation of the revised source terms.

I. Introduction

This year, 1992, marks the 50th anniversary of the first sustained nuclear reaction in the pile at the University of Chicago's Stagg Field. This year also marks the 30th anniversary of the publication TID-14844.(1) Since its inception, TID-14844 has served as the design basis source term for radiological assessments supporting the licensing of nuclear power plants in the U.S. The conservative TID-14844 model assumes that 100% of the noble gases and 50% of the iodines are instantaneously released to the containment and are available for leakage to the environment. TID-14844 is formally embodied in the U.S. Nuclear Regulatory Commission's (NRC) "Rules and Regulations," Title 10 of the Code of Federal Regulations,(2) in Parts 100 (siting) and 50 (review of control room habitability). TID-14844 is also embodied in a host of NRC Regulatory Guides and NUREG reports that address offsite consequences of releases of radioactivity and other postaccident radiological concerns.

The accident at Three Mile Island Unit 2 (TMI-2) in March 1979 spawned many NRC- and industry-funded efforts to better quantify accident scenarios, accompanying source terms, and their radiological consequences. Although the TMI-2 event itself demonstrated that an accident scenario does not cause instantaneous release of radioactivity to the containment as postulated by TID-14844, the industry was mandated to continue all licensing-related radiological assessments using the TID-14844 model.

On April 20, 1992, the NRC staff presented to the NRC Commissioners the draft of "Revised Accident Source Terms for Light-Water Nuclear Power Plants." This effort is documented in SECY-92-127(3) and provides us with the first official source term position of the NRC. The revised source term will affect many aspects of nuclear power plant design and operation, including offsite doses, emergency planning, equipment qualification and engineered safety feature (ESF) equipment operation. The purpose of this paper is limited to a review of the changes embodied in the revised accident source terms and an investigation of the effect of these changes on the evaluation of control room habitability. In addition, we will look at the impact of the revised accident source terms on the current habitability model to identify areas requiring additional clarification.

II. The Revised Accident Source Terms

Although the revised accident source terms described in SECY-92-127 are still subject to modification, two fundamental changes are immediately evident. First, rather than using the instantaneous release of the TID-14844 model, the revised source terms have a more realistically timed release over the various stages of the accident scenario - coolant release, gap release, and subsequent core melt. This has an immediate impact on the timing of containment isolation, and the actuation and operation of ESF equipment. Second, SECY-92-127 acknowledges that most of the iodine released from the core is in the form of cesium iodide (CsI) and remains in solution, provided the postaccident pH of the containment sump water is greater than seven. This part of the model will affect the presently required containment spray systems, ESF iodine removal (charcoal) systems, and control room habitability systems. A summary of the PWR version of these source terms are given in Table 1. The TID-14844 source terms are also included in Table 1 for comparison.

Table 1 LOCA source terms - fractions of core inventory released to containment.

	TID-14844	SECY-92-127 (PWR releases)			
		Gap Release	Early In-Vessel	Ex-Vessel	Late In-Vessel
Duration, Hr	0	.5	1.3	2.	10.
Noble Gases	1.	.05	.95	0	0
Iodine	.5	.05	.35	.29	.07
Cesium	.01	.05	.25	.39	.06
Tellurium	.01	0	.15	.29	.025
Strontium	.01	0	.03	.12	0
Barium	.01	0	.04	.10	0
Ruthenium	.01	0	.008	.004	0
Cerium	.01	0	.01	.02	0
Lanthanum	.01	0	.002	.015	0

The instantaneous source terms in TID-14844, which represented the best information available in 1962, provided the basis for a deterministic method to estimate the bounding impact of a loss-of-coolant accident (LOCA). This deterministic approach modeled fission product transport and provided the means for plant designs and operating conditions to be rapidly and consistently evaluated for their impact on accident consequences. The revised source terms are derived from detailed, probabilistic studies of current plant designs and represent the best available information today. A revised deterministic method for analyzing a LOCA will have to be developed, however, to incorporate the time-dependent source term into the fission product transport models used to produce upper bound estimates of the accident consequences. Although transport models are still under investigation, SECY-92-127 implies the basic approach in use today will continue to be applicable when the revised source terms are applied.

III. The Control Room Habitability Model

The design basis accident for control room habitability is normally the loss-of-coolant accident. The assumptions used for determining the release from a PWR containment following this accident are described in Regulatory Guide 1.4(4), which is based on TID-14844. Regulatory Guide 1.4 specifies that 25% of the core inventory of iodine and 100% of the noble gases are immediately available for leakage from the containment. This is the same as TID-14844 with the additional assumption that half of the iodine plates out on interior containment surfaces. Regulatory Guide 1.4 also specifies that 91% of the iodine is elemental, 5% particulate, and 4% organic.

Additional guidance on modeling the effect of containment sprays is provided in Standard Review Plan (SRP) 6.5.2(5). Credit can be taken for the removal of elemental iodine by sprays and plateout until a maximum decontamination factor of 200 is reached. Credit may also be taken for removal of particulates by the spray, but removal of organic iodines is generally not allowed without additional justification.

The effectiveness of the control room habitability system is normally evaluated using the procedure from the famous Murphy-Campe paper(6). This paper provides the methodology needed to model the transport of the source terms to the control room, the effect of HVAC systems, and the calculation of the dose to the control room operators.

To demonstrate the impact of the new source terms, a PWR control room of Murphy-Campe type A design (isolation with filtered pressurization) was analyzed using the current methodology. This analysis considered a control room with substantial unfiltered inleakage, which resulted in a marginally acceptable habitability system. Because of the small margin, any degradation of the HVAC system could result in a shutdown of the plant. A summary of the data used in the analysis is provided in Table 2.

The same design was then analyzed using the revised accident source terms. Because of the lack of guidance on the in-containment transport for the new source terms, the present calculation assumed that the 5% elemental fraction was airborne as soon as it was released and was subjected to removal by containment spray and plateout. The remaining activity stayed in solution. A decontamination factor of 200 for the

Table 2: Control room habitability system design parameters.

Parameter Description	Value
Containment Building	
Volume	$2.75x10^6$ ft^3
Leak Rate	
0-1 day	0.1% per day
1-30 day	0.05% per day
Spray Removal Rates	
Elemental I	20 per hr
Particulate I	10 per hr*
Organic I	0.07 per hr
Elemental I Plateout Rate	2.4 per hr
Atmospheric Dispersion (Chi/Q)	
0 - 8 hr	$3.5x10^{-3}$ sec/m^3
8 -24 hr	$2.0x10^{-3}$ sec/m^3
1 - 4 day	$1.3x10^{-3}$ sec/m^3
4 - 30 day	$5.7x10^{-4}$ sec/m^3
Control Room	
Volume	$1.2x10^5$ ft^3
HVAC Makeup Rate	1600 cfm
Makeup Filter Efficiency	99%
Unfiltered Inleakage Rate	140 cfm

*Particulate removal rate is reduced to 1 per hr after a decontamination factor of 50 is reached.

spray system was implemented by defining it as the ratio of the amount of elemental iodine in the liquid to the amount of elemental iodine in the containment atmosphere. This allowed credit to be taken for spray removal throughout the phased release as long as the spray system was operating.

The results of the two control room analyses are shown in Table 3. The control room thyroid dose calculated using the revised accident source term and continuous spray operation is substantially below the value calculated using the current model. The primary reason for the large difference in the thyroid dose is a combination of a smaller airborne fraction (5% compared with 25%) and the treatment of all the iodine as elemental. Doses calculated based on Regulatory Guide 1.4 and Murphy-Campe are dominated by the organic iodines that are relatively unaffected by the containment sprays. The whole body and beta skin doses, which are primarily caused by noble gas activity, are slightly smaller for the revised source terms. This is because of the smaller amount of activity available for release early in the accident, when the meteorological and containment leakage conditions are the worst and when relatively short-lived nuclides are available for leakage.

Table 3 Comparison of control room doses based on TID-14844 and the revised source terms.

Source Term Model*	Thyroid Dose, rem	Whole Body Dose, rem	Beta Skin Dose, rem
TID-14844	28.8	0.3	4.1
SECY-92-127	1.5	0.3	3.5
GDC-19 Dose Limits	30	5	30

*Based on the parameters in Table 2 and continuous operation of the spray system during the accident.

IV. New Issues in Control Room Habitability

The phased release affects several aspects of the current model, including removal mechanisms for gaseous species of iodine in containment, the behavior of aerosols, and the timing of worst case dose parameters such as atmospheric dispersion (Chi/Q) and control room occupancy factors. In addition, the commitment for availability of ESF systems may have to change to accommodate the revised source terms.

To illustrate one aspect, note that the results presented in Table 3 are based on continuous operation of the spray system over the entire (11.8-hour) release period. Typically, spray systems are designed to actuate automatically, to inject into containment liquid stored in an external tank and, when the tank is empty, to recirculate water from the containment sump to the spray header. The injection phase of containment spray is typically less than one hour, and the SRP 6.5.2 acceptance criterion for the operating period of the spray is only two hours. As shown in Table 4, if the spray period is reduced to two hours after the start of the injection phase, the thyroid dose rises to 56 rem, which exceeds the regulatory limit. If the spray is shut off at the end of the injection phase (1 hour), the thyroid dose rises to more than 100 rem. Clearly, an alternative method for modeling the iodine transport is required if the commitment for operating the spray system is not to be extended to many hours or days.

One alternative is to assume that plateout of the elemental iodine occurs regardless of whether the spray system is operating. This seems reasonable since plateout is a bulk transfer process, and the containment walls will remain wet regardless of the operating condition of the spray system. Using a continuous plateout rate and spray shutoff at the end of the injection phase results in a thyroid dose of 2 rem (Table 4), still considerably less than the dose resulting from the SRP 6.5.2 model.

Table 4 Effect of containment spray operating period on control room doses (revised source terms).

Containment Spray Operating Period	Thyroid Dose, rem	Whole Body Dose, rem	Beta Skin Dose, rem
Continuous Spray	1.5	0.3	3.5
2-Hour Spray	56.2	0.3	3.5
Injection Only	105.5	0.3	3.5
2-Hour Spray, Continuous Plateout	2.0	0.3	3.5
GDC-19 Dose Limits	30	5	30

V. Summary

This paper has demonstrated the integration of the revised source terms into the traditional, deterministic approach to analyzing control room habitability. A sample calculation indicates a phased release and a small elemental iodine fraction can substantially reduce the calculated dose to the control room operators. However, the calculated doses are very sensitive to assumptions concerning ESF operation and removal mechanisms for fission products. New assumptions concerning fission product transport need to be identified and incorporated into a control room habitability model that will be a worthy successor to Murphy-Campe.

VI. References

1. DiNunno, J. J., Baker, R. E., Anderson, F. D., and Waterfield, R.L., "Calculation of Distance Factors for Power and Test Reactor Sites," U.S. Atomic Energy Commission, TID-14844, March 1962.

2. U.S. Nuclear Regulatory Commission, "Rules and Regulations," Title 10 - Chapter 1, Code of Federal Regulations.

3. USNRC, Memo from James M. Taylor to the Commissioners, "Revised Accident Source Terms for Light-Water Nuclear Power Plants," SECY-92-127, April 10, 1992. (Also, draft NUREG-1465, "Accident Source Terms for Light-Water Nuclear Power Plants.")

4. USNRC, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Pressurized Water Reactors," Regulatory Guide 1.4, Revision 2, June 1974.

5. USNRC Standard Review Plan, Section 6.5.2, "Containment Spray as a Fission Product Cleanup System," NUREG-0800, Rev. 2, December 1988.

6. Murphy, K. G. and Campe, K. M., "Nuclear Power Plant Control Room Ventilation System Design for Meeting General Criterion 19," 13th AEC Air Cleaning Conference, August 1974.

DISCUSSION

SOFFER: I would like to make a rebuttal to several points raise by my esteemed colleague, Mr. Kovach. First of all, you stated that the primary impact of the source term is on a revised iodine chemical form. While that is important, it is by no means the only one. You kind of contradicted yourself when, later in your remarks, you pointed out the increased aerosol loading on particulate filters and what effect this might have.

A second quarrel that I have is that, you have stated that the NRC has quoted the organic iodine content to two decimal places, 2.85% for particulate and 0.15%, I believe you said, for organic. Unfortunately, you are confusing the EPRI proposed source term with the NRC proposed source term. We have not stated elemental iodine or organic iodine in those precise terms. What we stated is that the chemical form of iodine entering containment would be 95% cesium iodide and the remaining 5% would be either in elemental or HI form.

We have also acknowledged that organic iodide would be formed as a result of any elemental iodine that is generated in the containment.

KOVACH: SECY 92-127, Table 10, enclosure 2, which is part of the document, cites 2.85% elemental and 0.15 organic.

SOFFER: That is the EPRI evolutionary ALWR, licensing source term.

KOVACH: This is an actual enclosure to the second listing.

SOFFER: That is not the NRC source term. There may be confusion but that is not what we stated. That is what EPRI has proposed. We are not accepting it and we haven't stated it quite that way.

HAYES: I would like the panel to consider the evaluation as we have it now in TID-14844, to be really very simplistic. You immediately assume that the TID source term is released into the containment. The ESF ventilation systems operate on that source term, and then we calculate both the offsite consequences to the population and to the maximum individual. We also calculate control room operator doses. With the new source term, in many cases, we may be very accident specific in terms of scenario. So, it is very important when a particular part of the accident scenario occurs, such as core concrete interactions and when sprays operate. I wish the panel would comment on how they believe these uncertainties would effect a) their calculations, and b) determining operability. The reason I raise this is because of the information presented by Mr. Schwartz. It appears that, depending upon what type of assumptions you make, you can get an extreme range of doses in the control room, from 1 to 100 rem to the thyroid. It appears to be very important to be able to define the scenario. The question is, are we going to infringe both upon the NRC staff and upon the licensee in terms of defining these scenarios. In terms of operability, as many of you who operate power plants know, there is a continual question when certain equipment comes down. In other words, whether or not we continue to operate. Once again, we get into a situation where we have to make sure that we have defined the various scenarios associated with the operability or degradation of a particular piece of equipment.

VANPELT: My first thought is operability because that is the area we have dealt with in more of a crises mode. I understand your concern that there is a spectrum of accidents whereas we had one set of rules to follow as we went through all of them with particular reference to duration of release. Certainly, your exclusionary boundary dose, will be your limiting dose, but if you pick scenarios that have most of your release in two hours, you are certainly benefitting yourself a whole lot, but not necessarily being safe. As we see operability and things like that, we would probably be running the spectrum of accidents specific to the equipment in question and trying to assure that in all cases it would be okay. As far as taking equipment out of service, as I understand it, the initial time period before there is a core melt is a big concern because the release prior to that could, potentially, occur without a lot of the equipment that we couldn't be without after core melt began. So, we would like to take advantage of that period for doing maintenance and getting leeway to have systems in maintenance.

SCHWARTZ: As a preparer of calculations to be reviewed by the Commission, I see this as a first step. As it evolves into guidance, there will be documents equivalent to a standard review plan or a guidance document that will describe calculational methodologies that are acceptable for the industry to use for EAB-LPZ and control room calculations to make sure we operate under the same ground rules as preparers and regulators and users of this type of information.

SOFFER: Mr. Schwartz said that he saw this as the first step and that there was a need for additional guidance. I would say that is probably correct. Mr. Schwartz's analysis showed that control room doses, for example, were quite sensitive to the performance of engineered safety features and removal mechanisms. One of the things that we are continuing to work on (and we hope to have additional information in the final source term document) is a better discussion of fission product removal mechanisms. We are presently working with contractor assistance to evaluate things like sprays, suppression pools, and water depths overlying molten core debris to try to get some more realistic understanding of what impact they would have in fission product removal. Obviously, they will make a significant difference in actual doses. There are a couple of points of clarification. I think we are still operating under an old mentality. We are not going to be calculating exclusion area doses and doses at the LPZ anymore. If the proposed revisions to the reactor siting criteria come along as we expect, the exclusion area will be determined without a dose calculation. There will still be a need for dose calculations in areas like equipment qualification and control room habitability. They will be, of course, dependent not only upon the source term, but on the removal mechanisms that the plant will have.

PORCO: Dr. Kovach, you mentioned changes to prefiltration, and one of the things you suggested is using the moisture separator as a prefilter. I think the ASHRAE efficiency for the moisture separator is about 35%. Aren't you concerned about the dust holding capacity of the filter? What changes would you foresee for the other ASHRAE filters; in other words, what changes in prefilters would you expect to see? Keep in mind that ASHRAE filters have glass media like the HEPAs.

KOVACH: To answer both this question and an earlier one concerning how a change in iodine concentration will affect the challenge in particulates, I am concerned about the source term with a change in iodine forms. That doesn't create an extra challenge for existing air cleaning systems because we are already handling much higher levels of assumed organic forms of iodine based on the existing source term. The best way that I can describe the problem I have is to give you an example involving so-called prefilters. In some cases, people have containment coolers with prefilters ahead of them to protect the containment cooler from the dust associated with normal operation. The prefilters probably do it very well. However, when the accident we are now proposing occurs with a very high coating of a hygroscope aerosol on the prefilters, most likely the coating will either block flow or blow into the coils of the cooling system. These prefilters are not going to perform the way we expect them to. Therefore, I think we have to look at both the structure and loading capability of prefilters to see how much mass they can hold under these hygroscopic conditions. Will they fail or not? Currently, we don't have a test requirement, a surveillance test, or anything similar for prefilters or some of the less structurally sound moisture separators. I am not talking about the Savannah River type unit that is probably one of the best moisture separators, we have. I am talking about some of the less strong units. I think we have put these prefilters and moisture separators into systems with the idea that they will protect the HEPA filter and the adsorber from droplets and dust. I think we have to reexamine that idea because for very large challenges, the first item in the filter system will be these same prefilters and moisture separators.

HYDER: I just want to mention in this context, that there was a paper this morning by Klassen and Novick on the performance of one type of moisture separator used as a prefilter and the combined performance of moisture separators ahead of HEPA filters.

KUMAR: Mr. Schwartz, regarding your calculations of the cumulative 30-day dose to control room operators, are they made with or without the ESF operating?

SCHWARTZ: They are 30-day doses for containments containing a leak. They are 30-day dose numbers calculated for various combinations of spray and plateout scenarios.

KUMAR: Is the control room emergency ventilation system operating during all that time?

SCHWARTZ: Yes, it is operating at 1600 cfm makeup air with 140 cfm unfiltered in-leakage.

KUMAR: That means the result will depend upon the particular plant, because we restrict intake quite a bit.

WEIDLER: Mr. Scholten would you care to present a perspective on the source term issue from the European viewpoint?

CLOSING COMMENTS OF PANEL MEMBER SOFFER

We heard from a number of speakers; Mr. Vanpelt provided a utility perspective and indicated that the new source term provided a significant number of potential opportunities to look at accidents in a more realistic way and that our present systems were, he felt, slanted towards an unrealistic view of accidents. The new source term provides an opportunity for improved maintenance. He felt that the emphasis was shifting towards HEPA filters and away from charcoal filters. However, he also indicated that there was a potential for questions regarding equipment qualification, especially in a post-accident liquids and post-accident shielding environment, and that there were many practical aspects that needed to be explored to begin to take advantage of this source term insight.

Mr. Kovach then provided some remarks and questions concerning iodine chemical form. He felt that the specification of iodine chemistry to two significant figures was unrealistic. He also felt that there was the potential for large generation of organic compounds and that the specification of iodine chemistry in a pure environment was completely unrealistic considering the large and diverse number of chemical reactions that could and will take place in containment in a post-accident environment.

Mr. Hyder then discussed the new source term in relation to severe accident research that is presently underway at the K reactor in Savannah River. He indicated that there was a revised analysis of severe accidents that was being performed for the K reactor. As a result of this and as a result of EPA studies, they have developed new source terms for the K reactor and he was pleased that the NRC had developed source terms by proceeding along the same type of methodology, same approach.

Mr. Schwartz from Sargent and Lundy then looked at a potential application of new source terms with regard to control room habitability and indicated that the new source terms appeared to reduce thyroid doses significantly. However he indicated a number of factors that seemed to be quite important such as the effect of spray duration and that the doses that resulted were very sensitive to removal mechanisms.

There was then a discussion period. A number of the points that were brought up were a rebuttal by Mr. Soffer saying that the specification by NRC of iodine chemistry to two significant figures was not correct, but that these were part of an EPRI proposed formulation. There were discussions about how one would use equipment operability in regard to this kind of a source term. Others indicated that they saw this as a first step and that implementing guidance was required to be followed. It was pointed out that additional work on removal mechanisms was taking place.

Mr. Kovach pointed out, for example, that in regard to those installations using containment fan coolers the prefilters and moisture separators were likely to undergo a severe challenge from the particulate loading. This was an area that needed considerable examination.

Finally, there was a discussion from Mr. Scholten from the European Community who talked about efforts underway in Holland with regard to containment venting and the effects that filtering would have upon reducing the source term associated with this.

KOVACH: Reviewing the basis of the source term, it appears that the principal investigators who were involved in the various studies only considered organic iodide formation from elemental iodine. They did not consider organic iodide formation from cesium iodide. I think that this probably accounts for significant differences in the theories that people are willing to accept.

SOFFER: It is true that the investigators that were working on this, primarily at Oak Ridge, regarded the formation of organic iodide to be principally from elemental iodine. That is true, and I think that is a worthwhile comment.

EFFECT OF FILTERING AT CONTAINMENT VENTING ON THE CONSEQUENCES FOR THE ENVIRONMENT

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Abstract

Containment venting is considered in many countries as an option to avoid an uncontrolled release of radioactivity due to containment rupture in the case of a severe reactor accident. The source term is reduced by filtering the vented gases and so the consequences are mitigated further.

In this study the benefits of filtering are assessed by calculating the consequences of a release with and without a filter. The results show that with a filtered release the consequences for the environment remain below the intervention levels applied in the Netherlands, except those for land contamination with iodine.

I. Introduction

The Dutch Nuclear Inspectorate has asked the nuclear power plants to consider the installation of a filtered containment venting system (FCVS) to mitigate the consequences of an uncontrollable core-melt accident. The objective is:
" releases, if they cannot be avoided, to be limited in such a way that short-term countermeasures for the population will not be necessary and no extensive nor long-term contamination of land or surface water will arise."
This objective will be achieved if:
- the potential 24-hour dose to an individual is less than:
  - effective dose: 5 mSv
  - thyroid dose: 50 mSv
- surface contamination is less than:
  - I-total 5 kBq/m2
  - Cs-137 2.8 MBq/m2
  - Cs-134 4.4 MBq/m2
  - Sr-90 4.7 MBq/m2
  - Pu-total 2.8 GBq/m2

The consequences were calculated with the European ACA-code COSYMA[1,2]

II. Source term

The consequences were calculated for the environment of the Borssele NPP. This is a PWR of 450 MWe of a German design which has been in operation since 1973. To calculate the consequences of a scenario with a filtered release, a relevant source term has to be considered. At the moment a level-2 PSA for the Borssele NPP was not available, so an appropriate source term has to be established. Some

American risk analyses on comparable reactor types were used to choose a source term.[3,4,5,6] To calculate the benefits of venting, only those accident scenarios need to be considered for which venting is an option to mitigate the accident. In about 90% of the accident scenarios described venting is not necessary, since they do not lead to containment rupture. From the remainder the S3C scenario for the Seabrook plant was considered relevant for the purpose of this study. By filtering during the venting the source term is reduced. This leads to a source term according to table 1.

Table 1 Representative source term*

	no filter	with filter**
Xe - Kr	1	1
I	5.10^{-3} ***	3.10^{-4}
Cs - Rb	5.10^{-3}	5.10^{-6}
Te - Sb	3.10^{-2}	3.10^{-5}
Ba - Sr	5.10^{-4}	5.10^{-7}
metals	5.10^{-4}	5.10^{-7}
La - act.	5.10^{-5}	5.10^{-8}

* in fractions of core content

** decontamination factors DF= 1 for noble gases
DF= 10^3 for aerosols
DF= 10 for I_2
DF= 1 for CH_3I

*** 38% elemantary (I_2)
2% organic (CH_3I)
60% aerosol-bound

The decontamination factors given in Table 1 are a factor 10 lower than specified for the filter (except for the noble gases). This leads to conservatism in the consequence calculations. Furthermore an indication of the sensitivity of the results to filter efficiency is obtained.

The source term from Table 1 is reasonably comparable with the source term from the risk analysis by GRS for the Biblis-B plant.[7] Apart from the power the Bilblis-B plant is of the same design as the Borssele plant.

The partition of iodine release in elemental, organic and aerosol bound fractions is quite uncertain. Proposed figures for the US has been given by Soffer at this conference.[8] Figures for European countries are given in Table 2, which is taken from an international comparison exercise.[9] There is hardly any consensus. Therefore an extra sensivity analysis is performed for this point.

Table 2 Assumptions of the partition of released iodine in several member states [9]

	B	F	I	E	GB
molecular	0.91	0.9	0.495	0.91	0.000
organic	0.04	0.1	0.010	0.04	0.002
aerosol	0.05	0.0	0.495	0.05	0.998

III. COSYMA code

For the evaluation of the doses and ground contaminations in the environment, the probabilistic consequence assessment code COSYMA is used. This code was developed for the European Commission by KfK (Germany) and NRPB (UK). For the dispersion parameters σ_y and σ_z figures from the Dutch National Model [10] were used. Hourly data of weather conditions from 1982 and 1983 obtained at a nearby weather station were used as meteorological input. Stratified sampling will assure a well distributed selection of weather sequences out of the total spectrum of conditions, including extremes. For more details of the Code, see references 1 and 2.

IV. Results

Effective dose

Figure 1 presents the 95-percentile for the individual effective committed dose for exposure during the first 24 hour after the release as a function of distance. No countermeasures are taken into account. With the use of a filter a dose of 5 mSv, the postulated low intervention level for sheltering, will only be exceeded at distances shorter than 1 km. There are no people living within such a short distance. In extreme weather conditions the doses may be higher.

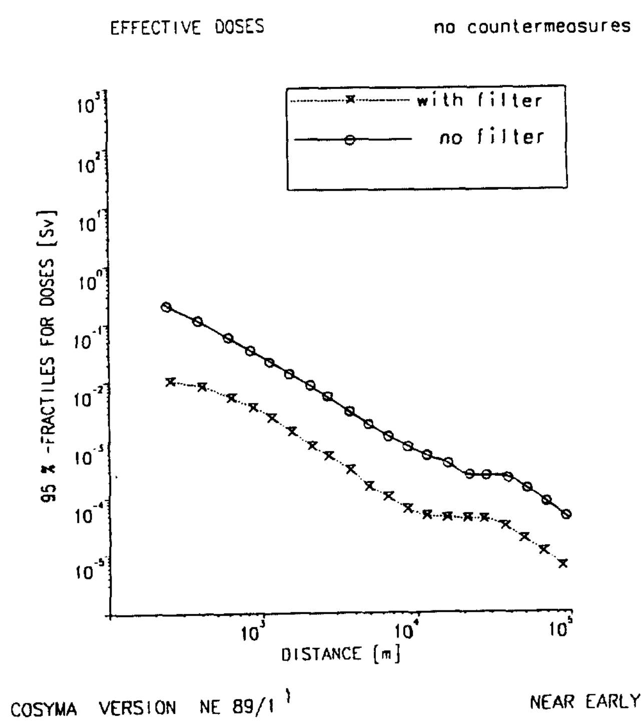

Figure 1 95%-fractiles for effective doses as function of distance from the plant

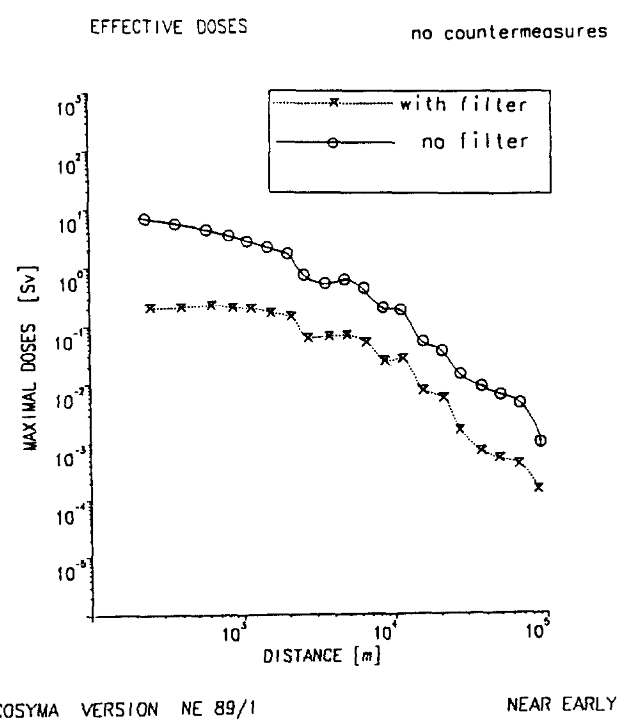

Figure 2 Maximum for effective doses as function of distance from the plant

Figure 2 shows the maximal expected doses under these circumstances. Without a filter the dose may increase to several sievert, a dose giving rise to severe non-stochastic injuries. With a filter, the dose will be at maximum 0.2 Sv at distances < 2 km; this is still a high dose, but it entails no risk of acute injuries. However, if the accident occurs, the probability of such a severe weather condition is lower than 10^{-4}.

Ground contamination

The CCFD for contamination without filtering for longer living, nuclides is given in Figure 3. The contaminated areas are quite small or absent in the case of Pu. If the release is filtered, no contamination levels will be exceeded at all.

In Figure 4 the CCFD for ground contamination with I-131 is given for release with and without filter. Despite the filter, still a substantial area is contaminated with I-131 above the intervention level for grazing. However, with the short half-life time of 8.05 days of I-131, the contamination vanishes within a few months.

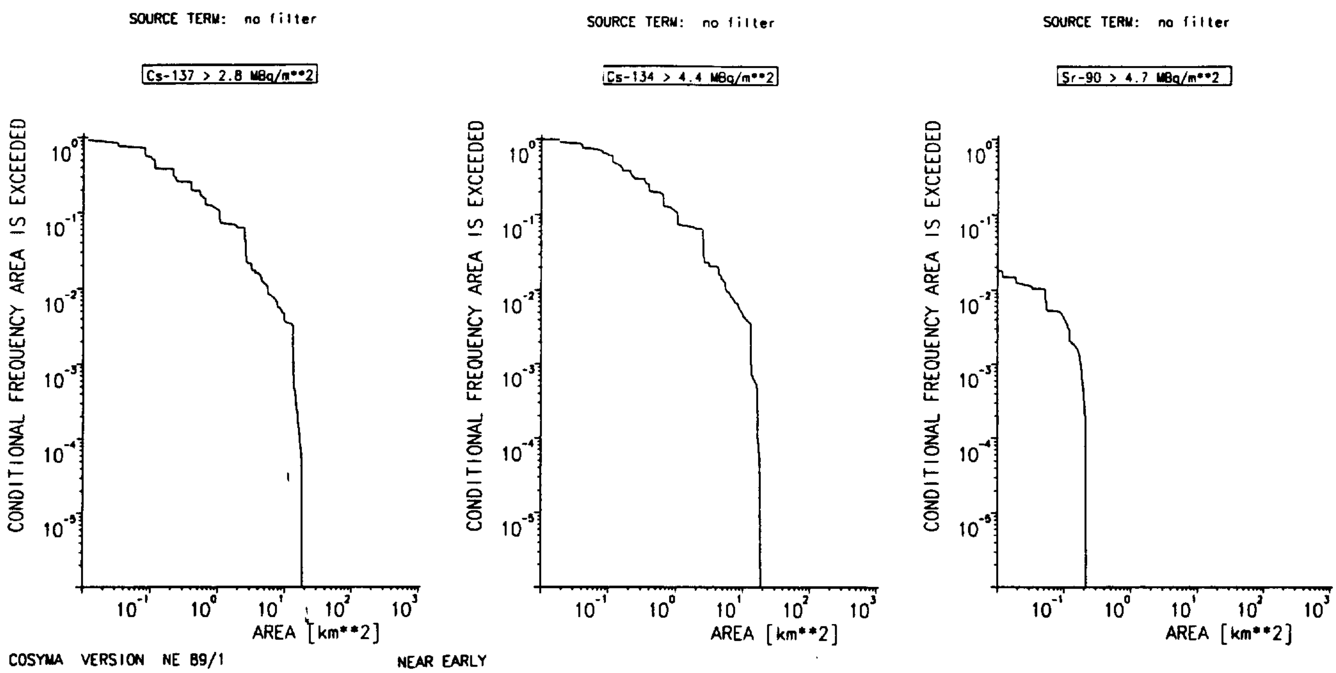

Figure 3 CCDF's for ground contaminations with long-living nuclides without the use of a filter

Effect of iodine species

A test was conducted on the sensivity of the results to the CH_3I content in the release. As the filter factor for this gas is set at unity in the calculations, a high sensivity can be expected. In Figure 5 the results are given for some percentages of CH_3I, expressed as fractions of total I-content in the core. The difference in doses between the highest and lowest fractions are about a factor 50. It can be concluded that the speciation of iodine plays a dominant role in the consequences of a filtered release. The capability of filters to retain organically bound iodine has to be considered.

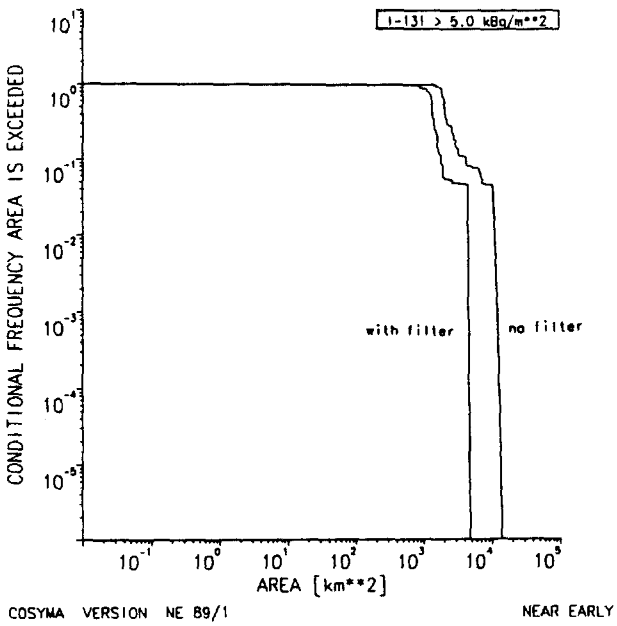

Figure 4 CCDF for contamination with I-131

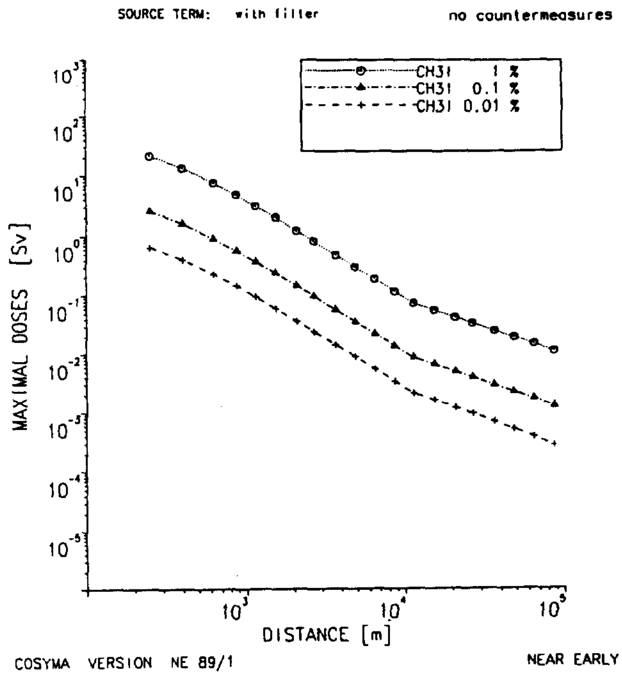

Figure 5 Influence of CH_3I as function of core content on thyroid dose

Influence of filter efficiency.

Inert gases are not filtered. The dose caused by the inert gases is therefore the same in filtered and unfiltered releases. However, in case of filtered venting, the dose will be governed by the inert gases. This is demonstrated in Figure 6. Increasing the efficiency of the venting filter will hardly lead to any more decrease of the dose. As stated before, we have conservatively supposed in our calculations that the filter efficiencies are a factor 10 lower than specified for the design. There is no reason to strive for higher efficiences for lowering the doses. Even the low figures used in the calculations should be acceptable. Only the areas contaminated with iodine might be decreased further.

V. CONCLUSIONS

From calculations performed with the probabilistic ACA-code COSYMA it is demonstrated that a venting filter is able to keep the doses in the environment below the intervention levels in most circumstances. Only in extreme weather conditions may the doses exceed these levels, but the probability of occurrence is very low.

The area contaminated with I-131 above the intervention level for grazing can be quite large, depending mainly on the filter efficiency for methyliodide. On the other hand, such contamination does not last very long. With filtering of a release the contamination with long living nuclides remains under the levels.

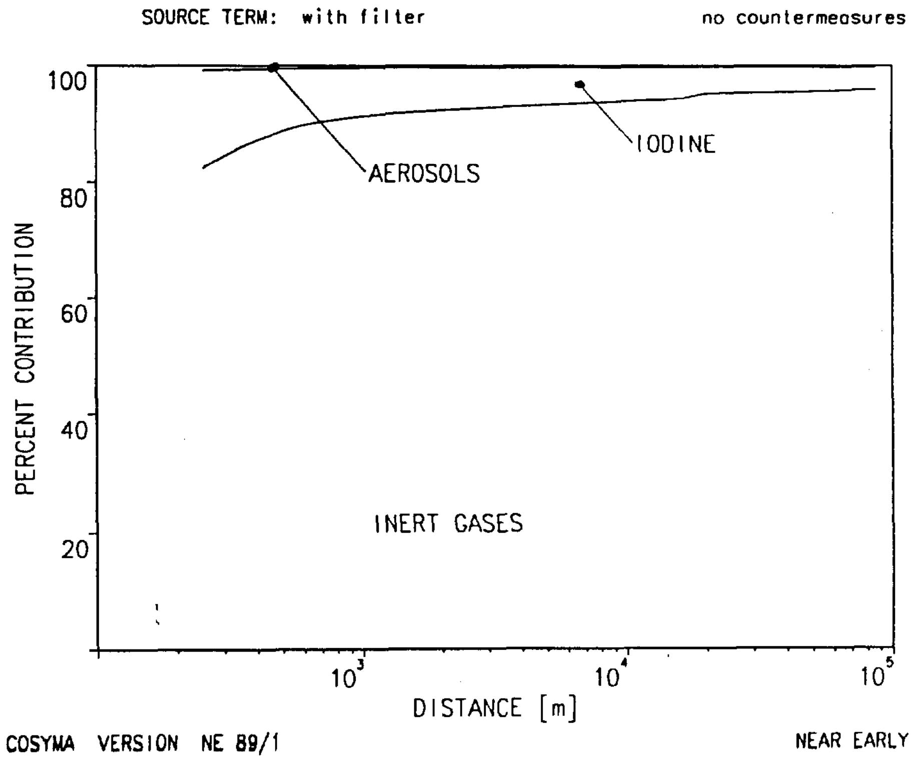

Figure 6 Relative contribution of nuclides groups to the effective dose

Acknowledgment

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