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subject Consultant's Report on the ACRS Subcommittee on Air Systems Meeting June 17, 1985, Washington, D.C.

The subcommittee on Air Systems held a meeting June 17, 1985, in Washington, D.C., to hear status reports on two topics:

(1) Control Room Habitability
(2) Pressurized Gas Systems

Comments I have on the oral presentations and written materials presented at this meeting on these topics are presented below.

Control Room Habitability

It is most apparent that the Control Room Habitability issue is in very competent hands. The survey report by the engineers from Argonne West was excellent and the follow up actions outlined at the meeting by Mr. Hayes and Mr. Gammill seem well-planned.

I will confine my comments, then, to some thoughts about how revisions in the severe accident source term might affect control room habitability and the design of systems to ensure habitability.

Design specifications and evaluations of the heating, ventilation and air conditioning (HVAC) systems are cast within the context of the so-called TID source term (1). This source term focuses on radio-iodine in the elemental state. As a consequence, there is an emphasis in the planning and evaluation of HVAC systems on the presence of activated charcoal getters to trap iodine from inlet gases to the control room atmosphere.

Modern analyses of radionuclide releases from plants during severe accidents* describe the nature of the released material in rather different terms than the TID source term (2). The most notable features of releases predicted by modern analysis are:

(1) Each accident at each plant has the potential of producing a unique release of radioactive material. This release can differ from the prescriptions of the TID source term in both qualitative and quantitative ways.

(2) The predominant physical form of radionuclides released from the plant during an accident is aerosol particulate. (Noble gases, of course, do not have this form.)

(3) Radionuclides released from the plant during an accident can be a good deal more diverse than just iodine.

(4) The chemical form of iodine is predicted typically to be predominantly cesium iodide (CsI) or other iodides (AgI, FeI_2, etc.) rather the elemental iodine (I_2).

(5) The radionuclide releases are accompanied by significant quantities of non-radioactive aerosol particulate.

Releases are now estimated using a series of mechanistic (deterministic) computer codes. These codes predict the nature of fuel degradation, the release of radionuclides during the degradation as well as the vaporization of non-radioactive materials. The subsequent behavior of these released radionuclides and vaporized materials are also predicted. The results of the calculations are sensitive to the design features of the plant and the peculiar features of any accident being examined. As a result of this sensitivity, it is difficult to define a generic release

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* A severe accident is not well-defined, but is, in general, taken to be one in which fuel degradation is well in excess of that allowed for the reactor design basis accident. The accident may involve complete core meltdown and containment breach.

applicable to a wide variety of situations. I work fairly closely with the development of these modern source term predictions, but I cannot offer, yet, totally satisfactory advice on a "design basis" source term that might be of use for designing HVAC systems. I can suggest features of the revised source term that may affect such designs.

The most obvious feature of the modern predictions of the source term is the emphasis on aerosols. Radionuclides and non-radioactive materials are vaporized from the core as a result of the high temperatures that develop in the fuel during an accident. The vapors are quenched, however, as they emerqe from the regions of high temperatures. An important and difficult task of the modern source term analyses is predicting the nature of the quenching process. In general, vapors, when quenched, condense on surfaces or nucleate aerosol particles. Those vapors that condense on surfaces pass out of consideration at least temporarily. The aerosol that nucleate and remain suspended in the atmosphere are available for release from the plant. How long they remain available and the nature of the particulate when it is released is determined by detailed analyses of the diverse physical phenomena affecting aerosols.

An example of modern calculated source terms is shown in Figure 1. The amount of material suspended in the containment atmosphere is shown in this figure as a function of time. Also shown are curves that indicate the cesium, iodine, and tellurium content of the suspended material. Cesium and iodine inventories are very strong functions of time. These materials are released from the fuel quite early in an accident. Aerosols composed of cesium and iodine (in the form of iodides) have an opportunity to agglomerate and settle in the containment if there is not a significant breach in the containment. This settling process sharply reduces the releaseable amounts of cesium and iodine. Tellurium suspended in the containment is a less sensitive function of time. Aerosols composed of tellurium or tellurides (Ag_2Te, FeTe, etc.) engage in the same sort of processes that reduce so sharply the inventory of releaseable cesium and iodine. But, the tellurium in the containment atmosphere is being continuously replenished by releases from the core debris as it interacts with concrete in the reactor cavity. The weak dependence on time of the total aerosol inventory in containment also arises because of the replenishment of aerosols from core debris/concrete interactions.

The source term description shown in Figure 1 is that to which control rooms will be exposed only if a breach or major leak path is formed in the reactor containment. The

potential load on the control room HVAC system depends then on the time of containment failure. The potential load is composed primarily of aerosols. The radiological threat to control room habitability is initially posed by cesium and iodine. This radiological threat evolves in time to become one posed by tellurium* and more refractory radionuclides such as Ba, La, and Pu.

The revised sou ce has some consequences on design of filtration system. The most obvious consequence is that HEPA filters unprotected by some sort of pre-filter are threatened. HEPA filters are very easily overloaded especially if the atmosphere is contaminated by the masses of aerosol material shown in Figure 1. When overloaded, HEPA filters fail. The next consequence is that activated charcoal will not efficiently getter the radiological threat posed by the new source term. Charcoal beds are poor traps for aerosols and will not getter iodine in the form of iodides.

The new source term may mean a good deal more attention is paid to the filtration features of HVAC systems for control room than to the activated charcoal getter aspects. Fortunately, the fitration requirements may not be as exacting as thought when the TID source term is the basis for the design. The aerosol particles have sizes that increase with time and aerosol concentration. Some typical sizes for aerosols predicted with the modern computational tools are shown in Figure 2. Mean aerosol particle sizes of a few micrometers are predicted typically. Obviously, such coarse aerosols can be filtered using more conventional and more robust technology than HEPA filters. In fact, sprays incorporated in some current designs to cool charcoal getters may serve as excellent means for removing aerosols after some changes in design.

Analyses of source terms done for the NRC portray the source term as acute. That is, the threat is very intense if containment failure is early in the course of an accident. The threat is then portrayed to go to zero as the time of containment failure is delayed.

Industry-sponsored analyses of the source term do not agree entirely with this acute time resolution of the source term. Recall in the discussion above that it was mentioned

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* ^{132}Te does decay to form ^{132}I which has not been considered in developing Figure 1. As a result of this decay process, the iodine threat is not totally removed.

condensing vapors may deposit on structures. Industry-sponsored analyses (4,5) have noted, correctly, that radionuclides deposited on structures will cause those structures to heat. Temperatures may be reached eventually that cause the more volatile radionuclides (cesium, iodine, and perhaps tellurium) to vaporize This revaporization will be slow, protracted, and will occur very late in an accident. Some results obtained in the industry sponsored analyses are shown in Table 1. Note that for some accidents radionuclide release is predicted to begin more than 24 hours after accident initiation and to continue for a few days! These results indicate that the source term threat is rather chronic, lasting for several days. Again, the chemical form of released radionuclides, aside from noble gases, is thought to be aerosol particulate and not iodine vapor.

Studies sponsored by the NRC also indicate a chronic component to the release of radionuclides from a plant. Very many accidents involve situations where much of the radioactive material is collected within the containment in water pools. Iodides (CsI etc.) in these water pools will ionize. Also, they will self-oxidize so that a partial pressure of I_2 develops over the water pool (6). Once containment has ruptured the I_2 will be continuously swept from the containment into the environment. This release process will create a low intensity, but very protracted source term for iodine. Similar chemistry can be imagined, but has not been investigated for Te and Ru.

It is then not entirely clear what the long term release of radioactivity from reactor containments will be. This long term release could be low intensity particulate or low intensity I_2 vapor. Presumably a design to assure control room habitability will have to be based on consideration of both possibilities.

A final topic that deserves mention is one of localized deposition of released radioactivity. This is a topic of fairly recent interest. The interest is prompted by the observed disposition of radioactivity released during 2 recent incident at the Ginna plant (7)

Most previous analyses of the expulsion of the release of aerosols from a plant have been based on models that neglect the presence of condensible steam. Deposition of aerosols from a plume escaping the plant then is slow and takes place over a broad area. When the possibility of steam condensing during the process of expelling radioactive materials from containment is included in the analysis then a different portrait emerges. Then, the presence of water droplets can cause rather local deposition of radioactivity

in high concentrations in close proximity to the plant. Such local deposition has been observed in non-accident situations(8). The possibility that there might be localized deposition in the vicinity of the control room even during design basis accidents cannot be discounted.

In summary, the description of radionuclide release in reactor accidents is undergoing substantial evolution. This evolution involves qualitative as well as quantitative revisions of the TID source term. Some caution is necessary is asking for changes to existing HVAC systems if the TID source term is to be abandoned or modified as a result of recent mechanistic analyses.

PRESSURIZED GAS SYSTEMS

It is apparent from the presentations made at the Subcommittee meeting that the nuclear industry suffers the same difficulties with pressurized gas that are suffered by all institutions. Recommendations made for improving the use of pressurized gas systems are, in fact, simply to enforce good practices. The first of these recommendations is to provide protection from "portable gas cylinder missiles". It is suggested that this recommendation be met by analyses or equipment. My own feeling is that suitable equipment exists that will obviate most of the dangers associated with gas cylinders. The difficulty is going to be to assure this equipment is properly used. That is a difficulty for which we all wish we had an answer.

Another recommendation is for gas line identification. This is, of course, a sound recommendation. The pressurized gas industry has actively attempted to establish three lines of defense for gas usage:

(1) color coding
(2) labeling
(3) fixturing specific to gas type.

Fixturing peculiar to gas type actually involves grouping gases into categories. Special threading and pipe sizes are specified for each class of gas. I myself have found the system is not entirely fool-proof. Fixturing usually prevents mistaken usage of gases from different classes. But, I have had an experience in which gas bottles within a class had labels and color codes that disagreed. I do not know if this is common or if it would produce a hazard. I would suggest the three lines of protection (color coding,

labeling, and fixturing) be adopted. Also, that some care be taken to assure that mix-ups within a class (air, oxygen, nitrogen, mistakes, for instance) do not cause difficulties or hazards.

References

1) J.J. DiNunno, F.D. Anderson, R.E. Baker, and R.E. Waterfield, Calculations and Distance Factors for Power and Test Reactor Sites, TID-14844, see also US NRC Regulatory Guide (Revision 2, June 1974) 1.3 and 1.4.

2) J.A. Gieseke et al. Radionuclide Release Under Specific LWR Accident Conditions

Volume II, BWR Mark I Design

Volume III, BWR Mark III Design

Volume IV, PWR, Ice Condenser Containment Design

Volume V, PWR, Subatmospheric Large Dry Containment Design

Volume VI, Zion PWR Large Dry Containment Design

BMI-2104, (draft), Battelle, Columbus Laboratory, Columbus, Ohio, July, 1984

3) R.J. Lipinski et al. Uncertainly in Radionuclide Release Under Specific LWR Accident Conditions

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SAND 85-0410, Sandia National Laboratories, Albuquerque, NM.

4) IDCOR Technical Report on Task 11.3, "Fission Product Transport in Degraded Core Accidents", Dec. 1983.

5) See for example, IDCOR Technical Report 23.1, "Peach Bottom Atomic Power Station Integrated Containment Analysis", Atomic Industrial Forum.

6) Technical Bases for Estimating Fission Product Behavior During LWR Accidents, M. Silberberg, editor, US NRC, NUREG - 0772.

7) C. D. Leigh et al. Analyses of Plume Formation, Aerosol Agglomeration, and Rainout Following Containment Reipture, NUREG/CR-4222, SAND84-2581 Sandia National Laboratories, Albuquerque, NM.

8) P. Brog, Reactor Congress. April, 1978

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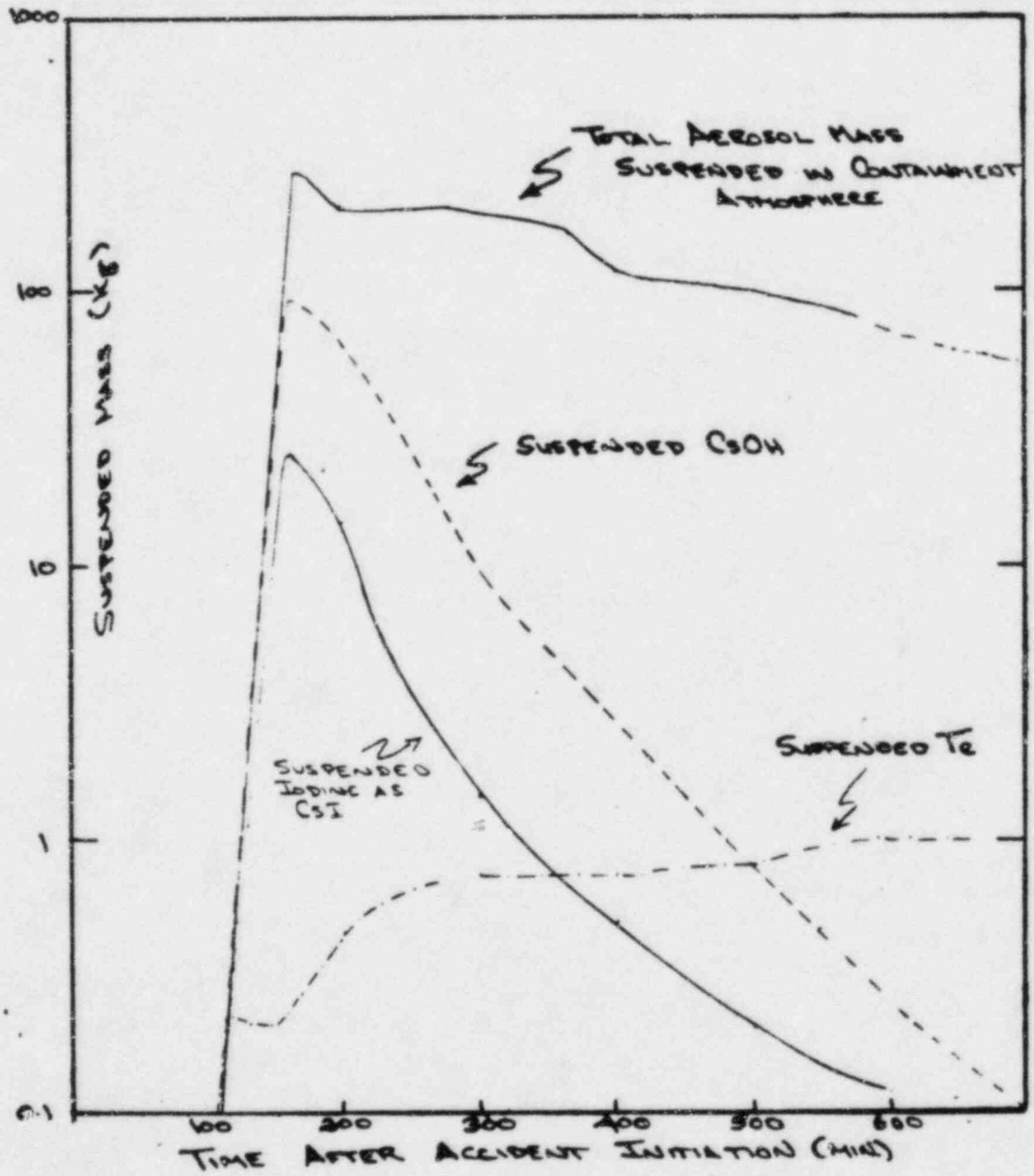
Table 1: EXAMPLES OF RELEASES PREDICTED IN INDUSTRY SPONSORED ANALYSES OF SEVERE ACCIDENTS

	Accident			
	TW	TC	S.E	TQVW
Time* Release starts (hrs.)	34	13	23	18
duration of release (hrs.)	80	50	30	30
fraction of Cs inventory released	0.13	0.034	0.01	0.05
fraction of I inventory released	0.13	0.034	0.01	0.05
fraction of Te inventory released	0.14	0.066	0.01	0.04

* Time after accident initiation

FIGURE 1 - TYPICAL SOURCE TERM DESCRIPTION OBTAINED FROM MODERN MECHANISTIC PROCEDURES



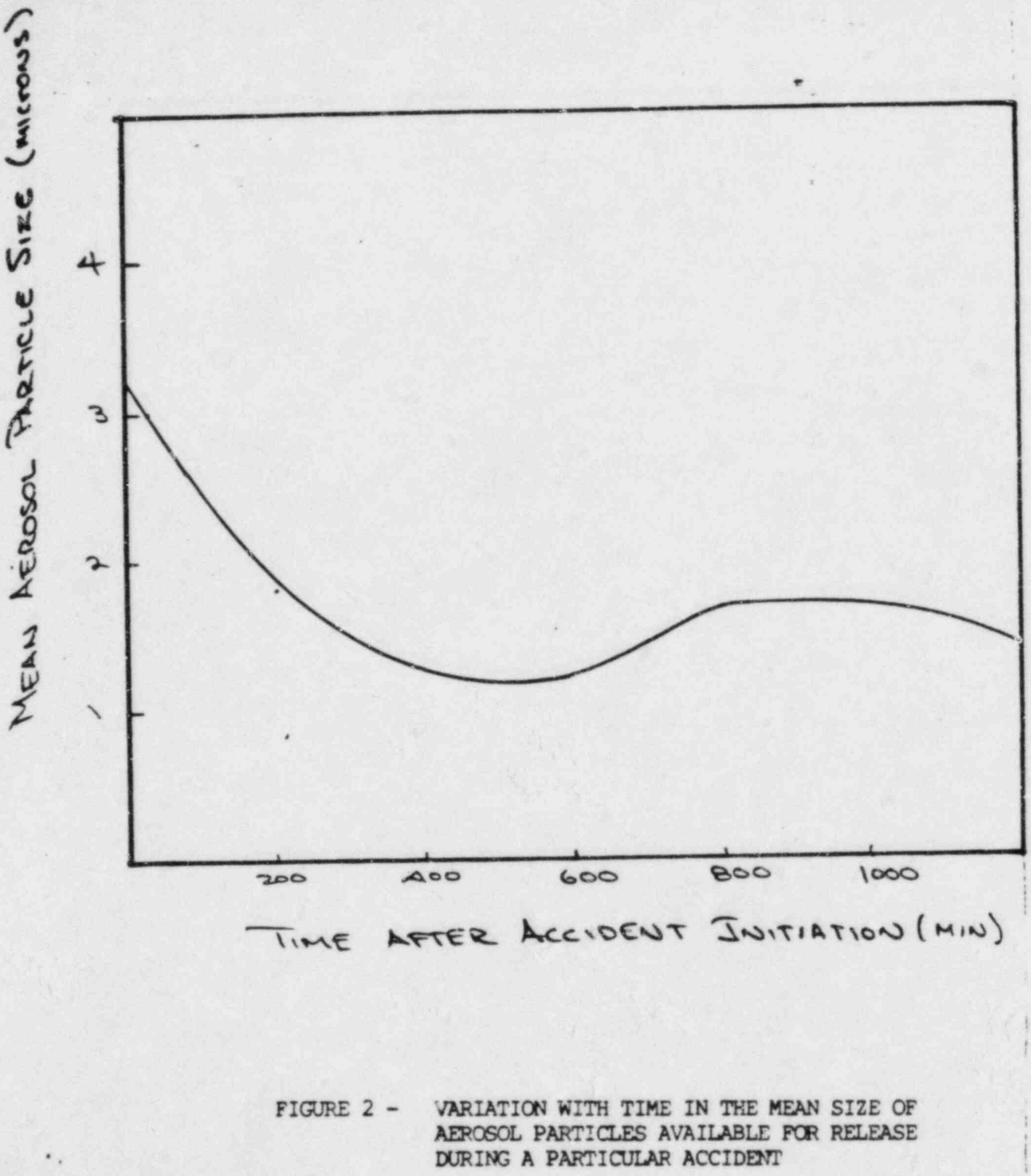


FIGURE 2 - VARIATION WITH TIME IN THE MEAN SIZE OF AEROSOL PARTICLES AVAILABLE FOR RELEASE DURING A PARTICULAR ACCIDENT