SESSION 1

OPENING OF THE CONFERENCE

Monday:	August 24, 1992
Co-Chairmen:	M. W. First
	R. R. Bellamy

WELCOME AND OBJECTIVES OF THE CONFERENCE

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I take great pleasure, pride, and a considerable measure of satisfaction in opening this the 22nd Conference devoted exclusively to nuclear air and gas cleaning technology. Pleasure in greeting many old friends as well as meeting new ones, pride in the part played by the Harvard Air Cleaning Laboratory in hosting this long series of important technical meetings, and satisfaction that our Program Committee has prepared yet another four days of excellent papers and thoughtful panel sessions. You will note among the names of the Program Committee members listed on the cover of your program, that there are a number from Europe and Asia. This recognizes the fact that although this is a U.S.-sponsored conference, representatives of other countries have, for many years, been a significant presence at these conferences and made major contributions to the technical content. Their joining with their U.S. colleagues in the planning of the Conference and their diligent solicitation of papers from their own area are gratefully acknowledged.

You will have already noted that the title of this Conference has been changed by the addition of the word "Treatment" in the title. This was done to emphasize a greater interest in the processing of gaseous effluents involved in nuclear waste treatment operations, among others, not all of which resemble simple air cleaning tasks. At the same time, interest in air cleaning requirements for nuclear power plants, as well as the chemical processing of fuel, continues to be a high priority for this Conference. In fact, this opening session will be largely devoted to presentations that discuss the current status of nuclear power in the U.S. and the development of advanced nuclear power reactors currently under construction in Asia. Later in the week, we will have a presentation by a Commissioner of the U.S. Nuclear Regulatory Commission that will be concerned with new approaches to nuclear power plant licensing. These are, indeed, interesting times in the nuclear industry and I believe this week's program will emphasize the excitement of these and other new developments that you came to hear about.

We offer our sincere thanks to the U.S. Department of Energy and the U.S. Nuclear Regulatory Commission for their continuing financial support of these biennial Conferences and we welcome the International Society of Nuclear Air Treatment Technology, Inc. (ISNATT) as a new and welcome financial contributor. ISNATT, with CONAGT, the Committee on Nuclear Air and Gas Technology, have made significant contributions to the technical content of this Conference.

GLOBAL CHANGE AND THE PRACTICE FOR AIRBORNE WASTE TREATMENT

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I. Introduction

The treatment of gaseous effluents at nuclear facilities relies in general on the application of the multiple confinement concept. Initially, the construction of these confinements were designed to protect the health of the operators. Later, gas treatment installations were put at the exit of each confinement to limit the radiation doses to man on-site and in the environment. The nearest environment has been considered to be the most highly exposed individual at the fence of the nuclear facility. Afterwards, process analysis and system assessment of the gas treatment installations were combined with health physics considerations on regional and global population to assess costs of release control measures and costs of health detriment in function of radiation exposure of justified practices. These cost-benefit evaluations evolved in the ALARA-principle (As Low As is Reasonably Achievable) meaning that technical efforts are optimized to the point that the industrial impact on the environment is as low as reasonable achievable under normal and accidental operating conditions within economic and health criteria. In any case, mankind has to be enough protected according to ICRP recommendations.

In this paper, the actual practice for airborne waste treatment in the nuclear fuel cycle applying multiple confinement and ALARA principle will be described. This practice will be confronted with the issue of global climate change starting from the source-terms for the principal airborne radionuclides.

II. The multiple confinement concept

Airborne waste treatment relies on the technical reliability of an emission control system that is situated between the airborne waste source and the device, that releases the decontaminated gas stream into the environment. Most often the release device is a stack in order to allow the atmospheric dispersion of the released impurities.

A prerequisite in this controlled release sequence of airborne waste is the necessity to confine all airborne waste pathways to enclosures with controlled outlets. However, any technical enclosure is never completely leak-tight. Uncontrolled discharges in a weak point of the confinement, often related to material transfer lines or to incomplete leak-tight equipment, have to be directed through professionally designed feedback and ventilation systems in order to protect the health of the operator. Finally, safety considerations lead to a third barrier system designed to isolate the accidently released airborne waste from the environment. In this way, the multiple confinement concept for nuclear installations relies in general on three barriers[1], as shown in Figure 1 :

- a primary confinement which consists of the walls of the process equipment that is in direct contact with the hazardous material. For instance the fuel cladding in a nuclear reactor. Another example is the installation of vessels, piping, etc. in a nuclear waste facility;
- a secondary confinement consisting of an enclosure or structure that enfolds the primary barrier. This second barrier is in direct contact with radiotoxic material only if small, unavoidable leaks of the primary confinement occur. For cases with high radiation levels, this second barrier is combined with mechanical protective structures to provide shielding against radiation. For instance, a complex structure of double wall hot cells for high risk, irradiated fuel characterization;
- a tertiary confinement consists of a structure or building with operational access to the shielding protection of the second barrier. This third barrier is generally designed to withstand to internal hazards (explosion, fire,...) and to external hazards (earthquakes,...). This tertiary confinement is in fact the casing that isolates the installation from the environment in normal operating conditions as well as in the case of internal or external accident. For instance, the double-walled dome of a nuclear reactor.

Usually, the operating area between the secondary and the tertiary confinement is well ventilated to prevent the accumulation of hazardous species and to maintain occupational safety for the operators at least under normal operating conditions. The effectiveness of this multibarrier confinement concept depends on the efficiency of the off-gas units installed to treat adequately the effluents from the various confinement areas.

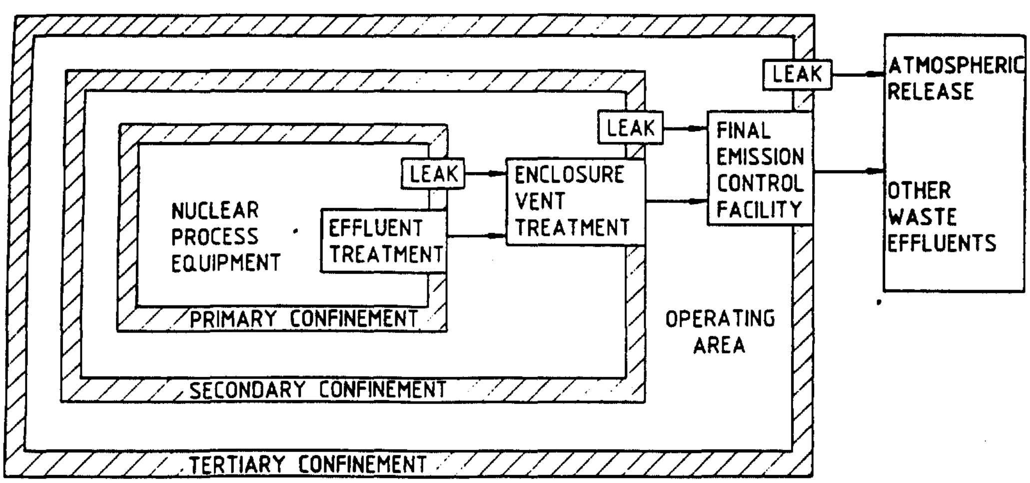


Fig. 1 The multiple confinement concept[1] in nuclear installations

III. The actual practice of airborne waste treatment

A survey of the available techniques for the treatment of airborne waste at nuclear facilities has recently been given in volume 2 of the radioactive Waste Management Handbook[1]. From the description of experience gained, it becomes clear that most recent nuclear facilities are in general adequately equipped with off-gas treatment units in order to meet authorization limits with an increasing application of ALARA-optimization methodology or referring its principles.

In relation to the subject of global change, the overall experience can be summarized as follows :
At a nuclear power reactor the major radioactive products are retained within the canned fuel. Under normal operating conditions in reactors with recent cladding technology the release of radioactive material to the atmosphere is relatively negligible in comparison to the inventory of radioactive products. Nevertheless, the Kr-85 release might be as high as 1 % of the Kr-85 inventory. With the development of mitigation systems the airborne release can be kept small even when a severe accident occurs[2] : a fraction smaller than 10^{-4} is released of the particulate matter and organic iodide is retained for more than 99 % in optimal operating conditions[3]; only part of the noble gases Xe and Kr are escaping through the primary barrier with decay in the third barrier[4] limited to short lived isotopes. Again Kr-85 penetrates through all barriers at a rate depending on the technical conditions.

With regard to the fuel cycle, two options are to be considered for its back end. In the first option, the once through cycle, the irradiated fuel is stored indefinitely. When some mechanical cutting of the fuel assembly is applied leaving the primary cladding barrier intact, 1 % of the gaseous fission products might escape during the cutting operations, but the proper use of adequate venting systems allows to retain nearly every isotope except the noble gas ones. Also during final storage, only the noble gases have to be considered as escaping very slowly from the storage area.

In the second option for the back end of the fuel cycle, the irradiated fuel is reprocessed after five to twenty years of cooling. During mechanical cutting followed by dissolution, the inventory of gaseous isotopes is set free, but suitable off-gas treatment techniques allow to limit the airborne release. The main airborne pollutant is the long lived krypton-85 isotope[5], that is released quantitatively. In this second option, also high level radioactive liquid waste is produced. This HLL-waste is conditioned for final storage by vitrification during which aerosols of fission products are formed. The major radionuclides in untreated melter off gas are submicronic Cs-137 and Sr-90[6]. Experience in the AVM plant in Marcoule (France) and in the German PAMELA plant in Mol (Belgium) has shown that a sequence of condenser, various scrubbers, NOx recovery unit and HEPA filters allow to obtain in optimal operating conditions a total decontamination factor for these radionuclides[6] far beyond the decontamination factor required to satisfy the imposed discharge limits based on health physics requirements for the near-by environment[7].

IV. Source-terms for radionuclides

From this survey on the actual treatment of airborne waste during operation of nuclear power stations and related nuclear fuel cycle installations, it is clear that only very minor quantities of radionuclides are released into the environment. The technical measures taken have been sufficient to protect the operators, the near-by population and the world population at large. Periodic reviews and incident analyses based on new knowledge of human behaviour and technical quality have allowed to improve gradually the real operational results. The minor quantities of radionuclides released in practice are in general of the noble gas type.

In relation to the potential global climate effects of nuclear electricity production, the long term radionuclide hazard is to be considered. Krypton-85 as long lived isotope is the key noble gas in this regard. The Krypton-85 escapes as airborne isotope from the nuclear fuel cycle installations : slowly as it diffuses through the subsequent barriers in the once through cycle option; abruptly in the case of the reprocessing option where krypton-85 is quantitatively set free in the dissolver.

In Table 1, the source-term for krypton-85 is given for the present effective equivalent nuclear power capacity of 229 GWe, resulting from a total nuclear electricity production of 2009 TWe.h supplied in 1991 worldwide by 420 nuclear reactors with an installed total capacity of 326.6 GWe[9]. For comparative reasons, figures are given in Table 1, for other long lived fission products that though are largely retained in the actual practice.

Table 1 Source-terms for a few long lived isotopes

Radio-nuclide	half-life years (1)	present power station production TBq/a (2)	natural production TBq/a (3)	power station production / natural production
H-3	12.35	172,000	148,000	1.2
C-14	5730	160	1,000	0.2
Kr-85	10.72	3,910,000	0.026	$1.5 \times 10^{+8}$
Sr-90	29.12	25,800,000	-	-
I-129	$15.7\ 10^{+6}$	7	1×10^{-7}	$7 \times 10^{+7}$
Cs-137	30	30,700,000	-	-

(1) from reference 10
(2) for an effective production capacity of 229 GWe[9]
(3) for H-3, C-14 and I-129 from reference 1;
for Kr-85 from reference 11.

As mentioned in Table 1, 3,910.000 TBq krypton-85 are annually produced at the moment. The natural annual production rate of krypton-85 can be estimated to be 0.026 TBq per year[11]. Hence, e annual man-made quantity of krypton-85 is 1.5 E x 10^{+8} times larger than the natural production rate. For the other isotopes considered in Table 1, the relative importance of the man-made quantity is orders of magnitude lower for tritium and carbon-14; is nearly of the same importance for iodine-129 and is not estimable for Sr-90 and Cs-137.

However, these man-made isotopes are not released immediately in the environment. For instance, in any option for the back end of the nuclear fuel cycle the isotopes Sr-90 and Cs-137 are isolated from the biosphere for about thousand to ten thousand years by the actual practice of airborne waste treatment during vitrification followed by the planned geological storage. After such a large isolation period, the radioactivity of the remaining isotopes of Sr-90 and Cs-137 is negligible. For iodine-129 there is a problem. This nuclide is either discharged into the ocean where it slowly builds up, or it is conditioned and stored[13]. The long life of I-129 in combination with its chemical properties let foresee that even after a terrestrial confinement of ten thousand years this isotope would still reach the aquifers[13]. Although the production level in itself is small, it is several orders of magnitude larger than the natural production. Accumulation of the man-made quantity in a local repository represents a dose contribution of 10 % of the natural background in the far future[13]. This matter is not further discussed here*.

The release of tritium into the environment depends on the tritium management procedures applied in relation to local and regional conditions[14]. Worldwide, the relative importance of tritium as estimated in Table 1, is relatively small, although on local scale an important contribution remains possible. This observation is valid for carbon-14[15] too.

This brings us back to krypton-85. Its release pattern depends on the option taken for the back-end of the fuel cycle.

Roughly[13], half of the nuclear fuel is actually planned to be reprocessed and the 100 % krypton-85 release is delayed according to the cooling time of 5 to 20 years. The other half of the irradiated fuel is not reprocessed, but is stored and possibly conditioned after a cutting operation releasing about 1 % of the inventory. In conclusion, for simplicity reasons it can be presumed that half of the annual production rate indicated in Table 1, will be released in the future into the air compartment of the environment, namely about 2 million TBq per year (54 million Ci per year). This is the annual release level retained further on in this paper, neglecting considerations on a normal expansion of the nuclear energy production in the future. Due to the delay in the operations of the back-end of the fuel cycle, it is the level

* In this paper, the environmental aspects are restricted to the air compartment neglecting the over-all hazard criterion conceived on the volume of drinking water required to dilute a mixture of radionuclides to the drinking water limits. This discussion is also restricted to fission products excluding actinides.

that might probably be attained from the year 2000 onwards.

V. The krypton-85 content of the air

Natural ionization by cosmic radiation, terrestrial radiation and natural radionuclides contained in the air have resulted in an average natural Kr-85 radiation background of 100 nBq/m^3 corresponding to a total natural Kr-85 inventory of 400 GBq[20].

This radiation level of 100 nBq/m^3 of Kr-85 has steadily been increased by man-made krypton-85 releases since 1945. The nuclear weapon tests, intensive in the periods 1951-1958 and 1961-1963, have added 148 PBq (4 MCi) of krypton-85 to the atmospheric inventory[14].

Later on, the krypton-85 discharges of the reprocessing plants became increasingly important both on a regional and on a global scale. Figure 2 gives a survey[11] of the resulting krypton-85 concentration as measured by ground stations. The concentration level of about 1 Bq/m^3 observed corresponds to a Kr-85 atmospheric inventory of about 3.9 EBq (105 MCi). The leveling off shown in Fig. 2 is not any more valid since the recent capacity increase at the reprocessing plant in La Hague, where about .5 EBq (14 MCi) of Kr-85 could annually be released.

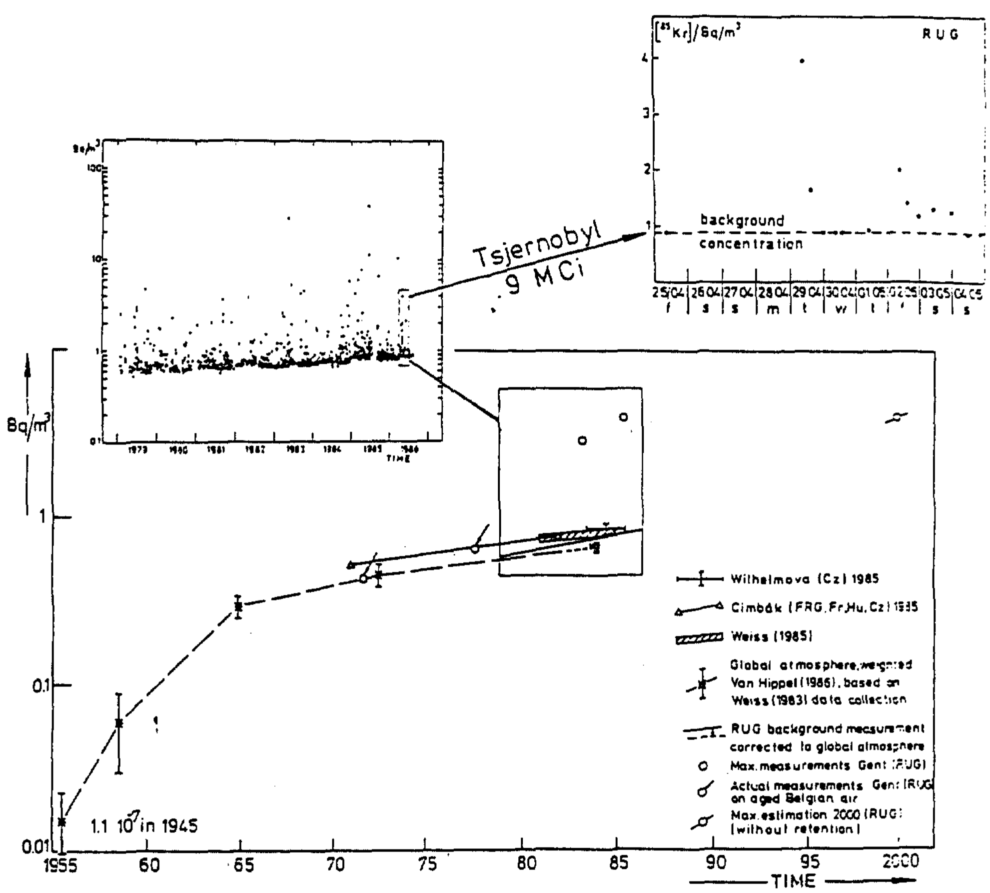


Fig. 2 Atmospheric concentration measurements of Kr-85 according to G.X. Eggermont et al[11].

The measurements at the ground level are characterized by high variability due to abrupt plume releases in reprocessing plants. The horizontal and vertical atmospheric dispersion of these Kr-85 peak points requires time. For instance, at Gent in Belgium 425 km north east of La Hague in France, the observed peak concentrations could be associated with French synoptic data and puff-releases at La Hague where in the past annually of the order of 100 PBq (3 MCi) of Kr-85 were released. On the figure is also indicated how the 33 PBq (.9 MCi) release of Kr-85 on 1986/4/26 in Tsjernobyl could be clearly detected in Gent as a 4 Bq/m^3 extreme value three days later on 1986/4/29. Gent is located 1910 km West of Tsjernobyl.

From Kr-85 records at four stations located in western and central Europe, the travel time of an air mass across Europe is estimated[16] to be on the average of the order of one week. The duration of the Krypton-85 puff releases at a reprocessing plant is estimated to last a few hours.

VI. The atmospheric behaviour of Krypton-85

Krypton-85 as a noble gas does not combine with other atoms to compounds. Krypton-85 disappears from the atmosphere only by radioactive decay. Its wash-out, its deposition on soil, its absorption on aerosols, its solubility in water and oceans are all negligible. Its transport from a local release point to the atmosphere mass of 5 x 10^{18} kg around the globe is governed by the mixing conditions between the tropospheric and the stratospheric compartment[17]. As the major European reprocessing plants are located at 40° to 60° N latitude, the ground level of Kr-85 concentration in the air has been observed[16] to be about 10 % higher on the European continent than in a station located in Miami USA.

In the past when the nuclear weapons tests were predominant, higher Kr-85 concentrations were observed in 1964 in the latitudinal bands where the main test area are located. In general, it is accepted that the estimated total weapon release of 148 PBq (4 MCi) Kr-85 occurred up to the lower stratosphere (30 km high)[11].

Consequently, it is clear that the homogenisation of the man-made krypton-85 in the atmospheric mass of 5 x 10^{18} kg takes several years. In the mean time, local hot spots are possible in the plumes of the reprocessing plants and concentrations higher than the mean value occur in the latitudinal band between 40° an 60° N where the major reprocessing plants are located.

The mean value of krypton-85 after complete mixing in the global atmosphere can be estimated to become 7.9 Bq/m^3 air in the far future on the basis of a long lasting nuclear energy programme releasing the presumed quantity of 2,000,000 TBq Kr-85 per year resulting in a steady state accumulation of 30277 PBq. This estimated concentration yields a skin dose of 3 µSv/y (.30 mrem/y) and a dose effective of 70 nSv/y (7 µrem/y). The radiological risk and the global collective detriment of these Kr-85 doses depend on the radiological weight factors handled[20].

VII. Ecological consequences

At an average concentration of 7.9 Bq Kr-85 per m^3 air, the global absorbed dose in air is 10 μGy/y (1 mrd/y) or 3.2×10^{-4} nGy/s. According to earlier laboratory experiments[21] at levels around .1 nGy/s (about thousand times higher than the extrapolated global dose of Kr-85), this low dose might result in very small synergistic effects for aerosol particle formation and for oxidation of SO_2 in the atmosphere.

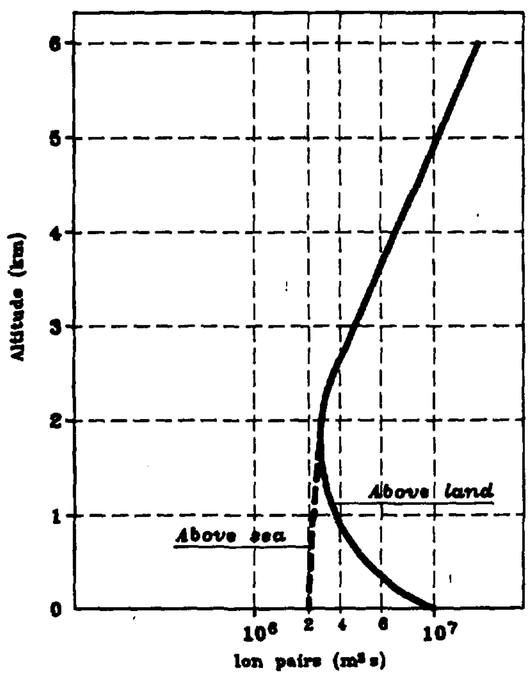
In general terms, it is more obvious to look at the ionization potential of this average concentration of 7.9 Bq Kr-85/m^3 air. The primary yield of exited states of ion pairs in air at ambient temperature and pressure has been estimated[18] to be 2.96 ion pairs formed per 100 eV completely dissipated in the gas. (This is the so-called G-value for product yields by radiolysis). The excited species thus formed are considered to be the most important precursors of radiation products. Using the average decay energy[10] of 250 keV for Krypton-85, the average atmospheric concentration of 7.9 Bq/m^3 air in the future of steady-state accumulation generates 6.10^4 I.P./m^3 s. Similarly, the ion pairs yield has been calculated for the other long lived airborne fission products in the case of a nuclear programme at an effective capacity of 229 GWe lasting 300 years. It has been presumed thereby that only a fraction of the fission products generated in the nuclear power station is released on the long term into the atmosphere during all nuclear fuel cycle operations, namely 5 % of the tritium; 50 % of the C-14, of the Kr-85 and of the I-129; 10^{-5} of the Cs-137 and of the Sr-90. The results are shown in the last column of Table 2. It is again clear that under these assumptions Krypton-85 shows by far the largest potential for ionization.

Table 2 Primary yield of excited states of ion pairs from airborne radionuclides

	decay energy[10] keV	accumulation* PBq	ion pairs I.P./m^3s
H-3	5.68	153	7
C-14	49.45	24	9
Kr-85	250	30277	57.000
I-129	48.88	1	0.5
Cs-137	186.9	13.3	19
Sr-90	195.7	10.9	16

* for a nuclear programme of 229 GWe during 300 years resulting in a steady-state accumulation for H-3, Kr-85, Sr-90 and Cs-137; the presumed release fractions are 0.05 for H-3, 0.50 for C-14, Kr-85 and for I-129, 10^{-5} for Cs-137 and Sr-90.

In comparison to the ionization potential of the nuclear reactor inventory, this Krypton-85 ionization is about 10^{20} smaller than the ionization that one might find in the gaseous radwaste treatment system of a nuclear power station before dilution with ventilation off-gas. This enormous difference illustrates the efficiency of the actual practice of nuclear waste management and particularly of the airborne waste treatment.
The estimated ionization potential of Krypton-85 in the far future at a global atmospheric average of 6.10^4 I.P./m^3s can be compared with the vertical profile of natural ionization[19] in the troposphere, as shown in Figure 3. Above oceans and polar regions cosmic radiation ionizes the air forming 2.10^6 IP/m^3.s at ground level and forming an increasing number of ion pairs at altitudes higher than 2 km. Above land terrestrial and radon radiation predominates at ground level pushing the number of ion pairs to 10.10^6 IP/m^3s. The man-made Kr-85 will thus increase the natural ionization with only 3 % at maximum under the conditions described earlier. This increment can be compared with the 26 % increase of the CO_2 content of the atmosphere due to 200 years of industrialization. This comparison does, however, not tell anything about the effects on the global climate.



Figuur 3: Vertical course of the natural ionization of the atmosphere

Fig. 3 : Vertical course of the natural ionization[19] of the atmosphere

This simple calculus based on average values is open for discussion for several reasons.

Firstly, the natural ionization of the atmosphere varies in terms of time and space. The radon content of air near the ground depends, indeed, on local geological layers and on weather conditions giving field for a variation with a factor ten. Further, the day and night rhythm of cosmic radiations results in large fluctuations of the natural ionization. On the other hand, the man-made Kr-85 is ionizing day and night. The man-made ionization might thus be very important in comparison to the small cosmic radiation during night time in the troposphere. This is certainly an item for research in the near future.

Secondly, ionization as such does not tell much about what really might happen in the atmosphere. The excited species formed by ionization are most often the initiators for photochemical reactions. During day time synergetic effects with ultraviolet based photochemistry are possible resulting in changes in global atmospheric chemistry and climate. Probably, the troposheric content of ozone and of the hydroxyl radical will change resulting in other dynamical balances of various substances important for greenhouse phenomena. Only an intensive research programme can clear up in which direction the climate might change due to this relatively small increase of ionization. It is not only a matter of additional radiation, but also a problem of high energetic ionizing radiation of the Krypton-85. Might the Krypton-85 permanent radiation create other radicals and consecutive products than those generated by the rather soft sun light penetrating during day time into the troposphere (soft ultraviolet radiation with wave-lengths between 290 and 400 nm). What does this Krypton-85 radiation mean in relation to the traditional greenhouse gases ?

Thirdly, before homogenization there are areas with larger Kr-85 content than the average value. This is certainly the case in the downwind area of a reprocessing plant where the Kr-85 concentration in the stack release is orders of magnitude larger than the average global value. In the downwind plume, it is almost certain that photochemical synergetic effects occur. Some authors claim that this might even change the electrical conductivity of the air causing effects on thunderstorm frequency and on water content of the air(19). Similar phenomena can be expected after an accidental release, such as the Tsjernobyl accident. The electrical conductivity of the air in the plume of Tsjernobyl increased with a factor 4, the air humidity was halved(19).

As an illustration of these unknown effects, let us take the ozone formation potential of the 7.9 Bq Krypton-85 per m^3 air as example. This Krypton-85 load presuming a steady-state accumulation in the far future, has theoretical potential to generate day and night 10^5 molecules ozone per m^3 air and per second in a tropospheric atmosphere containing at the moment 10^{12} molecules ozone per m^3. It depends on the dynamical reaction kinetics of the numerous photochemical reactions whether this permanent ozone creation by Kr-85 is counteracted by ozone destructive chain reactions or is amplified by photochemical chain mechanisms. The result might differ from day time to night time. It is known[19] that the man-made release of chemicals such as CFCs, nitrous oxide, methane, carbon dioxide does affect the ozone profile in the troposphere and in the stratosphere. The assumed homogeneous Kr-85 content of the atmospheric air mass means that an additional ozone source might probably be formed. Information is, however, still lacking to predict the effect of this additional ozone source. It is still not clear which path the ion pairs formation of the Krypton-85 radiation follows in the troposphere with its content of water vapour, aerosols and fractions of many man-made chemicals.

VIII. Conclusion

The actual practice for airborne waste treatment is in general quite efficient, also from a global point of view. The analysis presented has indicated that Krypton-85 can be considered as the most important airborne isotope for the global atmosphere : a nuclear programme of 229 GWe might result in a steady-state average load of 7.9 Bq Kr-85 per m^3 air in the global atmosphere in the future.

The ecological consequences of this predicted Kr-85 load can, at the moment, not be assessed on global scale. Specific features of this Kr-85 load are the addition of a small but permanent ionization potential to the atmosphere and also the relatively high energetic character of the Kr-85 radiation. Homogenization on global scale taking time, regional climate variations are possible, although our actual knowledge does not allow to quantify the effects.

This suspicion should incite the nuclear energy community to assess the different operations of the nuclear fuel cycle taking into account the potential long term effects on the environment of radionuclides released in the atmosphere. This assessment should include experimental investigations in smog chambers with appropriate radiation sources. Further on, case studies have to be performed applying the intricate mathematical models under development in order to predict the trend of photochemical reactions in a mixture of many man-made substances evolving in an open system of earth atmosphere.

Acknowledgement :

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DISCUSSION

FIRST: I have two questions, (1) Should we be worried? and (2) Why should we be worrying about krypton when the natural emission of radon is large throughout the world?

GOOSSENS: In answer to your first question, Yes and No. Considering, firstly, the average worldwide environmental hazard, the radon isotope and krypton-85 show on the average a similar magnitude of global environmental hazard after complete mixing in the atmosphere. The estimated future steady state (equilibrium) value of 817 x 10^6 Ci of Kr-85 (30277 PBq) with an average decay energy of 250 keV produces 1.46 times more ion pairs per sec than the cited 25 x 10^6 Ci of radon with an average decay energy of 5590 keV. It has to be noted that this conclusion is valid under the condition of complete mixing of both isotopes over the atmospheric mass. This condition is, however, not valid for radon with its half life of only a few days (3.82 d for Rn-222). This means that the radon hazard is the largest at ground level. For example, an average outdoor air concentration of 55 Bq Radon per m^3 has been quoted for the USA (Nero A.V., et al., Science Tot. Env. 45; 223, 1985). This means an ionization potential of 9 x 10^6 I.P./m^3.s. This near surface potential of radon is about a hundred times larger than the ionization potential of the atmospheric average of 7.9 Bq Kr-85 per m^3. Note, that this comparison is open for discussion as the near surface concentration of Kr-85 might at least locally be an order of magnitude larger. Also the radon content for outdoor air is locally dependent.

Leaving the zero ground level, the radon content of the air is decreasing fast with altitude, as shown in Figure 3 of my paper for the ionization related to radon. For instance, Wilkening M. mentions on page 90 in his book on "Radon in the Environment" (ref. Studies in Environmental Science 40, Elsevier, 1990) that the chief ionizing agents in air near the ground are the radon and thoron decay chains which yield 4.6 x 10^6 IP/m^3.s, a value about half the value calculated above for the USA. This value exceeds the terrestrial radiation value of 4 x 10^6 IP/M^3.s. The sum of both, namely 8,6 10^6 IP/m^3 is the difference between the above land value and the above sea value in Figure 3.

The intersection of the two curves in Figure 3 suggests that at an altitude of 2 km, the ionization contribution of terrestrial or radon-thoron decay chains is reduced to zero. What remains is only the ionization by cosmic rays estimated to be 3.10^6 IP/m^3.s at that altitude. Under the reasonable hypothesis of complete mixing of Kr-85 over the full earth atmosphere, the steady-state value of 7.9 Bq Kr-85 per m^3 initiates a global atmospheric average of 6.10^4 IP/m^3.s, or 2% of the cosmic radiation effect at the 2 km altitude. This 2% increase in relation to cosmic rays is, however, several magnitudes larger than the potential contribution (nearly zero) of radon at this level.

Should we worry? Yes and no!
No, we should not worry so much for the near surface effect of Kr-85 because near the surface the radon issue seems to be more important. Also at altitudes above 2 km, the cosmic rays are predominant on the average.
Yes, we have to worry about the indication that after complete mixing in the atmosphere, the krypton-85 hazard appears on the average to be somewhat larger than the global radon hazard. Under the assumption of complete homogenization, the krypton-85 hazard does show a few percentage increase of the natural ionization around the 2 km attitude, exactly where precursors for climate change phenomena are present and where thus synergetic phenomena might be suspected. The half life of 10.72 years indicates that these interactive phenomena occur over a relative long period in comparison to the radon effects that are induced with a half-life of a few days. Further, the permanent presence of Kr-85 at any altitude differs from the day and night fluctuations of cosmic rays. Where, during daytime, synergetic effects of cosmic rays and Kr-85 radiation on critical photochemical reactions are possible, there are indications that during the night-time, with Kr-85 present at any altitude, the course of the photochemical reactions might take other proportions than before the man-made Kr-85 release. During night-time, krypton-85 is indeed predominant.

In addition, special attention is due to the real practice of Cs-137 and Sr-90 retention. A DF of 10^5 for the off-gas treatment of the high level waste vitrification has been assumed in the paper. Data have to be collected on the real practice over the lifespan of a vitrifying installation.

THE NUCLEAR INDUSTRY'S PLAN TO ACHIEVE NEW NUCLEAR POWER PLANT ORDERS IN THE 1990'S

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Abstract

Since the Arab Oil Embargo of 1973, there has been a direct relationship between the growth in the Gross Domestic Product and the growth in the use of electricity in the United States. That close relationship between economic growth and electricity will continue. If that is true, the United States Department of Energy says we will need between 190,000 to 275,000 megawatts of new generating capacity in the next 20 years.

Electricity is one of the cleanest and most efficient uses of energy. Of all the ways to generate electricity, nuclear power plants are the cleanest, producing no air pollution and no greenhouse gases.

To help supply the needed increase in electricity generating capacity, the U.S. nuclear power industry has developed a Strategic Plan for Building New Nuclear Power Plants. The plan identifies fourteen issues which must be dealt with to create the conditions under which utilities could place orders for new nuclear plants by the mid-1990's. The plan was published in November of 1990 and significant progress has been made on most of the fourteen issues.

The plan and progress made are reviewed in depth.

Good morning.

I'm very pleased to be here today ... and I would like to thank the organizers of this conference for their kind invitation to speak.

I want to cover several areas this morning.

First ... I want to discuss one or two key energy trends in the United States.

Second ... I want to explain why -- in light of these trends -- nuclear power makes more sense than ever.

And third ... I want to give you a status report on the U.S. nuclear industry's plan for ordering and building new nuclear power plants.

Let me start by reminding you about some key trends.

Since 1973, the year of the Arab oil embargo, one energy trend in the United States overshadows all the others.

I'm not talking about this country's dangerous and chronic dependence on imported oil.

I'm not talking about the ebb and flow in the fortunes of the natural gas industry.

I am talking about the steady electrification of the U.S. economy ... the continuing substitution of electric power for direct burning of other fuels.

Since 1973, the U.S. economy -- measured by gross domestic product -- has grown just over 50 percent.

Electricity use has grown by about 60 percent.

For the last 19 years, since the 1973 oil embargo, economic growth and electricity use in the United States have run virtually parallel -- not quite a one-to-one relationship, but close.

By the way, in this same period ... the use of non-electric energy declined about 5 percent.

Now ... simple common sense suggests that the close relationship between economic growth and electricity use will continue.

To meet the electricity needs of a growing economy, the United States will need between 190,000 megawatts and 275,000 megawatts of new generating capacity in the next 20 years, according to the U.S. Department of Energy.

We have about 700,000 megawatts of capacity installed in the U.S. today ... so you can see we're talking about a large increase.

This brings me to my second point.

Nuclear power makes more sense today than ever.

We know that electricity is the cleanest, most efficient use of energy we have.

And of all the ways we can generate electricity, nuclear power plants are the cleanest.

No air pollution.

No greenhouse gases.

The only source of electricity that comes close is hydro power ... and it is almost impossible to find sites for new hydroelectric development.

This brings me to my third point.

What are we doing in the United States to make sure that electric utilities start ordering and building new nuclear power plants?

In November 1990, the U.S. nuclear power industry published a *Strategic Plan for Building New Nuclear Power Plants*.

The Plan was organized and published by the Nuclear Power Oversight Committee.

NPOC is a group of senior executives representing all segments of the nuclear energy industry -- electric utilities, equipment suppliers and engineering firms. NPOC provides an industry-wide forum to consider broad policy issues.

Our goal?

To create the conditions under which utilities can place an order or orders by the mid-1990s, with the first new nuclear unit on line around the turn of the century.

The plan is supported by the entire industry -- private and public electric utilities, equipment suppliers and architect-engineers.

The plan focuses on the light water reactor.

This focus on light water reactors was deliberate.

It reflects the electric utility industry's conviction that the next nuclear plants ordered in the United States must be based on a mature, successful technology that has proven its worth around the world.

And it reflects the utility industry's conviction that the job of resurrecting the nuclear option will be difficult enough ... without the added challenge of proving out a new technology.

But if we succeed in getting orders for new light water reactors ... I'm confident that orders for advanced technologies -- like gas-cooled and sodium-cooled reactors -- will soon follow.

To satisfy the utilities, new nuclear plants must provide very high protection of the utility's investment.

That means predictable construction costs and schedules ... assured licensability ... predictable operating and maintenance costs ... higher reliability ... and very low risk of accidents.

The U.S. utilities took careful note of all the lessons learned during the construction and operation of the 110 commercial nuclear plants now operating in the U.S. ... and the 400-plus units on line around the world.

These lessons involved such things as ways to improve safety ... economics ... construction management and construction practices ... ease of operation and maintenance.

These lessons have been incorporated into the four new designs now being developed.

They are:

> The Advanced Boiling Water Reactor (ABWR), a large, 1,300-megawatt design being developed by General Electric Company. As you well know, the first two of these are being built by Tokyo Electric Power Company.
>
> The System 80+, a large, 1,300-megawatt pressurized water reactor being developed by ABB Combustion Engineering.
>
> The AP-600, a smaller, 600-megawatt design being developed by Westinghouse Electric Corporation.
>
> The SBWR (or Simplified Boiling Water Reactor), a 600-megawatt design being developed by General Electric Company.

The NPOC Strategic Plan identified 14 key issues or "building blocks" ... assigned responsibility for managing them ... and set timetables and milestones against which progress could be measured.

Some of the building blocks are very specific ... like securing regulatory approval for the new designs.

Some are rather broad... like building public acceptance for nuclear energy ... or enhancing government support for new nuclear plant construction ... or developing arrangements for financing, building and operating new plants.

Some are within the industry's direct control ... like continuing to improve the performance of our operating plants.

Some require action by ... and the industry's cooperation with ... regulatory agencies and the federal government.

Securing approval and acceptance for new nuclear plant sites is one of these.

Now ... we recognize that implementing this plan will not be easy.

It is a long-term, 10-year assignment.

Even in the short time ... less than two years ... since the plan was published, we've made much progress.

Let me list just a few items.

First ... the basic engineering ...

In late February, the Department of Energy and a consortium of electric utilities called the Advanced Reactor Corporation (ARC) signed a contract to launch a five-year, $200-million program to do detailed engineering on at least two advanced-design nuclear power plants.

The federal government will kick in $100 million ... to be matched by $50 million from electric utilities and $50 million from nuclear plant vendors.

So far, 16 utilities have agreed to participate, although others may join.

This so-called first-of-a-kind engineering will produce designs that are sufficiently detailed to allow utilities to place orders ... confident that they know what the plant will cost.

The FOAKE program will carry at least two -- and possibly more than two -- of the four new ALWR designs beyond the level of detail required for NRC certification ... and achieve standardization of these designs beyond the scope of regulation and certification.

Second ... performance ...

Our plan recognizes that we must continue to improve the performance of America's 110 operating nuclear plants.

The U.S. industry met this challenge in 1991.

Last year, U.S. nuclear plants posted record output for the second year in a row.

In 1991, output rose 6.1 percent to 643.5 billion kilowatt-hours, according to preliminary data.

The average capacity factor reached 69.3 percent, up from 67.5 percent in 1990.

Third ... regulation ...

Certification or pre-approval of plant designs by the Nuclear Regulatory Commission is crucial.

As you know ... design changes during construction tripped up many a construction schedule in the 1980s.

Late last year, the industry and the NRC agreed on a satisfactory schedule for certification of the four new plant designs.

Fourth ... siting ...

The NRC's new licensing rules allow pre-approval of nuclear plant sites.

In 1991, subsidiaries of the Southern Company, Public Service Electric & Gas Company and Commonwealth Edison Company joined forces to demonstrate this provision.

This is a three-phase, $20-million program, cost-shared with the Department of Energy.

Phase one will review all applicable federal regulations, and develop criteria to assess potential sites.

In phase two, a site will be selected.

Phase three involves site characterization ... preparation of an environmental impact report ... and submittal of an early site permit to the NRC.

The NRC would issue the early site permit by the end of 1995.

Fifth ... licensing reform ...

The NRC took a big step in April 1989 when it issued new licensing rules.

Those rules allow approval of nuclear plant sites and designs before construction begins and billions of dollars are at risk.

The new approach also provides a single license for construction and operation.

Just to be sure a new group of commissioners doesn't change the rules, however, the industry wants legislation to make them stick.

In February, the Senate passed licensing reform legislation as part of the comprehensive energy bill, S. 2166.

The bill provides for public hearings when a plant design is certified ... when a site permit is issued ... and when a construction/operating license is sought.

It also limits the opportunities for mischief and delay by anti-nuclear groups once a plant is built and approved as safe by the NRC.

Identical language passed the House in late May as part of its omnibus energy bill.

All of us hope this vital legislation will be passed this year ... although it still faces a number of hurdles.

Sixth ... standardization ...

Last year, utilities and vendors made a binding commitment to standardize new nuclear power plants.

This commitment to standardization covers future plant designs, operations, maintenance and training.

Seventh ... nuclear waste ...

Last July, the Department of Energy resumed exploratory drilling at Yucca Mountain in Nevada for the first time since 1986.

Last year, the federal courts also cleared a backlog of lawsuits brought by Nevada officials against the repository program.

Nevada has instigated nine lawsuits since 1985, and ultimately lost them all.

In addition, a recent assessment by the National Academy of Sciences found no scientific or technical reason to disqualify the Yucca Mountain site ... based on the scientific work to date.

And on a parallel track, Mr. David Leroy, the U.S. Nuclear Waste Negotiator, has received over 20 requests for grants from various entities ... Native Americans and others ... which may be interested in hosting a facility for temporary storage of spent fuel until the permanent repository is ready.

Eighth ... public acceptance ...

Americans show more support for a nuclear future.

An August 1991 Gallup poll showed that 73 percent of U.S. adults believe nuclear energy "should play an important role in meeting the future energy needs of the United States."

That's up eight percentage points from February 1990.

Ninth ... industry support ...

The strategic plan's goal -- a new nuclear plant order by the mid-1990s or soon after -- fits well with the utility industry's needs.

In a recent poll, about 80 percent of nuclear utility CEOs said they'll need more baseload generating capacity in the first decade of the next century.

Of that 80 percent, about three-quarters of them would seriously consider an advanced-design nuclear power plant -- if the industry's strategic plan is executed as envisioned.

This is just a partial list of the progress we have achieved in the last 12 to 15 months.

I believe the nuclear industry's strategic plan was the catalyst for much of that progress.

Let me digress for just a moment to explain why the U.S. electric utility industry is spending hundreds of millions of dollars ... and many thousands of man-hours ... to ensure nuclear energy is available as an option for the future.

Every executive in the electric utility business accepted an obligation to serve his customers.

Yet today, all of us face a future filled with uncertainties and unanswered questions, which make it increasingly difficult to plan for and build the generating capacity we will need to discharge that obligation to serve.

As we promote energy efficiency, we face many uncertainties about programs to conserve and manage growth in electricity demand. There is much we do not know about the cost and effectiveness of demand-side management programs over time.

We face uncertainties about the 1990 amendments to the Clean Air Act, and their impact on existing coal-fired capacity and the economics of new coal-fired generation.

We face uncertainties about the future price and supply of natural gas.

There will be an increase in the amount of natural gas used for power generation in the 1990s ... but few long-term price and supply assurances are available ...and all of us remember the interruptions in supply and sharp, upward movements in natural gas prices which we experienced in the 1970s.

So, everywhere we look, we see many uncertainties.

Every fossil fuel we use -- oil, natural gas, coal -- carries a risk.

In this uncertain environment, it would be absolute neglect for our country not to plan for a future that can include new nuclear power plants.

Deciding on the type of generating capacity that must be installed in the 1990s and the early years of the 21st century is a complex undertaking.

Those decisions will require the balancing of many risks, many uncertainties and many competing interests.

No single fuel can satisfy all circumstances.

Fuel diversity is one of the great strengths of the U.S. electric supply system, and nuclear energy has a key role to play.

There is no single answer to our energy problems.

We must throw everything we have into the breach ...

... improved energy efficiency ...

... cleaner fossil fuel technologies ...

... increased electrification, especially in industry and transportation ...

... the use of photovoltaics and other renewables wherever they are appropriate ...

... and, of course, nuclear energy.

In the United States, the nuclear industry is building its future on a very solid base.

Nuclear energy enjoys strong public and political support.

Our existing plants operate well, and are operating better all the time.

And now ... we have the one thing we were missing ...

... a strategic plan for the future ...

... and the will to make it come true.

DISCUSSION

FIRST: The large public support for nuclear energy that you reported is staggering in view of the very, very bad press that nuclear energy has gotten and continues to get. Can you explain this discrepancy?

BAYNE: I certainly can, and I am glad you asked that question. I gave you the quote from the Gallop poll in August 1991, but we have a poll by Bruskin that was done in February of this year that shows the same results. 73% of the American public feels that nuclear power should be important in our future. In March of 1992, we did a poll of opinion leaders. We asked 500 federal legislators, state legislators, academics, people from Wall Street, and so on, what they thought, and 72% of them said they felt nuclear should be important in our future. We asked an additional question to those opinion leaders. We said, Do you think the majority of American public thinks that nuclear power should be important in the future? Sixty percent of the opinion leaders felt that the American public would not say that. I reflected on that for a longtime, and I finally came to the conclusion that I think you alluded to: the negative press has convinced our opinion leaders that the American public is against the future use of nuclear power when our opinion leaders, eminently qualified in their fields, feel in their own mind that we should use nuclear power.

If you ask the American public, "Do you think you ought to build a nuclear power plant in your neighborhood in the next ten years?", 22% would say, Yes, and 24%, No, with the rest of them undecided. If you follow on and ask the question, "Do you think you will need a power plant in your neighborhood in the next 10 years?", you will always get the answer "no". People don't think they need it and since they don't think they need it, they don't want to build it.

MILATOVIC: In the past it took about 10-12 years to build a nuclear power plant in the United States. What is the time expectancy for future plants?

BAYNE: Time expectancy is 5-6 years. The plant being built in Japan, one of the plants that will be available in this country, will go online in 1996 and it started construction November last year. So you see, they plan to build them in 5 years. For the first group of plants we built, the engineering was not completed when we began construction. You know, yourself, you don't start building a house and then decide where you are going to put the kitchen. But if you do, it is going to take you a long time and cost you a lot of money. That is what happened to us. We became so eager to get ahead with it that, we didn't finish the engineering. In the new plants, the engineering will be done first. That is the reason we are doing the first-of-a-kind engineering, and that is the reason we are seeking certification. Therefore, when a utility ex- ecutive says, "I want to invest in a nuclear power plant," he will know how long it is going to take to build, and how much it is going to cost.

BELLAMY: What do you think about public involvement? Anytime the NRC tries to do anything today, we get requests for public hearings. Even when we put a note in the Federal Register to make a very minor change in operations, or even an improvement to the way a contaminated site is going to be cleaned up (which is obviously a benefit to the public), we get requests from the public for a public hearing. I wonder if this is not going to stretch out your estimate of 1995 for a site approval.

BAYNE: We are working with Advanced Reactor Corporation as they get ready to do their early site selection process. We reminded them that you just cannot announce that you are going to build on a site, you have to get public participation. We are developing a plan to get that public participation. I would like to say, though, that you just cannot allow unlimited participation. We need public participation, but we also need to be looking very closely at those that would subvert the process just to get the plant shut down or not built. There are people who would do that. Most of the people who request public participation are people with legitimate concerns and it is to our advantage to address those concerns. We cannot build a power line or a coal plant, or a hydro plant without public participation.

KUMAR: I have a two-part question. One is, whether multi-polarization by various communities has been factored into your time estimate. Second, what about public utility commissions turning down rate hikes down the road which put the utilities in a very tricky position as far as financial matters are concerned.

BAYNE: The threat of multi-polarization by various communities has not been factored into in our plans because it really isn't one of the things we have been looking at. What we did was to identify all the problems that we had to face as an industry. Then, the unique thing we did was to assign someone in the industry with the responsibility to handle each problem. Multi-polarization was not one of the problems we identified. The problem of not allowing all of the plants to get into the rate base was identified and is being worked on very actively with the national association of regulators. You can't force those fellows to do anything. They are elected or ap- pointed officials. What we have to get across to them is that if they continue to act in an irresponsible fashion to save today's rate payers a few dollars, the utilities are going to be very reluctant to build anything and that will eventually harm our country. We spend an awful lot of time talking to those people. I happen to think that when we get that first plant built, everyone will be looking at it, and then we will really go. So, when we decide where to build that first one, we may take into account the regulatory environment. As you know and I know, we cannot twist the arms of the regulators and force them to accept all the money in the rate base. What we can do is what we call rolling prudency, which is similar to what we are doing with the NRC as far as certification processing. When we have a certified design there are certain set of tests and analyses that can be performed to prove that we have built that plant in accordance with the certified design. And, if we build it in accordance with the certified design, and the NRC inspectors are there checking and making sure that we do that, then, at the end of the process, we won't have a surprise. In the case of rolling prudency, we would like to get the regulatory entities involved first. Then when we decide we need a plant, we will have them involved in the decision that it is needed. And then, as it is built, we will have them involved to show that we are building in a prudent manner. You do this so that at the end they do not tell you, "That's fine, but we are not going to let you get anything out of that plant."

MILLER: There are a couple of units under construction in Korea. KEPCO is building WGN 3 & 4 on a 5-6 year time schedule. I think that is important to know. But the real issue is, an ability to generate power at a competitive cost. Right now, the utilities are forced to go in with plants that are very competitive with IPPs that cost in the area of $1,000/kw. The advanced reactors are about $1,500/kw, right in that range.

BAYNE: We just did a report on that. The results showed that the advanced plants will be competitive for the per kilowatt cost of electricity with gas plants and coal gas-fired plants.

MILLER: That is where we need to do more work because, based on what I have been looking at, that is a stretch right now. There is probably about a $500 per kilowatt capital investment difference between the lowest cost coal-fired and combined cycle plants and the figures that the nuclear industry is using. I think that the fuel mix issue is one that is very important, but it is not perceived by the public to the same degree of importance as it may be perceived by the providers of electricity and energy. I think that is where the polls have to change.

BAYNE: I agree with everything you said. I would just like to bring up a little past history that has nothing to do with nuclear. As said, I was with the New York Power Authority. We built a hydro plant at Niagara Falls and it went on line in 1960. It was built in 4 years. When that plant went on the line, the cost of electricity from it was not competitive. It cost more than the other sources of generation in New York. However, there were some enlightened people in New York that got long term contracts on that power and it is currently the cheapest power in the United States. Now that is a 30 year period. So, utility executives, when they are making a decision, have got to take these things into account. You can build an awful lot of gas plants right now, cheaply, but what will it be 5 years from now? That is a difficult call. I hope that utility executives maintain the diversification of fuel, because I happen to think that, if we are going to have to increase capacity in this country by a third in the next decade or so, we are going to need every source of electricity that we can come up with.

MILLER: Unfortunately, the Public Service Commissions are going to play a large roll in what the utilities will be able to do in the next decade. It appears that they will have to be competitive with the IPPs or else the rate commissions are going to be in jeopardy or they will feel they are in jeopardy. That is where we are going to have to do more work, because in many states they are appointed officials, as opposed to elected officials.

BAYNE It is even more dangerous when they are elected, because if they can cut the electric bill by a few cents, they can get re-elected. Maybe that is all they are after. I am happy to see that you have identified the tight-rope that all utility executives will be walking in the next 5 or so years.

McGALLIAN: Has the problem with the education of the public on nuclear power been brought up in the strategic plan? Do you think it would be beneficial to further education of the general public so that they would have a more favorable consensus about nuclear power in the future?

BAYNE: As a matter of fact, we have looked at that and have done an education survey. We are a membership corporation with limited resources and can't take on everything. But, we felt, as you do, that education of the public is very important. We found that every utility that has a nuclear plant spends a great deal of money in an effort to educate the public. I am happy to say that I feel that the DOE spends a great deal of time and effort educating the public. What we have done is to pull together all those educational processes and put them into a source book for those who are interested. They can see what is being done in their area and whether a little bit more here and there can be done. Unfortunately, my organization, although we would like to do it, cannot take on that task. What we would like to take on is the task of developing videos and magazines and pamphlets and articles that tell the truth about nuclear power. I think it is very, very vital that factual pieces of information get out. We make them available to anyone who writes in and when we do advertizing, we always put our name at the bottom and ask people to call us. When they do, we send them this kind of material. We get 5,000-10,000 requests for material a year. We are doing as much as we can, and we have a source book of what is available in United States for those who are interested.

McGALLIAN: I have found that during the early start of power plant construction, there are public demonstrations, but when more knowledgeable people arrive at the power plants for startup, the public seems more favorable. I have seen utilities go out and conduct public education programs and I have seen a vast improvement. So that, at the completion of the startup of the facility, you have a larger number of people in favor of the power plant. That was just a comment.

BAYNE: I would like to answer that comment a little bit. One of the best utilities in the country for doing that is Duke, and they have a very good program. I would like to give you a little anecdote to show that maybe it is not as bad as people think. I managed Indian Point III, and when I first got there, back in 1976, there was a great deal of furor over Indian Point III. The antis called for a debate and I debated Pollard in Putnam County. As I walked into that facility, I looked in the parking lot, there were about 150 people there and almost every car was from Connecticut, Massachusetts, New Jersey, Pennsylvania, all over. I got to thinking about it. It was a highly anti crowd and it showed up in the paper the next day as being an anti crowd. As a matter of fact, it showed up in the paper like the local populace was against it. But then, when you go around and talk to the population around the plant, they are all for it because of the tax breaks and so forth. I thought to myself, in the vicinity of Indian Point there were 22 million people at that time, and these people had to go to Pennsylvania, Maryland, New Jersey, Connecticut, Massachusetts to drum up 150 people to come out and be vocal. Then, the TV and press came out saying the local population is against nuclear power.

HAYES, John: There is a need for advanced reactors and advanced reactors are going to come forth, yet, at the same time, you see situations in Oregon, where the utility will not spend $100 million for new steam generators and the Trojan Plant is going to shut down 20 years before its license expires. Would you care to comment on the sort of divisive information that is being given to both the industry and the public?

BAYNE: Each time that comes up, it is an individual economic decision. The board of directors of any publicly owned company has to make those kinds of decisions all the time. You get it in the headlines when it is a nuclear plant, but there are other kinds of plants that are shut down. When I was at Indian Point, we were faced with the same decision to replace the steam generators. We did an economic analysis that showed that we would get a payback in 5 years if we replaced the steam generators because we were spending so much time inspecting the old ones in accordance with NRC regulations, which were appropriate. We were spending so many days inspecting the plants, extending our outages, and not generating capacity, whereas if we replaced the steam generators we would regain the capacity that we were losing in the inspection process and pay back the $120 million it cost us to replace them. And we did it. Now, they have decided otherwise at Trojan. I don't know what factors entered into their decision, but you know, they are in a place that has a lot of hydro power, where there is a lot of cheap electricity, and where there is excess capacity. They may have made that decision because of all the excess capacity. When they replace it, they will probably be able to sell electricity to their customers cheaper. That is an economic decision that has to be made at each and every one of these plants. But, I have got to tell you, if you are sitting in Ohio and you are faced with the fact of putting scrubbers in all your coal plants, and it comes up you have got to replace the steam generator in one of your nuclear plants, I think you will keep that nuclear plant online, because it is going to be cheaper than the coal plants before it is done. But that is just my opinion. You would have to do a lot of economic analysis to come up with a decision and each is a separate and distinct economic decision. It is not a nuclear decision, it is an economic decision.

OLSON: Over the past few years, with the lack of construction of nuclear power plants, many suppliers are leaving the nuclear business by either dropping their N-stamps or dropping their Q/A programs and exiting the industry. Have your estimates of the costs and schedules for constructing new plants taken into consideration the availability of the components that will be needed for the construction of these units?

BAYNE: We haven't looked at it from that aspect. As was pointed out, ABB-Combustion Engineering is building plants in Korea and hopes to build more in Taiwan that are very, very close to their System 80 plant. So they have a great deal of technical expertise in that area. General Electric Company is building their ABWR in Japan, so they also will have a cadre of people. As a matter of fact, in the discussions we had when we were developing the strategic plan, plus the discussions we had when we were going out to the utilities to see whether they would support the first-of-a-kind engineering and the early site selection process, one of the things that we discussed was, that if we don't give the impression that this is a viable industry, we are going to have trouble maintaining and operating the plants that we have for just the reason that you have said. We are going to have difficulty filling the pipeline in the various colleges and universities that still have nuclear engineering programs. We are going to have difficulty recruiting operators, and such. So, every chance we get with a utility that has a nuclear plant and is saying, I don't know whether I really support building a new plant for my company, we tell them, whether you support building one for your company or not, we need to have this as a viable industry just so that you can have people to run your existing plant. Most of them think about it deeply enough that they agree and support the program.

JENKINS: Regarding your comments on limiting participation for public involvement with the licensing of plants and sites, how would you go about limiting, or qualifying, those individuals that would like to participate from the public sector?

BAYNE: I don't think you limit individuals. I think you set up a timeframe, or something of that nature, that says, here is when we will take comments, you don't limit the individuals. Here is my own personal opinion. I don't think you can say, OK, we are going to have a hearing process and once it is over if you want to come back and reopen it, it is OK; and if you want to reopen it still later it is alright. I think you have to set guidelines and rules and then stick to them .

JENKINS: Perhaps I misunderstood, then, because I thought you were referring to somehow limiting or qualifying those that you allowed to participate in the process. I didn't see how that could be done.

BAYNE: No, I agree with you. I don't think it can be done.

Severe Accident Issues for Advanced Reactors

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Abstract

The NRC is reevaluating its regulatory approach for the licensing and design certification of advanced reactors. At the same time, reactor designs are being proposed that are substantially different from the systems that have been licensed in the past. While the details of both the designs and the changes in the regulatory program are now being developed, a number of issues have been identified. These issues are reviewed in this paper.

I. Introduction

The protection of the public from the effects of a severe accident in a nuclear power plant has been the major responsibility of the Nuclear Regulatory Commission (and the Atomic Energy Commission) since President Eisenhower's Atoms for Peace program was initiated. Substantial efforts continue to improve safety, and all indications are that current safety margins are significantly greater than they were even a decade ago [1]. However, even though the demand for electricity continues to grow, no construction permit for a nuclear plant has been issued since the TMI accident in a 1979 and no order for a nuclear plant that was not subsequently canceled has been placed since Callaway in July 1973. Over the past several years, reactor vendors have developed updated and advanced designs for power reactors. These designs are at various stages of development, ranging from the GE-ABWR, which has been under formal NRC review for about two years, to the newly submitted Westinghouse AP-600 design. Review of the ABB/CE-80+ also is underway and submission of the GE-SBWR is expected shortly. In addition to the evolutionary improvements in light water reactors and CANDU-3, three advanced reactors are under consideration:

- Modular High Temperature Gas Cooled Reactor (MHTGCR)
- Power Reactor Innovative Small Module (PRISM)
- Process Inherent Ultimate Safety (PIUS)

Submission of these new plant designs for review has necessitated major changes in the regulatory program. Designers need to understand the regulatory requirements before they can complete their work. Reviewers, on the other hand, need a relatively complete understanding of the design before they can complete a serious review, or even develop valid review criteria. This is not a new situation. Shippingport was ordered before Congress passed the Atomic Energy Act of 1954 which permitted private ownership of such facilities; construction permits were issued for Dresden 1, Fermi 1 and Indian Point 1 immediately following the publication of 10 CFR Part 50, [2] which created the regulatory bases for such permits; a dozen construction permits were issued before 10 CFR Part 100 [3] established site requirements; the methods for calculating design basis accident doses were delineated in TID-14844, [4] but designs had progressed so far that the methodology was never used for licensing calculations; regulatory requirements were finally defined by the issuance of the Standard Review Plan [5] but all plants ordered since then have been canceled as have been most of the plants for which SRP-based construction permits were issued.

Today there is a regulatory program in place. It is being changed in some important ways but designers have a good basis for judging what the regulators will require. Regulators, similarly, have a wealth of design and operating experience that provides a reasonable basis for determining what to require, what questions to ask, etc. There are important issues and their resolution will not be simple but there is every reason to believe the issues will be resolved. Some principal issues at this time are:

α Restructuring of the regulatory requirements
β Accident evaluation
γ Containment performance
δ Emergency preparedness
ε Reactivity control
ζ Operator staffing
η Control room design
θ Safety classification
ι Residual heat removal
κ Positive void reactivity
λ Uses of probabilistic safety analyses

II. Revision of 10 CFR 100, Reactor Site Criteria

Since 1962, Part 100 has provided the basic radiation dose criteria for the evaluation of nuclear plant safety [3]. A plant was licensable if the worst design basis accidents produced doses of no more than 25 rems to the whole body or 300 rems to the thyroid in (a) 2 hours at the exclusion area boundary, or (b) 30 days at the low population zone boundary. Less serious design basis accidents were limited to doses "well below" (½ of) these values and the consequences of even lesser accidents were not allowed to exceed a "small fraction" (10% of) the Part 100 dose criteria. The dose calculations were performed with prescribed non-mechanistic assumptions, including the instantaneous release of 100% of the noble gases and 25% of the halogens to the containment, containment leakage at design rates, 10% probability meteorological conditions, etc. This approach provided great design flexibility and a high level of safety.

However, the non-mechanistic approach can result in designs that meet regulatory requirements rather than improved designs that take advantage of improving state-of-the-art and operating experience. Also, the "site criteria" of Part 100 actually do not control site selection or approval. In reality, almost any site would meet the criteria if the plant design parameters were selected properly. Consequently, other *de facto* site requirements were developed (i.e. no urban siting) [6]. Of course there were many design requirements that were not related to the dose criteria; in fact, most of the accidents addressed in the standard review plan are required to release no radioactivity and so require no radiological analysis. The radiological criteria do influence many design parameters (e.g. containment leak rate) and operational limits (e.g. radioactivity levels in the reactor coolant).

Presently a proposed change to Part 100 that will "decouple" the plant design from the siting requirements, at least to the extent of breaking the tie to the dose calculations, is underway. (The design still will be affected by site characteristics such as hydrology and soil conditions.) The first step in this process is the revision of the regulations to move the dose criteria from Part 100 to Part 50. At the same time, Part 100 is being revised to add demographic site criteria and to eliminate the prescriptive seismic criteria. Seismicity, of course, continues to be an important consideration, but the proposed revision calls for the use of both probabilistic and deterministic evaluations to provide a basis for judgement by the NRC staff as to the acceptability of the specific reactor design for a site. The proposed demographic criteria also would be subject to judgement but if the criteria were not met, an applicant would be required to provide justification. The proposed criteria are:

Current population density to 30 miles ≤ 500 people/mile^2
Projected population density in 40 years ≤ 1000 people/mile^2
Exclusion radius ≥ 0.4 miles (See Figure 1)
Low population zone distance: 10 mile emergency planning zone
Population center distance: eliminated

III. New Source Term

From the beginning of the nuclear power program, the "source term" was used for evaluating the consequences of possible accidents. The quantities of the various nuclides in the core were well known. The extent to which they would escape from the fuel matrix in an accident was dependent upon many factors, many of which were not understood. Fission product release measurements had been made since 1942, [7] but for the most part they were made with laboratory-scale specimens under conditions very different from the conditions that might exist in a severe accident. The measurements did show that fission product release could be affected by various things including heat rate, maximum temperature, cooldown rate, the presence of steam or air, etc. The only practicable regulatory approach available was to assume a conservatively representative release and use it for all serious core damage accidents. This standard source term was documented in TID-14844 [4] and is still in use.

There seemed little doubt that if the core were severely damaged, essentially all the noble gases would escape into the coolant volume. Also, the laboratory measurements showed that under certain conditions, most of the halogens could escape from the coolant. The Windscale accident demonstrated that such a release from a damaged core was possible [8]. The internal dosimetry work of the International Commission on Radiological Protection indicated that the largest internal dose from a release of mixed fission products would come from the radioiodines [9]. Furthermore, other nuclides that might be released would be in particulate form and therefore readily removable by the filter systems available around 1960. Consequently, the "source term" was assumed to consist of 100% of the noble gases, 25% of the radioiodines and 1% of the other fission products present in the core.

Although the "TID" source term was used extensively, it was criticized for being non-mechanistic and overly conservative. After the TMI accident, where the release to containment may have been close to the TID source term, but where the release to the environment was much smaller than the regulatory model suggested, a new evaluation of the TID source term was strongly recommended [10]. The NRC undertook an extensive study that has resulted in the publication for comment of a report defining new source terms. The new source terms are somewhat different for BWRs and for PWRs but in either case the release is larger that the TID source term. [11] The new source terms consist of gradual releases that will complicate the dose calculations, especially if a time limitation continues to be placed on the exclusion area boundary dose. In addition, the chemical form of the airborne radioiodine is assumed to be 95% CsI. It is recognized that no measurement has ever shown the airborne radioiodine to be essentially all particulate but then, no one has analyzed the release directly from a severe accident [12].

Methods have yet to be developed for using the new source terms in licensing calculations. During the next year the NRC staff will be developing methods for using source terms that are released slowly; that contain large amounts of particulates including Cs, Te, Sr and Ba; and that include large quantities of non-radioactive particulates. It will be a challenging task.

With the advanced reactors the picture is complicated by the decision to use mechanistic source terms. It is recognized that actual source terms would be different for each reactor and for each accident. With the uncertainties in such calculations being so great, the Commission decided that the simple surrogate source term approach was sufficient for ensuring safety. More studies probably will be required to address this issue for some of the advanced designs.

IV. Uses of Probabilistic Risk Analyses

People have been championing the use of probabilistic risk analyses (PRA) in assessing reactor safety at least since 1957 when Bassett performed a PSA of the Ford research reactor [13] and Gomberg applied the approach to the siting of Fermi-1. That same year, probability of severe accident estimates were provided in WASH-740 but those estimates were based on a Delphic approach [14]. PRA was applied to space nuclear systems in the 1960s [15]. The "Reactor Safety Study" [16] in 1975 offered full PRAs of two nuclear power plants. More recently, PRAs for several other plants were provided [17]. Now, in the individual plant evaluation (IPE) program various levels of PRA are being prepared for most operating reactors [18, 19].

Considerable experience in PRA for nuclear power plants presently exists. Nuclear power plant safety clearly has benefitted from these studies. The use of PRA in the certification and licensing processes is presently evolving. A PRA is required by 10 CFR 52.47 to be part of all applications for standard design certifications. The regulations do not state what should be done with this PRA, but a reading of the Commission's Severe Accident Policy statement [20] provides guidance. The Commission did not intend that the PRA be used merely to validate a completed design but to use the PRA as a design tool to improve the design, enhance safety and to provide insights into plant-specific vulnerabilities. The staff is currently gaining experience in the use of PRA as part of the "lead plant" design certification of the Advanced Boiling Water Reactor (ABWR).

The ABWR PRA is being used to understand design vulnerabilities to severe accidents and plant features important to reducing risk. The goal is to focus more traditional design reviews on understanding and eliminating significant vulnerabilities and to ensure that features important to reducing risk are maintained. PRA insights are being used to help identify ITAAC, establish important equipment to be included in a reliability assurance program, aid in definition of technical specifications, and to support closure of severe accident issues. We are formalizing experience with ABWR so that it can be applied to review of subsequent designs. In particular, review to the Westinghouse AP-600 should benefit from the ABWR experience.

V. Emergency Preparedness

Emergency preparedness traditionally has been independent of the accident calculations, being deemed an essential element in the "defense in depth" approach [21]. Probabilistic calculations are not sufficient to justify reduction or removal of the final level of protection. At this time it seems that some relaxation in the requirements may be in order for extremely safe advanced reactors: however, some degree of off-site emergency preparedness will be maintained.

VI. Revision of 10 CFR Part 50

As a part of the effort to decouple site and design acceptance from dose calculations, a first step is to move the dose criteria from Part 100, [3] which addresses site requirements, to Part 50, [2] which addresses reactor design and operational requirements. This change will have little impact because the dose criteria are now being used primarily as a bases for reactor design parameter values.

The next step in the decoupling process is the replacement of the dose criteria with specific engineering design requirements. This is a major change from past practice because the dose calculations have played a major role in past licensing and enforcement decisions. It is not unprecedented, however, because most of the requirements imposed by the present system are not directly related to dose calculations. Even in the accident analysis part (Chapter 15) of the Standard Review Plan, most of the accidents addressed do not involve a radiological analysis [5].

It would not be particularly difficult to replace the dose calculational dependence with hardware requirements for present reactors. Experience has demonstrated what requirements would ensure the same high level of safety as do present dose based requirements. It would be difficult to express those hardware requirements in a manner that would provide anything like the degree of flexibility that is provided by the present system. The problem under consideration, however, is formidable. There is no operational experience, or even detailed designs, to use as a basis for selecting requirements for advanced reactors. Work is progressing in this area.

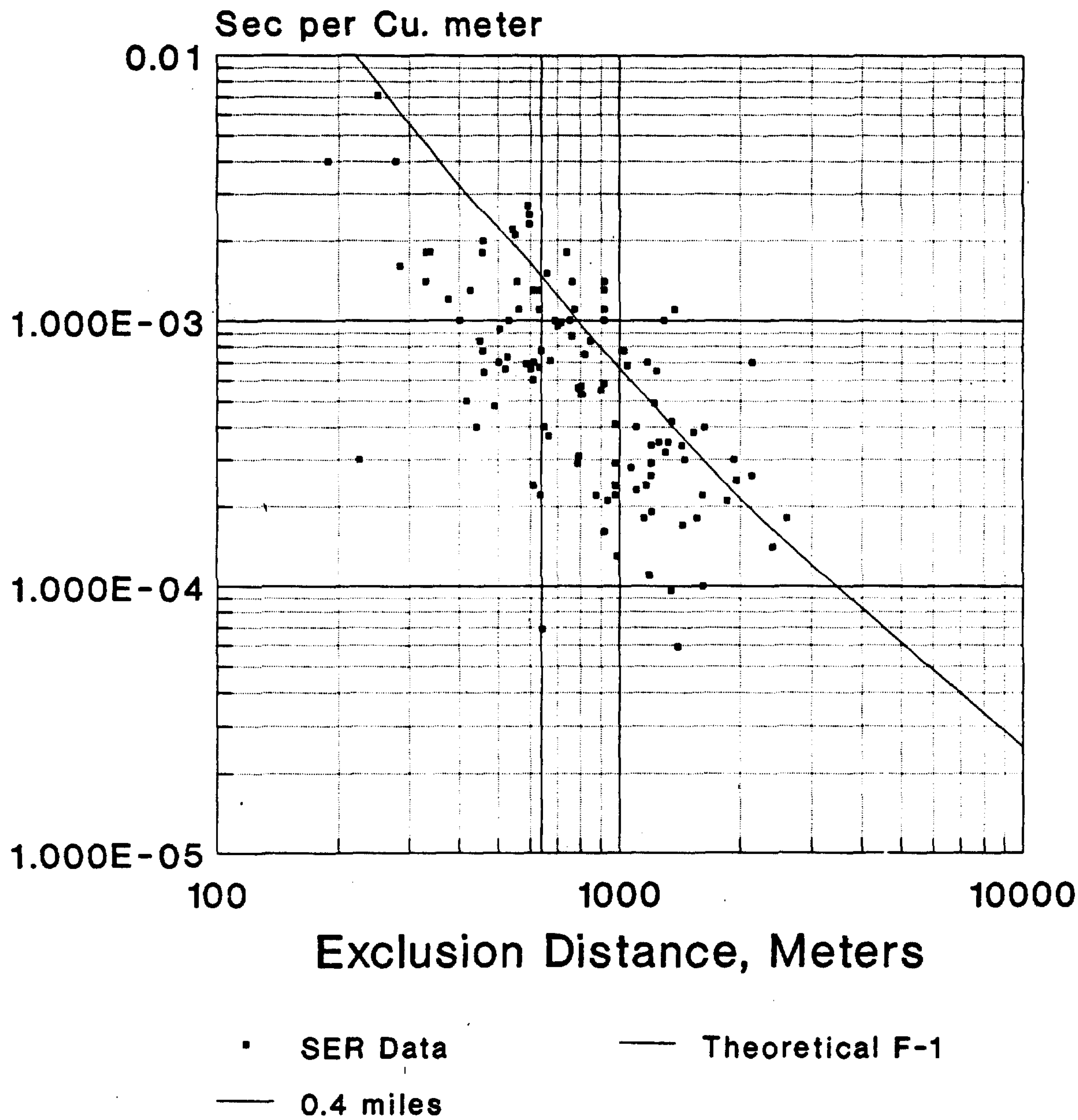
VII. Other Issues

Several other important safety issues are being addressed. These include the safety criteria, including whether they should be more stringent than present criteria and whether they should include probability values. Another critical issue is containment integrity, specifically, should containment integrity be required for a day or so following a severe core damage accident? There are reactivity issues, including the acceptability of a core without control rods and the acceptability of a positive void coefficient. The classification of structures, systems and components important to safety raises several issues. In particular, do the operators and the control room need to be considered important to safety for passive systems? Work is in progress on these issues and it is expected that PRA will be important to their resolution.

VIII. Conclusion

Regulatory requirements are being revised as new reactor designs are being developed. This poses difficulties for both designers and regulators but joint progress is essential to the safe and timely development and operation of advanced reactors.

Meteorological Dispersion Factor
NPP Accidents, Sec per meter cubed



Includes canceled plants

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DISCUSSION

McGALLIAN: Has the Code of Federal Regulations been evaluated for DOE facilities used for weapons productions?

CONGEL: Not to my knowledge, but I have nothing to do with this aspect. Maybe somebody in DOE is looking at it, but my group has no involvement with applying the regulations to DOE facilities.

KELBER: As an old timer, I want to amplify your tribute to the people who did the dose calculations in the past. Remember, they were hampered by a lot less technology than we have now. Remember, that on your desks, in your PCs, you have many orders of magnitude more computing power than they had and, therefore, they were confined to their own personal integrity in exercising their judgment. They couldn't get a PC to lie for them. There is another point to be made, hampered by the lack of technical capability, they couldn't solve every problem and therefore, they sought to look for problems they could solve. These are the bounding problems. I think they were merely used by the regulatory community and the safety community. Trouble came when people, some of whom were involved in defining these bounding problems, suddenly decided that they were realistic estimates of events. No one, I think, ever anticipated that the TID dose term would be representative of what would actually happened in an accident that would test the containment. These problems were solved with a view to protecting public health and safety, not to provide a "realistic scenario." The criticisms that were made by people who suddenly turned around and said, "Help! This accident didn't look at all like the TID source term and therefore the regulatory community is full of soup," were absolutely way off the mark. I think the criticism was undeserved. I think your tribute should be very well taken. It was an excellent piece of work and it remains an excellent piece of work. I think the work that is coming along bears all the hallmarks of having benefitted from that experience.

KUMAR: With the proposed changes in the rules, do you envision any changes to the emergency preparedness plan for the current operating plants?

CONGEL: It is a highly controversial issue and our intent is to solicit and listen to proposals about changing the EP. This is a pretty new consideration on our part. I want to emphasis that the EP distance of 10 miles is a policy decision that was made by the Commission. Of course, like all decisions, it was supported in good part by technical analyses. It remains a policy decision. If any consideration is given, either by the Commission to the staff or vice versa, to re-evaluating the 10 miles, it will probably take some effort. The reason I am hesitating some is because it can really turn out to wave a red flag that I personally don't feel is needed to be waved at this particular time. All of the operating plants now accommodate the 10 miles reasonably well. My group has an excellent rapport now with FEMA. We have very few problems with it, and I think just in terms of timing, this is not the time to call it into question. But I do not make that final decision. I do know that there will be a request exactly along the lines you are suggesting. If it comes to pass, we will do our analysis. I can't emphasis enough that the 10 mile EPZ is looked at as the final level in the defence in depth concept. Attempting to change it at this point, in light of all the other questions that still have to be answered, may not be the wisest thing.

GE's Advanced Nuclear Reactor Designs

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Abstract

The excess of U.S. electrical generating capacity which has existed for the past 15 years is coming to an end as we enter the 1990s. Environmental and energy security issues associated with fossil fuels are kindling renewed interest in the nuclear option. The importance of these issues are underscored by the National Energy Strategy (NES) which calls for actions which "are designed to ensure that the nuclear power option is available to utilities." Utilities, utility associations, and nuclear suppliers, under the leadership of the Nuclear Power Oversight Committee (NPOC), have jointly developed a 14 point strategic plan aimed at establishing a predictable regulatory environment, standardized and pre-licensed Advanced Light Water Reactor (ALWR) nuclear plants, resolving the long-term waste management issue, and other "enabling conditions."

GE is participating in this national effort and GE's family of advanced nuclear power plants feature two reactor designs, developed on a common technology base, aimed at providing a new generation of nuclear plants to provide safe, clean, economical electricity to the world's utilities in the 1990s and beyond. Together, the large-size (1300 MWe) Advanced Boiling Water Reactor (ABWR) and the small-size (600 MWe) Simplified Boiling Water Reactor (SBWR) are innovative, near-term candidates for expanding electrical generating capacity in the U.S. and worldwide. Both possess the features necessary to do so safely, reliably, and economically.

I. Background

During the past 15 years, there has been no need for new nuclear plants or, for that matter, new base load plants of any kind in the U.S. Utility purchases of new plants in the early 1970s produced electrical capacity well in excess of that necessary to meet demand. Since new plants were not needed, there was little incentive to confront the difficult choices among greater reliance on conservation, increased burning of fossil fuels, or construction of more nuclear power plants. The excess of electric generating capacity, however, is coming to an end.

Fifty-six percent of the U.S. electric supply comes from coal fired plants, and this nation's coal reserves are still plentiful. However, coal plants account for a large portion of sulfur dioxide, nitrogen oxide, and carbon dioxide atmospheric emissions (see Figure 1). Each year, a 1,000 megawatt coal plant releases 70,000 tons of sulfur dioxide - a major contributor to acid rain.[1] The acid rain provisions of the Clean Air Act amendments would have damaging effect on electric supply, especially in the Mid-West. According to The North American Electric Reliability Council, the Clean Air legislation could result in an estimated capacity loss of 12,600 megawatts - the equivalent of 15 large power plants. This loss represents those power plants that could no longer be economically operated, either because of the expense of adding emission control equipment or reduction in

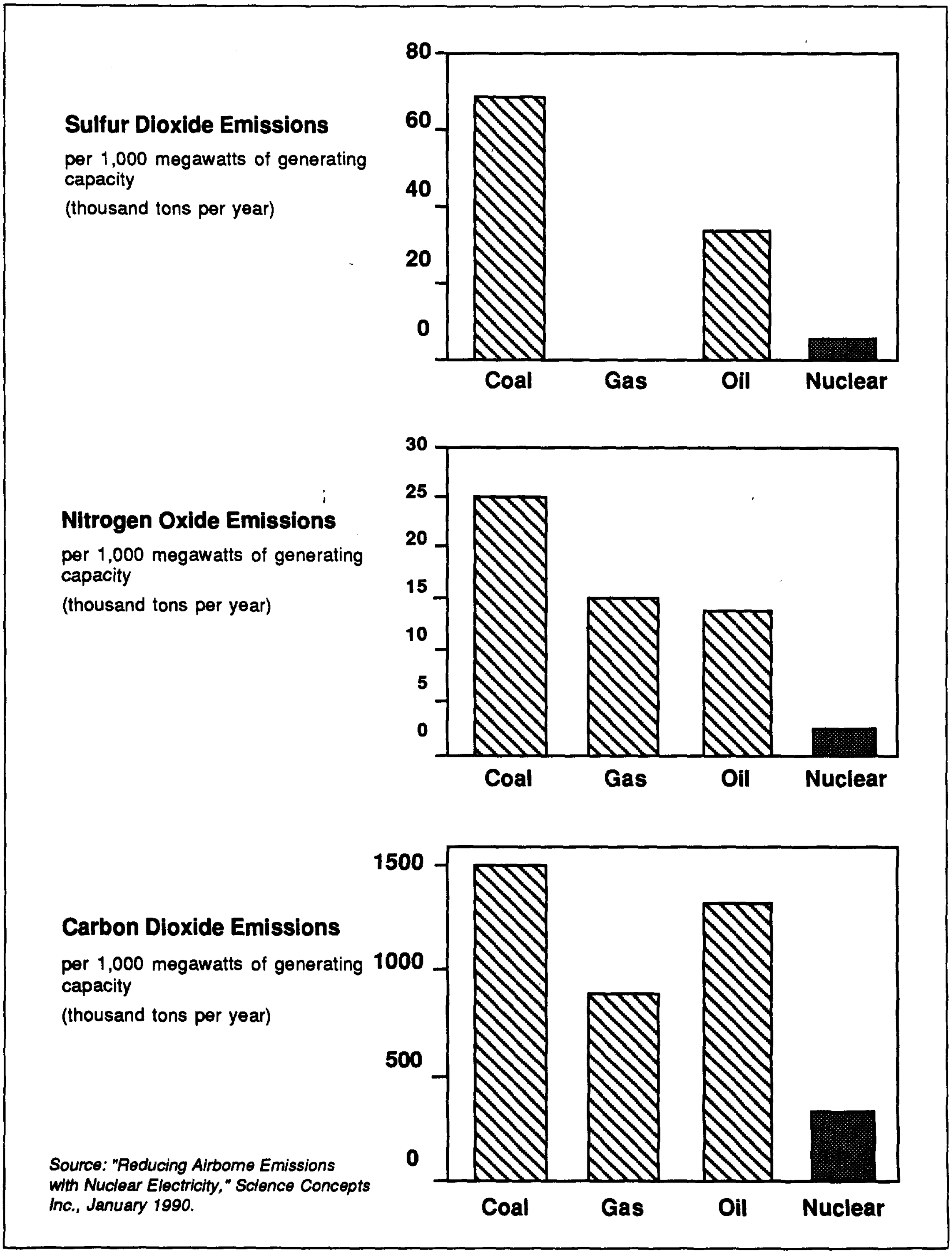

Figure 1 Comparison of Power Plant Emissions

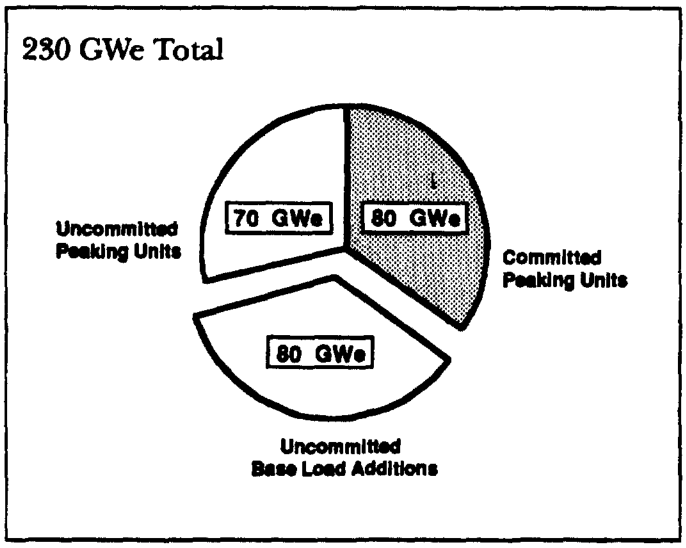

Figure 2 Forecast of U.S. Capacity Additions (1990-2005)

plant output as a result of complying with the law.

The U.S. needs a viable nuclear option. Nuclear power, while not risk-free, is today producing 17% of the world's electricity and 21% of this nation's electricity safely and economically without polluting the air, contributing to the "greenhouse effect," or subjecting our energy supply to the vagaries of Mideast governments. Nuclear energy could play an even greater role in meeting our future energy needs while easing environmental strains and stabilizing our energy supply and economy.

Nuclear energy generates electricity with virtually no impact on our air and atmosphere (see Figure 1). Nuclear energy plants themselves emit zero pollution, but the production of nuclear fuel in the U.S. currently uses coal-fired power - thus the charts include emissions from that coal-fired generation. In 1991, this nation's 112 nuclear energy plants generated 643 billion kilowatt hours of electricity,[2] enough to meet the needs of more than 50 million homes. In this process, these plants eliminated 150 million tons of carbon dioxide emissions, 6 million tons of sulfur dioxide emissions, and 2 million tons of nitrogen oxide emissions. To put this reduction in perspective, the 1990 Clean Air Act amendments would reduce yearly sulfur dioxide emissions by 10 million tons and reduce annual nitrogen oxide emissions by 2 million tons by the year 2000.[3] In short, nuclear energy plants are today making a contribution to environmental cleanup comparable to that which the Clean Air Act is forecast to make by the end of the century.

The market for advanced light water reactor (ALWR) nuclear plants has not yet emerged in the U.S. What is emerging, however, is a demand for additional baseload capacity. GE forecasts that through the year 2005, the U.S. will require an additional 230 GWe of capacity (see Figure 1). If nuclear power is utilized to meet this demand, GE believes that markets will develop for both large (1300 MWe class) and small (600 MWe class) power plants. Decisions between these options will be based largely on regional or utility-unique considerations such as grid size, growth, financing, etc. GE, unlike other domestic designers, has developed and will license power plant designs for both large and small market segments.

II. Introduction

The ABWR has been adopted as the next generation standard BWR in Japan. During 1987, the Tokyo Electric Power Company, Inc. announced its decision to proceed with two ABWR units at its Kashiwazaki-Kariwa

Table 1. Specific Utility Concerns

Concern	ABWR/SBWR Design
Availability	Simplified plant features, greater design margins, more redundancy, and failure tolerance in equipment and semi-automated plant operations
Maintainability	Integrated layout with built-in features to simplify and automate maintenance
Operability	State-of-the-art man-machine interface with computer aided operations and procedures
Radiation Exposure	Simplified plant features, better materials and more automated maintenance
Radwaste Reduction	State of the art design, better materials, and better operational practices
Metallurgy	Fully qualified and tested nuclear grade materials

Table 2. BWR Key Performance Characteristics

	Typical U.S.Plant	ABWR	SBWR
Electrical Output (MWe net)	600-1300	1300	600
Construction Schedule (Months)	80-140	48	36[2]
Unplanned scrams per year	1.3	<1	<1
Availability Factor (%)	75[1]	87	87
Daily Load Following Range (% of Rated Power)	50-100	50-100	50-100
Core Damage Probability (Per Year)	$<10^{-5}$–10^{-4}	$<10^{-6}$	$<10^{-6}$
BWR Occupational Exposure (manrem/year)	377[1]	<100	<100
BWR Solid Radwaste (m^3/year)	233[1]	<100	<100
Overnight capital cost ($/kWe)[3]	2000-4000	1400	1700
Production cost (¢/kWhr)[3]	1.4-5.3[1]	1.3	1.6

1. 1991 mid-year INPO data, operating plants
2. Rolling 4x10 basis
3. USCEA 1992 Report (for a single unit in 1991$)

Nuclear Power Station. In May 1991, the Japanese Government issued a license for the ABWR. Construction has already begun and commercial operation of the first unit will occur in 1996 and the second in 1997. Both units are supplied by a consortium of GE, Hitachi, and Toshiba, with GE selected to supply the nuclear steam supply systems, fuel, and turbine/generators. In the United States, the ABWR is the lead plant scheduled to receive U.S. Nuclear Regulatory Commission (NRC) approval as the first certified U.S. standard plant. Final Design Approval (FDA) is expected in December 1992.

International cooperative efforts are currently underway aimed at certification of a smaller BWR employing natural circulation and additional passive safety systems. Building upon the BWR technology base already developed for the ABWR, the SBWR conceptual design is complete and shows significant technical and economic promise. In 1989, the SBWR was selected by the U.S. Department of Energy (DOE) and the Electric Power Research Institute (EPRI) to complete the design and obtain U.S. NRC certification by 1995.

The ABWR and its smaller counterpart, the SBWR, share a common advanced BWR technology base. In the development of the ABWR design, the ABWR team, led by GE with participation of an international team of BWR manufacturers, addressed specific utility concerns of worldwide utility customers (see Table 1) by utilizing innovative designs and systems and incorporating the best proven features from BWR designs worldwide. In adopting these proven features from BWR designs in Europe, Japan, and the United States; as well as state-of-the-art electronics, computer, turbine, and fuel technology, the ABWR and SBWR designs are expected to show improvements over the current fleet of BWRs in plant availability; plant operating capacity factor; plant safety and reliability; while reducing power generation costs; construction schedule; occupational exposure; and radwaste. (see Table 2)[4]

Further improvements in safety, performance, and economics are made by simplifying the design of components, systems, and structures and by using natural safety systems.

As the same advanced BWR technology is applied to ABWR and SBWR, both designs have much in common. The only essential differences between the ABWR and SBWR is the power rating, core flow recirculation (internal pumps for the ABWR and natural circulation for the SBWR), and the extent to which some of the safety systems employ active versus passive features. More information is provided in Reference 5.

III. Advanced BWR Key Design Features

<u>Fine Motion Control Rod Drives (FMCRDs)</u> – The FMCRD design is an improved version of the drives which have been in operation in a number of European BWRs for a number of years. The FMCRD has been specifically

designed to reduce the periodic maintenance required thereby also reducing the associated occupational exposure. The advanced BWR FMCRDs are distinguished from the locking piston CRDs, which are in operation in all current GE plants, in that the control blades are moved electrically during normal operation. This feature permits small power changes and improved startup time and power maneuvering. The FMCRD, as with current drives, is inserted into the core hydraulically during scram. The FMCRD, however, having the additional electrical motor, will drive the control blade into the core even if the primary hydraulic system fails to do so, providing an additional level of protection against Anticipated Transient Without Scram (ATWS) events.

Core Flow Recirculation – Both the ABWR and the SBWR utilize new simplified designs and principles for reactor core flow recirculation. The ABWR utilizes ten internal pumps for recirculation flow while the SBWR uses natural core flow circulation. The elimination of the external recirculation piping permits a compact containment design, elimination of all large vessel nozzles below the core, and reduced in-service inspections (ISI). Elimination of the large nozzles permits designing a safer and more economic Emergency Core Cooling System (ECCS). The ABWR and SBWR cores will never be uncovered during any Design Basis Accident. Elimination of the recirculation piping and the use of the vessel forged rings has resulted in over a 50% reduction in welds, and therefore ISI, for the primary system pressure boundary. This, in turn, reduces the occupational exposure during ISI.

The internal pumps selected for the ABWR are an improved version of the wet-motor glandless type design. Significant plant operation experience with these pumps has been accumulated in a number of European BWR plants.

Natural circulation technology is not new to BWRs. The Dodewaard plant in The Netherlands has been operated at a lifetime capacity factor of 84%. The small size of the SBWR allows the use of this feature. Larger bwrs (Liebstadt and Vermont Yankee among others) have been operated at 50% power levels in the natural circulation mode to prove the SBWR's natural circulation feature.

Control and Instrumentation – The control and instrumentation designs feature system redundancy, fault tolerant operation, and self-diagnostics while the system is in operation. This is made possible by the extensive use of state-of-the-art digital technologies. As an example, multiplexed C&I signals are transmitted along fiber optic networks. With this use of multiplexed fiber optics for C&I signal transmission, the amount of copper cabling

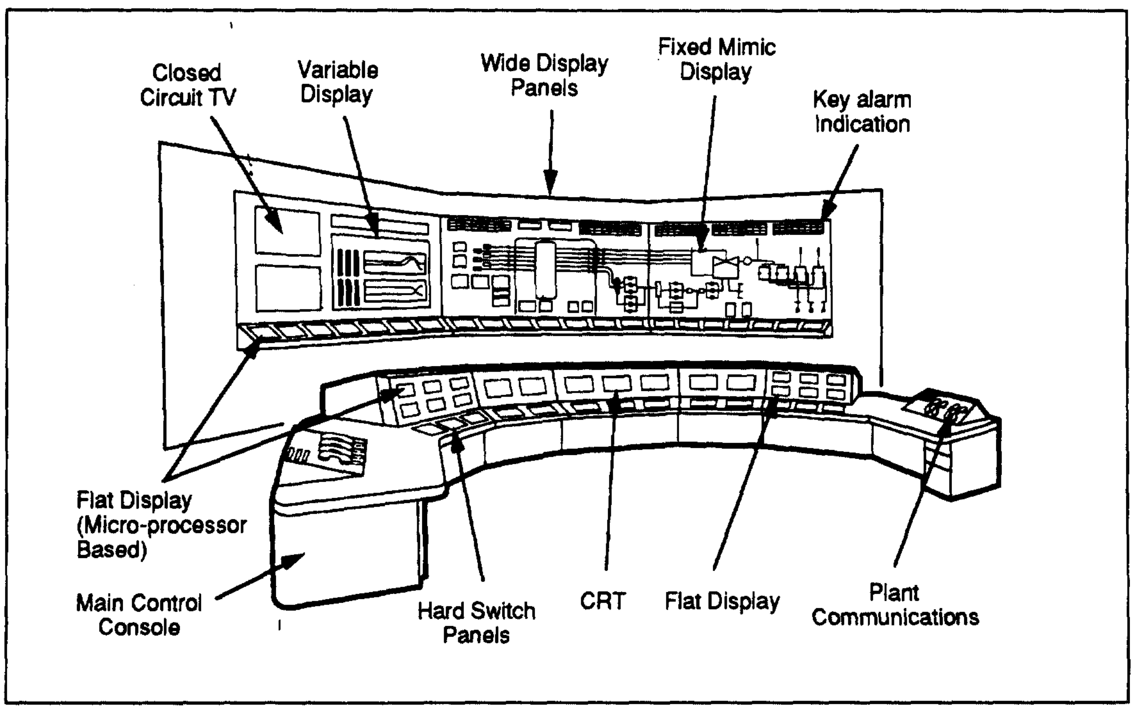

Figure 3 Key Features of Advanced BWR Control Room Design

throughout the plant is significantly reduced so that lower construction costs and shorter schedules are achieved. Through the application of such advanced digital equipment technologies, the C&I designs significantly improve operability, availability, and support shorter construction schedules.

The use of modern technology is visibly evident in the control room of both the ABWR and the SBWR (Figure 3). The size of the control room is smaller and the layout is streamlined. Operators monitor plant activities on a large display that graphically depicts plant operation. It is possible to run the ABWR and SBWR with only one operator because of the wide array of support features built into the control room: CRT displays, automation and menu-driven prompts for manual operation, and simplified tech specs which are available to the operator on the computer monitor.

Reactor Building/Containment – The reactor building structural design is of steel-lined reinforced concrete with a high seismic capability. The containment design is of the pressure suppression type with a covered suppression pool. The reactor building design is very compact and economical compared to past designs, especially considering the high plant power rating. The advanced BWRs continue GE's past practice of surrounding the primary containment with another barrier to radiological releases, in this case, the Reactor Building itself. In arranging the Reactor Building GE has provided improved separation, fire protection, and security.

Engineered Service and Maintainability – GE has worked closely with our utility sponsor to ensure that the equipment design and building arrangements are such that maintenance requirements are minimized and that, when required, proper accessibility, servicing equipment and shielding are available to minimize the cost, schedule and occupational exposure incurred in performing it. In particular, highly automated equipment has been developed for servicing the internal pumps and the FMCRDs; as well as performing in-service inspections of primary boundary welds.

U.S. Turbine Island Design – The Advanced LWR Certification Program in the U.S. has been based on a turbine island design developed specifically to meet U.S. licensing and utility requirements. This design utilizes the advanced GE turbine generator with 52-inch last stage buckets developed for the TEPCO projects. The turbine island has been placed "in-line" with the Reactor Building in order to meet EPRI licensing requirements and eliminate the possibility of damage to the reactor system if a turbine failure were to occur.

Passive Severe Accident Capability – The advanced BWR capability to prevent severe reactor accidents from occurring and the capability to withstand a severe accident in the extremely unlikely event that one should occur were evaluated with a probabilistic risk assessment (PRA). This evaluation indicates that events resulting in damage to the reactor core are extremely unlikely, but that if such events were postulated to occur, passive accident mitigation features would limit the offsite dose so that the effect on the public would be insignificant.

IV. Status of ABWR and SBWR

The ABWR represents the next generation light water reactor (LWR) to be introduced into commercial operation this decade. It is currently being applied as a two-unit project by the Tokyo Electric Power Co., Inc. (TEPCO) at the Kashiwazaki-Kariwa site in Japan. On May 15, 1991, Japan's Ministry of International Trade and Industry (MITI) formally granted the "Establishment Permit" to TEPCO for the construction of two ABWR units at the Kashiwazaki-Kariwa site. This licensing milestone culminates the successful safety review in Japan and clears the way for construction of the two ABWR units. The units are being supplied by a joint venture involving GE, Hitachi and Toshiba, with GE supplying the nuclear steam supply systems, fuel, turbines and generators for both units. Ground-breaking for the first unit occurred in September 1991 and the second unit in February 1992. Excavation to bedrock is expected to take 15 months. First concrete to turnover is scheduled to take 48 months. Commercial operation of the first unit is scheduled for 1996 followed by the second unit in 1997.

In the United States, the ABWR and SBWR have been adapted to the needs of U.S. utilities established through the EPRI's Advanced LWR Requirements Program. The ABWR was reviewed and found to be in conformance with these utility requirements. Many of the ABWR design features even exceeded the EPRI requirements. A similar review of the SBWR design will be performed when the final design is submitted to the NRC for review.

The ABWR is currently being reviewed as the lead candidate by the U.S. Nuclear Regulatory Commission for certification as a pre-approved U.S. standard design under the U.S. Department of Energy's ALWR Design Certification Program. The NRC is close to finishing the ABWR's licensing review. As a sign of real commitment, GE and NRC management have been meeting on a regular, monthly basis to ensure timely closure of open review items. Final Design Approval is expected in December 1992 and design certification to follow in 12 to 18 months. When the ABWR receives the final design approval (FDA) and design certification license, it will be the first pre-approved U.S. standard Advanced Light Water Reactor. Development of pre-licensed, standard designs is considered to be a key element in the U.S. industry's efforts to make nuclear energy a viable option in the U.S.

The SBWR conceptual design was completed in 1990. The development of the SBWR design was accompanied by extensive testing of new features. Since 1990, GE and its SBWR team members, which includes 40 worldwide organizations from 11 nations, have been improving the SBWR design and performing detailed engineering in support of the licensing review process. Well over 50 international associates are currently working along side GE engineers in San Jose to ensure that the best ideas and technology are incorporated in the SBWR design.

In January of 1992, work began on the preparation of the SBWR Standard Safety Analysis Report (SSAR). The 21-volume document will be submitted to the NRC for review later this summer. More than 100 GE engineers and technical associates are currently supporting this effort. The NRC review of the SBWR SSAR is expected to take 22 months. The quick review is made possible by the extensive use of ABWR technologies, design features, methodologies, and licensing review process. NRC design certification expected by 1995.

However, many institutional and social issues must first be resolved before nuclear energy can play an expanded role in meeting the needs of U.S. utilities. The Nuclear Power Oversight Committee (NPOC), whose members consist of senior executives from utilities, utility associations and suppliers, in 1990 unveiled a strategic plan to have an ALWR plant operating in the U.S. by the year 2000. The plan addresses 14 issues which could pose obstacles to a revival of U.S. nuclear plant construction. Many organizations are currently involved in this revival effort. Progress is being made and momentum is building.

As the need for additional generation capacity emerges, GE will be prepared to further support utilities with large and small advanced BWRs which are economically and environmentally sound.

V. References

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3. "A Perfect Match: Nuclear Energy and the National Energy Strategy," NPOC position paper, September 1990.

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DISCUSSION

BELLAMY: I think it would help if you explained the difference between approval and certification. Why would it take a year for something to be certified if a Federal agency has approved it.

BERGLUND: Final design approval (FDA) is the completion of the technical review by the staff and the Commissioners. It does not include public hearings, which only happen during the rule-making portion of the process. Certification, as provided in 10 CFR part 52, follows FDA via public hearings and completion of the certification rule. As stated in my talk, FDA on ABWR is scheduled for December 1992 and certification is scheduled for early 1994. Hope this covers your question.