PLANNING THE APPLICATION OF PROTECTIVE MEASURES FOR ACCIDENTS PRODUCING SEVERE RADIOLOGICAL CONSEQUENCES IN NUCLEAR POWER PLANTS

Bruno, H., Kunst, J.J., Boutet, L.I. and Nollmann, C.E.
Comisión Nacional de Energía Atómica, Argentina

INTRODUCTION

In order to evaluate the consequences and pre-plan the application of countermeasures on the population irradiated by a release of radioactive products from a nuclear power plant, the dose equivalent is calculated during the passage of the "radiactive cloud" and during irradiation resulting from the radiactive deposit accumulated on the ground.

When an accident takes place, the resulting exposure can only be substantially limited by implementing protective measures. The possible protective measures are: "sheltering" and supplying those exposed with stable iodine tablets, during the early phase. In a second stage, when the irradiation is due to ground deposit, the main countermeasure is the evacuation of people. This practice takes more time but may be implemented without extreme urgency.

RADIOLOGICAL CRITERIA FOR IMPOSING COUNTERMEASURES

In pre-planning the application of protective measures for accidents producing severe radiological consequences in nuclear installations, the underlying short-term objetive is to ensure that prompt action is taken to avoid the incidence of high levels of individual exposure. This may take the form of advice to the public to shelter in their houses, while stable iodine tablets may be supplied as a thyroid blocking agent. In a second stage, evacuation must be considered, when ground deposit external irradiation is the dominant way of exposure.

The Argentine radiological authority has established the following dose limits above which the countermeasures must be implemented: a) Sheltering and distribution of stable iodine tablets, when the effective dose equivalent is 1 rem or greater, or when the organ dose equivalent reaches 10 rem, both concerning the passage of the cloud; b) When the dose due to external irradiation from the ground is over 10 rem within the first 6 hours after the accident, evacuation is mandatory. Nevertheless, if the dose is 10 rem or more within the first 24 hours after the accident, the evacuation should be implemented only for those cases in wich the detriment expected from the countermeasure is less significant than the radiological detriment.

CHARACTERISTICS OF THE RELEASES

The characteristics of the 3 hypothetical releases, designated as 1, 2 and 3, are summarized in Table 1. The fraccional releases of different groups of nuclides from the reactor core are specified along with other assumed characteristics, such as duration, height and heat content of the release and delay between reactor shut-down and release.

In general terms, the characteristics of release 1 are typical of a large degraded core accident release postulated for HWRs (1). Release 2 is similar to Nr. 1, but the release of most elements, except for noble gases, is a factor of ten lower. Release 3 is a typical noble gas release.

The reactor inventory at shut-down is summerized in Table 2 and was calculated by means of the ORIGEN 1 code, adapted for a 1100 MW heavy water reactor (2). The quantities of each radionuclide released in each case can be obtained from the release fractions shown in Table 1.

DOSIMETRIC MODEL

The SEDA (3) dose-assessment model has been used for the calculation of individual doses. The dispersion model used in it, is the so-called Gaussian model. In it, it is assumed that the material released to the atmosphere will be carried with the wind and spread like a smoke plume. At distances greater than 20 km, concentrations and doses calculated with the Gaussian model are usually overestimated.

The plume rise due to the heat content of the release was taken into account and calculated according to a formula provided by Briggs (4). Decreases in the concentration of the plume due to deposition were evaluated by using the source depletion model.

The individual doses are calculated for three forms of irradiation: i) External gamma irradiation from the plume; ii) Inhalation (lungs and thyroid); and iii) External gamma irradiation from ground deposited material.

Finally, it has been assumed that people stay outdoors all the time and, therefore, shielding factors were disregarded so as to fix the distances at which the countermeasures had to be implemented.

DOSES TO INHABITANTS

The individual doses calculated as functions of the distance from the reactor, for the three releases under consideration, are shown in Figures 1 to 6.

The highest doses due to immersion in the radioactive cloud were 140 and 750 rem for Pasquill's classes D and F respectively, in release 3, both within one kilometer from the reactor. Releases 1 and 2 produce lower doses but at greater distances because of the heat content of the released gases.

The doses in thyroid due to inhalation of radioactive material were calculated. The highest doses are caused by release type 2: over 1500 and 2200 rem, under D and F conditions, within two kilometers from the source. For release type 1, the maximum doses reach approximately 800 rem, at 15 km from the reactor.

The highest doses in lungs were produced by a release type 1, with 130 and 170 rem at 4 km and 12 km from the reactor, for D and F Pasquill atmospheric conditions, respectively.

Doses due to irradiation from the radioactive material deposited on the ground were calculated for six and twenty-four hours after the end of the release. In the first case, the maximum dose was 23 rem, at 1.5 km from the reactor, for a release type 2, under the F Pasquill condition, while, at 4 km from the reactor, the doses were over 10 rem.

The dose integrated until 24 hours after the deposition, was larger in a type 2 with values over 60 rem at less than 1 km from the source, under a D Pasquill condition. Doses over 10 rem were calculated at 45 km, in a release type 1, under the F Pasquill condition.

CONCLUSIONS

The individual doses were calculated on the "hot line" of the radioactive plume, under unfavourable meteorological conditions for 3 hypothetical releases. Some simple countermeasures, such as "sheltering" and blockade of the thyroid gland, can significantly reduce the doses incurred by immersion in the cloud and by inhalation.

The doses due to irradiation from the radioactive material deposited on the ground indicate that the late evacuation plans must cover areas within at least a ten kilometer radius around the reactor site. This could be extended to 45 km for those cases in which the countermeasures themselves do not mean further significant risk.

Table 1

Release categories for accidental releases considered in the assessment

TYPE	tr (h)	td (h)	hs (m)	QH (MW)	Noble gases	Iodine	Cs-Rb	Te-Sb	Sr-Ba	Ru	La
1	2.5	0.5	25	5.88	$9\ 10^{-1}$	$7\ 10^{-2}$	$4\ 10^{-2}$	$3\ 10^{-2}$	$5\ 10^{-3}$	$4\ 10^{-2}$	$3\ 10^{-4}$
2	2.0	3.0	0	0.29	$6\ 10^{-1}$	$9\ 10^{-3}$	$4\ 10^{-3}$	$3\ 10^{-3}$	$5\ 10^{-4}$	$3\ 10^{-4}$	$4\ 10^{-5}$
3	2.0	3.0	10	-	1	$1.5\ 10^{-4}$	$5.1\ 10^{-4}$	$5\ 10^{-4}$	$5.7\ 10^{-5}$	$4\ 10^{-5}$	$6.5\ 10^{-6}$

Table 2

Inventory of nuclides considered in this study

Nuclide	Inventory (10^6 Ci)	Nuclide	Inventory (10^6 Ci)	Nuclide	Inventory (10^6 Ci)	Nuclide	Inventory (10^6 Ci)
Kr- 85	0.055	Cs-136	0.56	Ba-140	59.91	Ce-141	54.05
Kr- 85m	8.83	Cs-137	0.45	Mo- 99	60.90	Ce-143	50.77
Kr- 87	17.25	Te-127	2.14	Tc- 99m	52.88	Ce-144	12.37
Kr- 88	25.05	Te-127m	0.23	Ru-103	17.30	Pr-143	49.60
Xe-133	61.72	Te-129	12.23	Ru-105	30.15	Nd-147	22.67
Xe-135	.4.60	Te-129m	1.82	Ru-106	3.30	Np-239	931.06
I-131	32.82	Te-131m	4.93	Rh-105	20.0	Pu-238	$4.0\ 10^{-4}$
I-132	48.64	Te-132	46.24	Y- 90	0.36	Pu-239	$4.7\ 10^{-3}$
I-133	65.09	Sb-127	2.46	Y- 91	34.91	Pu-240	$3.9\ 10^{-3}$
I-134	74.20	Sb-129	13.09	Zr- 95	41.46	Pu-241	0.25
I-135	58.09	Sr- 89	29.53	Zr- 97	56.24	Am-241	$3.0\ 10^{-5}$
Rb- 86	$5\ 10^{-3}$	Sr- 90	0.27	Nb- 95	29.33	Cm-242	$3.7\ 10^{-3}$
Cs-134	0.165	Sr- 91	41.58	La-140	62.15	Cm-244	$1.6\ 10^{-5}$

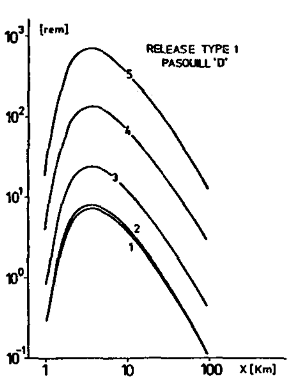

FIGURE 1

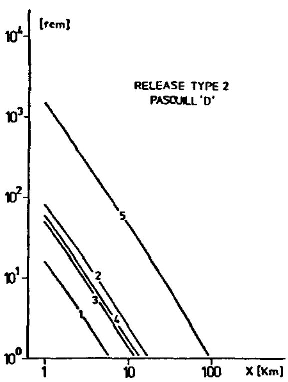

FIGURE 2

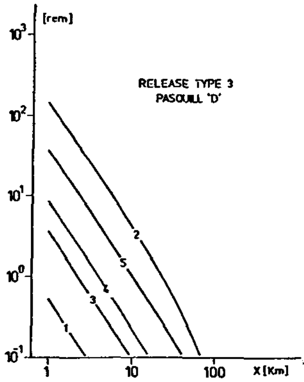

FIGURE 3

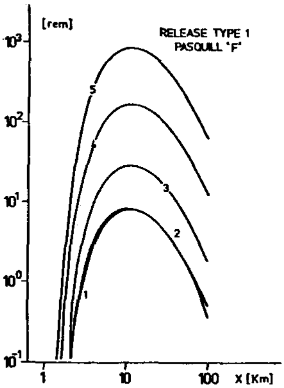

FIGURE 4

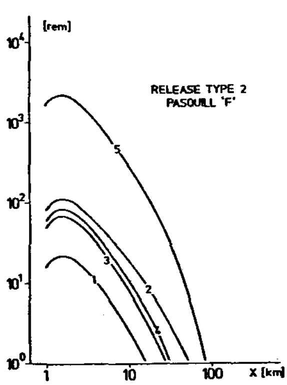

FIGURE 5

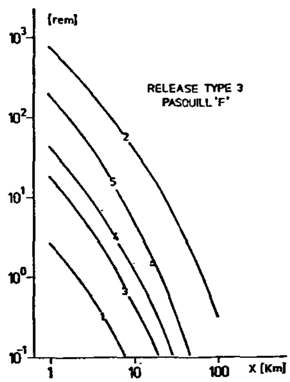

FIGURE 6

1. H_E due to a deposit, integrated in 6 hours.
2. H_E due to a deposit, integrated in 24 hours.
3. H_E due to immersion in the cloud.
4. Dose equivalent in thyroid, due to inhalation.
5. Dose equivalent in lungs, due to inhalation.

BIBLIOGRAPHY

1. Gesellschaft für Reaktorsicherheit, Germany, F.R. "Deutsche Risikostudie Kernkraftwerke" Germany, Verlag TUV Rheinland GmbH, 1980.
2. Kivilovsky, L. and Volkis, J. 1978 CNEA-RE CA 78-14.
3. Kunst, J.J., Boutet, L. and Bruno, H. 1982 CNEA (in print).
4. Briggs, G.A. 1969 TID-25075.