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STUDY OF A NUCLEAR PORT IN ALGECIRAS (ESTUDIO DE UN PUERTO NUCL--ETC(U)
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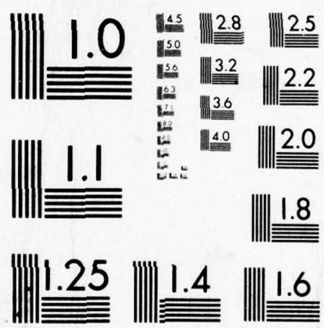

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STUDY OF A NUCLEAR PORT IN ALGECIRAS*

Madrid INGENIERIA NAVAL in Spanish Aug 77 pp 434-441

[Article by Naval Engineer Francisco Sayans Gomez (degree in Nuclear Engineering)]

1. Introduction

The specifications of the final draft project called for a nuclear powered container vessel for the Cadiz-Yokohama route. A series of conventional technical requirements, along with others of a nuclear nature, weighed against using Cadiz as a terminal port. As an alternative, the possibilities offered by the Bay of Algeciras were studied and evaluated, and the location of a conventional-nuclear superport there for the distribution of goods to the Mediterranean ports was approved as acceptable.

2. External Safety

The choice of location for a superport with these characteristics is made on the basis of economic considerations, provided the safety requirements are met. To synthesize these requirements, we might say that the population in the environs must not be exposed to damage above the acceptable level, not only as a result of the normal transit of nuclear vessels at the docks and in the anchoring grounds, but also in the unlikely event of a nuclear accident in the inner harbor.

After the location of the superport in Algeciras Bay was approved as optimal from an economic viewpoint, studies were needed to establish in what part of the bay it could be built. This location should meet three basic requirements: it must provide a sufficient mooring line and adequate draft and must meet the safety requirements noted in the preceding paragraph.

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*This work is a condensation of the chapter entitled "Nuclear Safety" in the final draft produced by naval engineers Manuel Moreu, Francisco Sayans and Jorge Sendagorta.

On the basis of the first two requirements, the Getares Cove was chosen. Now it remained only to show that from the nuclear point of view, the third requirement was met, and that the city of Algeciras would run no risk, in the event of an accident on a vessel in dock in Getares.

In planning the nuclear installation a norm which must be observed calls for a study of the consequences which would be produced by the MAP (Maximum Accident Foreseeable). It is a fact that given the peculiar mobility characteristics of the vessel and its greatly reduced installed power in comparison with nuclear plants on land, the consequences of the MAP would be greatly diminished.

2.1. The Maximum Accident Foreseeable

The USAEC (United States Atomic Energy Commission) deems the maximum accident foreseeable to be the breakdown of the primary refrigeration circuit, which could result in causing the fusion of an important fraction of the core of the reactor with the uncontrolled release of a large part of the gases, the halogens, and a small fraction of the other nuclides. It is presumed that the accident will not cause the destruction of the containment system, which will continue to function normally.

2.2. Leakage

Given the number of openings existing in the containing enclosure, as well as the special characteristics of some of the resulting fission products, the internal pressure following an accident would not be maintained and a considerable volume of leakage to the outside would be inevitable.

With a view to assessing the most adverse conditions, the fission products present after 900 days (EOL -- end of life) were determined.

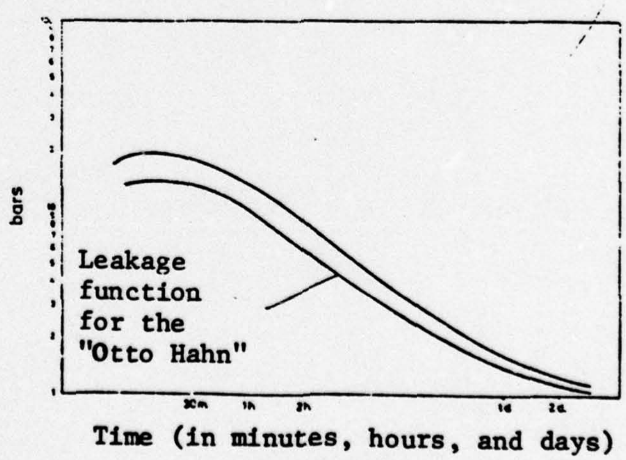


Figure 1

It was presumed that 100 percent of the nucleus was fused and that this occurred instantaneously, although it might take up to 15 minutes, due to the entry of the safety mechanisms into operation. The input data for the computer programs used were prepared according to the suggestions contained in the Maritime Administration -- Atomic Energy Commission ORNL-NSIC-5 [Oak Ridge National Laboratory - Nuclear Safety Information Center-5] guide, presuming that the fused nucleus releases the following into the containing enclosure:

100 percent of the inert gases, iodine and tellurium
95 percent of the cesium
70 percent of the ruthenium
1 percent of the strontium
2 percent of the other nuclides.

An efficiency filtering factor of 99% has been presumed for all the nuclides except the inert gases, where the efficiency will be zero. Five periods following the accident were considered: 1/2 hour, 1 hour, 2 hours, 24 hours and 48 hours.

The gaseous mass in the containment enclosure escaped from it at a rate which Electricite de France suggests be calculated on the basis of Nikuradze's formula:

$$\frac{q^2_{mi}}{q^1_{mi}} = \left[\frac{1 - \frac{P^2_{atm}}{P^2_2}}{1 - \frac{P^2_{atm}}{P^2_1}}\right]^{1/2} \times \left[\frac{M_1}{M_2} \times \frac{T_2}{T_1}\right]^{1/2}$$

in which the symbols have the following meaning:

q^2_{mi} = leakage in percentage of the mass initially contained, at the instant t_2.

q^1_{mi} = leakage at peak pressure during the accident, taking 1 as 100.

P_2 = total pressure at the instant t_2.

P_1 = total peak pressure at the instant t_1, taking P_1=20 bars.

P_{atm} = atmospheric pressure, taking P_{atm}=1 bar.

M_1 and M_2 = molar mass of the mixture of gas at the instant t_1 and t_2.

T_1 and T_2 = temperature of the gas mixture at the instants t_1 and t_2 in °K.

The values for the various P_2 have been derived from the development of the pressure in the containment enclosure on the presumption that this development will be similar to that in the containment enclosure of the Otto Hahn. It has also been presumed that the radioactive particles are in suspension within the steam mass, with the temperature of the gas being that of the corresponding steam saturation; on the other hand, the relation of the molar masses will be invariable and equal to the unit, such that Table 1 can be drawn up.

Time after Accident	Pressure	Temp. °K	$\left[\frac{T_2}{T_1}\right]^{1/2}$	$A=\left[\frac{1-\frac{P^2 atm}{P_2^2}}{1-\frac{P^2 atm}{P_1^2}}\right]^{1/2}$	$\frac{q^2 mi}{q^1 mi}$	$q^2 mi\cdot$	$Seg^{-1}=\frac{q^2 mix.01}{86400}$
0	20	484	1	–	–	.1	1.157×10^{-8}
30 minutes	18.6	480.7	.9965	.9998	.9963	.0996	1.153×10^{-9}
1 hour	13.6	465.7	.9809	.9985	.9794	.979	1.133×10^{-8}
2 hours	8.5	445	.9588	.9943	.9533	.953	1.103×10^{-8}
24 hours	1.65	385.4	.8923	.7964	.7106	.710	8.217×10^{-5}
48 hours	1.25	377.2	.8828	.6007	.5303	.053	6.134×10^{-9}

Table 1
Development in the Containment Enclosure, According to Nikuradze.

2.3. Consequences of the MAP

If a Maximum Accident Foreseeable were to occur, the containment enclosure would be filled with a radioactive liquid and gaseous mass.

The containment system must meet two basic requirements. The first has to do with ability to tolerate the pressure and temperature conditions which would be produced as a result of the release of energy. Secondly, the containment barrier will also have to be provided with mechanisms for dissipating the energy liberated.

In any containment system, however perfect its design and careful its construction may be, the possibility of leakage is inevitable. The problem posed comes down to establishing a leakage rate which is both technologically and economically feasible and compatible with safety.

As a result of these leakages, once a MAP has occurred, a radioactive cloud appears, and the meteorological conditions prevailing at the moment will cause it to develop in one way or another.

The personnel near the vessel will be exposed to radioactivity thanks to the effects of three mechanisms:

Immersion in the cloud.
Inhalation.
Direct gamma rays.

3. Division into Land Zones

Three zones are established on the basis of distance from the vessel, in the ORNL-NSIC-5 norms, for which maximum allowable levels are given for the dosage received.

Zone A, Controlled. The vessel personnel are responsible for the direct control of this zone, and it must be such that in case of accident it can be evacuated in 2 hours. Beyond this zone, no person will during the 2 hours following the accident receive a dosage of more than 25 rem (roentgen equivalent man) externally γ or 150 rem in the thyroid gland by inhalation.

Zone B, Low Population Density. It is reasonable to expect that in this zone, in the event of an accident, total evacuation can be carried out or adequate protective measures taken. At the outer limit of the zone, a dosage of no more than 25 rem, externally γ, or 150 rem in the thyroid gland by inhalation can be received during the 24 hours following the accident.

Zone C, High Population Density. It is presumed that this zone is adjacent to the preceding one.

The AEC norms for nuclear plants on land take as the outer radius 4/3 of the radius of the low density zone. Immediately after an accident has occurred, this zone could not be evacuated, controlled or protected.

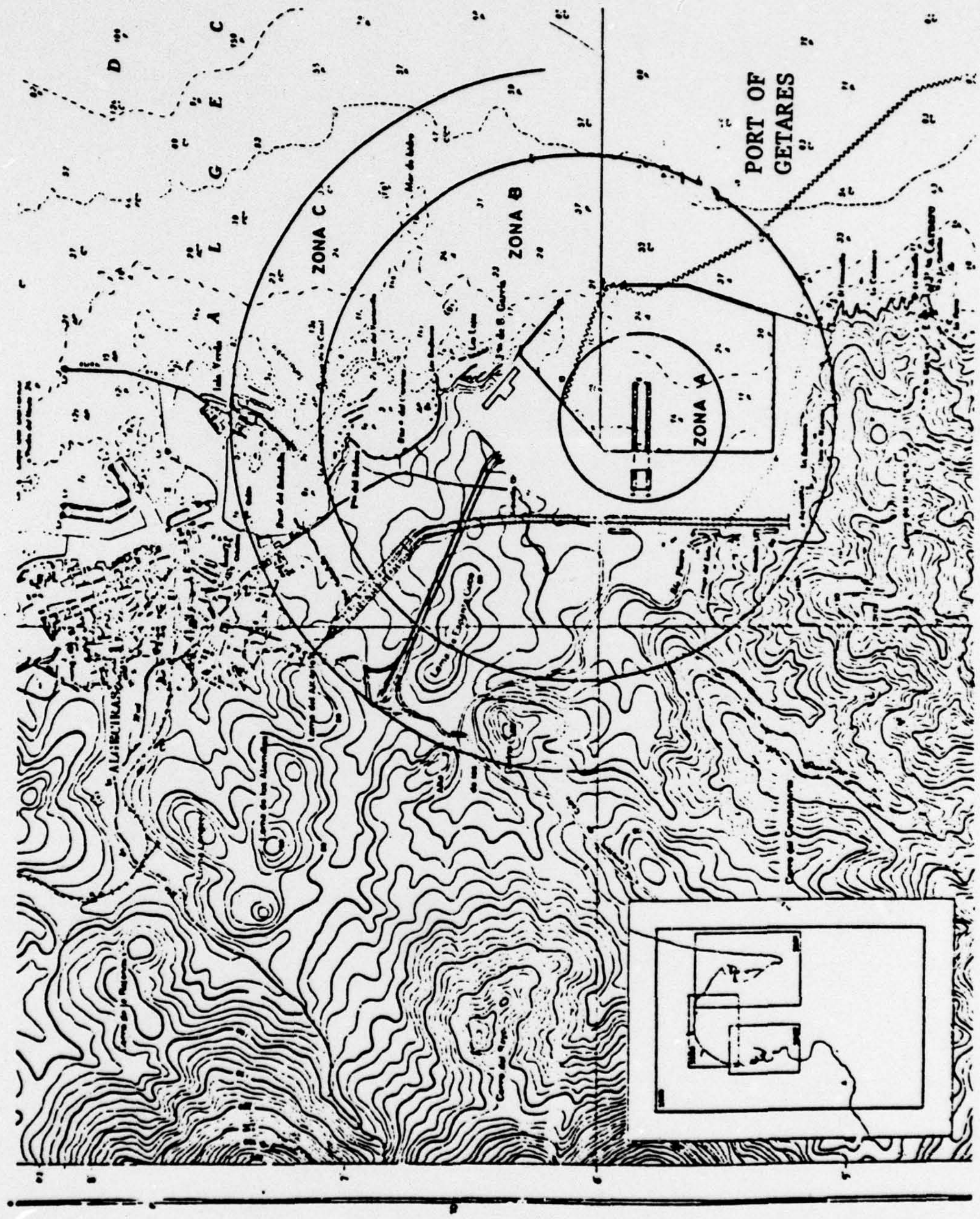
While the ORNL gives 24 hours as the time period for the low population zone, the USAEC Safety Guides for nuclear plants on land gives 30 days. The difference can be ascribed to the fact that the mobility of the vessel plays a role as a safety factor.

4. Mathematical Models Used

The ESDORA (Estimation of Radiological Dosages) computer program estimates the damage done by continuous or instantaneous leakage of the fission products into the atmosphere. It is divided into four subprograms:

ESD 1. Inventory of the fission products, on the basis of the operational mode experienced by the fuel of the installation.

ESD 2. Determining the volume of fissionproducts leaking into the atmosphere through the stack or the containment enclosure, taking the technological safeguards used into account.


ZONA C
ZONA B
ZONA A
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ESD 3. Calculation of the concentrations included in the radioactive cloud, as well as contamination of the earth resulting from the precipitation of the fission products, taking meteorological conditions into account.

ESD 4. Estimate of the external dosages β and γ resulting from immersion in the radioactive cloud and the internal dosages received by various organs of the human body through inhalation.

4.1. Esdora 1

Each nuclide has two ways of developing: directly by fission, with a yield ν_i or by the disintegration of its precursor (λ_{i-1}). There are two ways it can disappear: absorption of neutrons (effective section σ_i) and disintegration (λ_i). We will not consider the absorption of neutrons.

The operational process at a nuclear installation is divided into functional cycles. A functional cycle consists of two periods: the period of irradiation ($\nu_i \neq 0$) and the cooling period ($\nu_i = 0$).

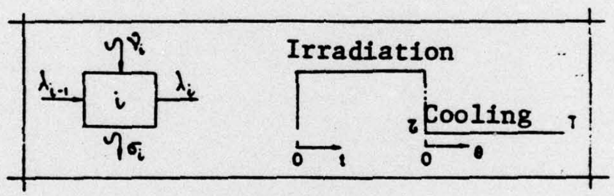


Figure 2

The balance of each nuclide was studied, and the corresponding equations drafted for the periods of irradiation and cooling.

Irradiation:

$$\frac{dN_i}{dt} = XP\nu_i + \lambda_{i-1}N_{i-1} - \lambda_i N_i$$

Cooling:

$$\frac{dN_i}{d\theta} = \lambda_{i-1}N_{i-1} - \lambda_i N_i$$

wherein:

N_i = number of atoms in the nuclide i.

t = time variable in the irradiation period.

θ = time variable in the cooling period.

X = 3.2×10^{10} fissions/W.sec.

ν_i = yield from fission of nuclide i.

P = power of the reactor.

The initial conditions for each cycle are the final conditions of the preceding cycle.

The parameters of the various nuclides used in this program are stored in the memory bank.

4.2. Esdora 2

The number of atoms in nuclide i escaping into the atmosphere from the outer containment enclosure and the time interval n are obtained by:

$$ {}_nQ_i^{\mu}(T) = e^{-\lambda_i T'}\, {}_nV^{\mu} D_i \int_{t_{n-1}}^{t_n} {}_nN_i^{\mu}(t)dt $$

through the ventilation system:

$$ {}_nQ_i^{\mu}(T) = {}_nE^{\mu} \int_{t_{n-1}}^{t_n} {}_nN_i^{\mu}(t)dt \; . $$

through the containment barrier:

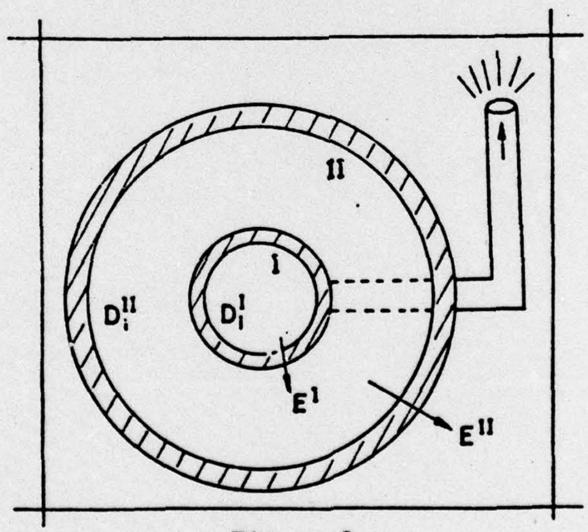


Figure 3

wherein:

${}_nQ_i^{\mu}(T)$ = number of atoms in nuclide i escaping into the atmosphere from the last containment enclosure in the time interval n with a duration of: $T=t_n-t_{n-1}$.

λ_i = disintegration constant for nuclide i.

${}_nE^\mu$ = value of the leakage function of the enclosure in the interval n, equal to the fraction of the atmosphere within the containment barrier μ escaping per unit of time.

T' = the lag time of the ventilation system for the enclosure μ.

${}_nV^\mu$ = the value of the ventilation constant in the enclosure μ in the interval n, equal to the fraction of the atmosphere within the barrier removed by the ventilation system in the unit of time.

D_i = the transmission factor for nuclide i in the enclosure μ, equal to the ratio between the volume of i leaving the system in the unit of time and that coming in during the same period.

${}_nN_i^\mu(t)$ = the number of atoms in the nuclide i present in the network μ in the interval n.

The calculation of ${}_nN_i^\mu$ is carried out on the basis of the system:

$$\frac{d}{dt}\,{}_nN_i^\mu(t) + \Sigma_{in}^\mu N_i^\mu(t) = {}_nE^{\mu-1}\,{}_nN_i^{\mu-1}(t) + \lambda_{i-1}\,{}_nN_{i-1}^\mu$$

wherein

$$\Sigma_i^\mu = \lambda_i + P_i^\mu + W_i^\mu + \begin{cases} {}_nE_i^\mu \\ {}_nV^\mu D_i \end{cases}$$

P_i^μ precipitation constant.

W_i^μ washing constant.

Contour conditions:

$${}_nN_i^\mu(t_n) = {}_{n-1}N_i^\mu(t_{n-1})$$

in other words, the quantity of nuclide i present in the containment enclosure μ at the beginning of the time interval n is equal to that at the end of the time interval n-1.

E^μ and V^μ are mutually exclusive, since if ventilation is provided it is designed such that even in the event of an accident it can maintain the containment system at a lower pressure than the outer atmosphere, thus avoiding leakage and making $E^\mu(t)$ equal to zero.

4.3. Esdora 3

The formula yielding the atmospheric diffusion is:

$$E_i(x, y, z, \tau) = \frac{Q_i(\tau)\, e^{-\frac{y^2}{2}\sigma_y^2(x)} \cdot e^{-\frac{z^2}{2}\sigma_z^2(x)}}{\pi\, u\, \sigma_y\, \sigma_z}$$

wherein

$E_i(x,y,z,\tau)$ is the concentration integrated over the period of time, with the axis x being the direction of the wind.

$Q_i(\tau)$ is the integrated quantity of nuclide i which has leaked from the outer containment enclosure. A correction must be made for radioactive disintegration en route and fallout due to rainfall or dry precipitation on the ground.

u is the velocity of the wind.

σ_y, σ_z are horizontal and vertical dispersion functions.

If the emission is disturbed at its origin by the presence of a building of which the horizontal dimension of the maximal section perpendicular to the direction of the wind is L and the vertical is H

$$E_i(x, y, z, \tau) = \frac{Q_i(\tau) e^{-\frac{y^2}{2} \sigma_y^2(x)} \cdot e^{-\frac{z^2}{2} \sigma_z^2(x)}}{\pi u [\sigma_y^2(x) + \Sigma_y^2]^{1/2} [\sigma_z^2(x) + \Sigma_z^2]}$$

$$\Sigma_y^2 = \frac{L^2}{12} \qquad \Sigma_z^2 = \frac{H^2}{12}$$

If the emission occurs from an elevated point, at altitude h, z is replaced by z-h in the equations given above.

4.4. Esdora 4

Internal dosages. For each organ we have:

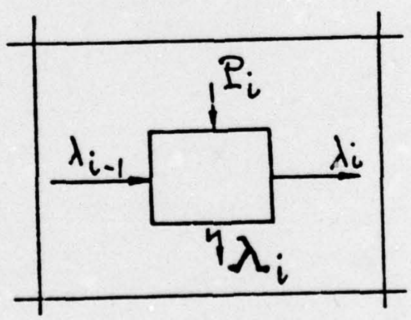


Figure 4

Terms of the source:

$$P_i = \frac{E_i R f_i}{\tau} \quad ; \quad \lambda_{i-1}$$

P_i is the velocity of inhalation.

E_i is the integrated concentration of nuclide i (obtained from ESDORA 3).

R is the volume of air inhaled in m^3/sec.

f_i is the fraction of atoms i passing into the organ in question.

τ is the inhalation time.

λ_i is body wastes.

Λ_i is the biological elimination constant.

External dosages. Dosage β due to immersion in the radioactive cloud:

$$D_\beta = 4.455 \times 10^{-12} E_i \lambda_i \Sigma_{\beta i} S_i$$

$\Sigma_{\beta i}$ is the energy β released by the disintegration of an atom of nuclide i.

S_i is the tissue/idem. air absorption coefficient.

4.455×10^{-12} is the constant for the expression of dosages in rads.

Dosage γ:

$$D = 6.1949 \times 10^{-12} F(x) E_i \Sigma_{\gamma i} \lambda_i$$

F(x) depends on the distance covered, x, and the Pasquill stability categories.

5. Basic Parameters

As we have already said, the purpose of this study is to establish the design prerequisites and zones of exclusion for the installation necessary in order that the radioactive contamination produced by the MAP will remain within the limits specified by the pertinent norms.

We will supply the nominal power of the reactor as initial data, for we will presume that the maximal accident occurs when the reactor is operating at maximal power, 330 MWt, a very conservative supposition, because our hypothesis is that the accident occurs in port.

On the basis of thermohydraulic considerations, we reached the conclusion that the exposure time for the fuel until the first refueling will be about 900 days.

In addition to the norms specified in Section 3, we will take into account some other aspects as explained below:

- No reliance will be placed on the emergency refrigeration.

- Leakages of 0.1% per day from the containment enclosure will be presumed.

- It will be presumed that the filters are 99% efficient for all nuclides, except the inert gases, for which the efficiency is zero.

- It will be presumed that the wind velocity is 1 m/sec with a constant direction, for 48 hours following the accident.

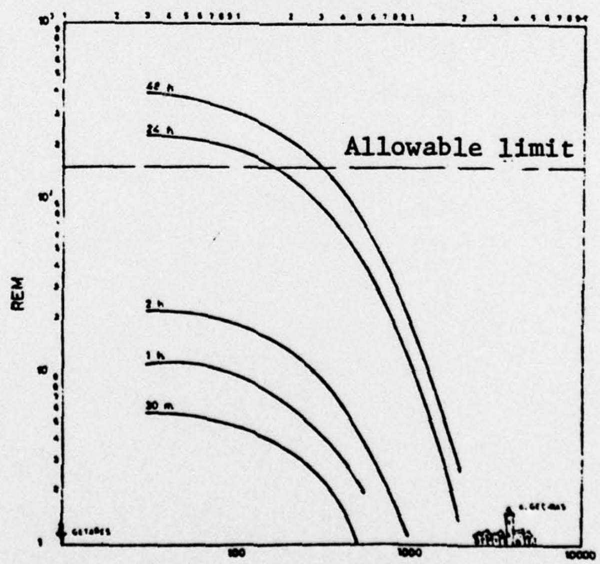
- Inversion conditions (F. Pasquill) over 48 hours will be taken into account.

- Limit areas for 25 rems for 1/2 hour, 1 hour, 2 hours, 24 hours and 48 hours after the accident will be established, and the same will be done for 150 rems (for the thyroid gland).

- Precipitation of the fission products during the accident will not be taken into account.

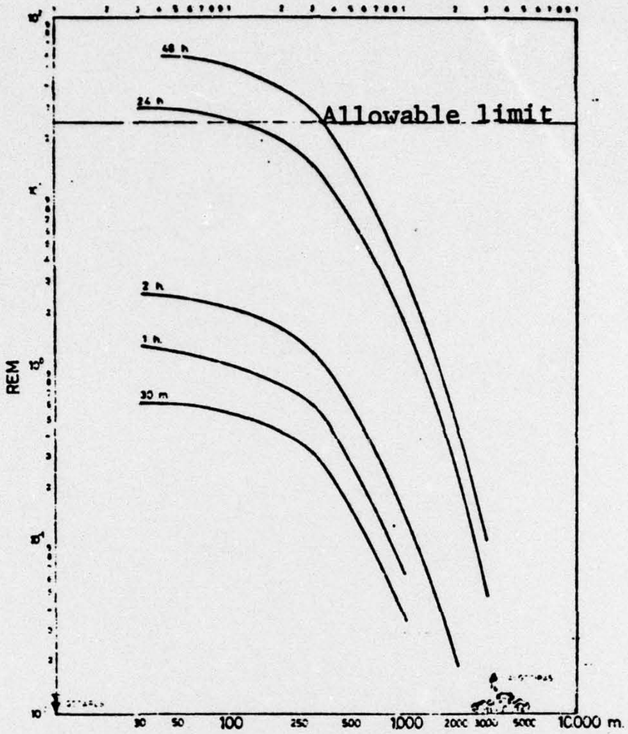
6. Establishment of the Dosages Obtained by Immersion and Inhalation

The product of the ESDORA computer program enables us to establish the following curves:



Thyroid Gland Dosage

Figure 5



Body Dosage (γ and β) from Immersion

Figure 6

This first study was made on the basis of the suggestions in Safety Guide No 14 for a situation in which the pressure development curves in the containment enclosure are not known. It can be seen that an individual remaining on the container platform for 24 consecutive hours after the accident, at a distance of approximately 200 meters from the vessel, would absorb a dosage which, integrated over a period of 50 years, exceeds the allowed limit in Spain.

The authorities in charge can exert complete control over the personnel exposed within a radius of 1,000 meters. The area up to a distance of 2,500 meters from the vessel is uninhabited and the thyroid gland dosage after 48 hours of uninterrupted exposure would be within the range of 1 to 20 rems, or, as can be seen, is not even close to the dosage allowed by the administration. The city of Algeciras lies between 2,000 and 5,000 meters away, and its inhabitants, after 48 hours of exposure, would have absorbed between 1 and 0.0035 rems.

7. Establishment of the Gamma Ray Dosage

The determination of the dosage of direct gamma rays emitted by the reactor is calculated on the basis of the directions in the document TID 14844 published by the USAEC.

The external gamma ray dosage due to the fission products contained in the reactor in the various exclusion and low population density zones is calculated on the presumption that the fusion products liberated from the primary circuit enter the containment enclosure are the radiation source. The isotopes of I (iodine), Kr (krypton), Xe (xenon) and a mixture of solid fission products are taken into account.

(1) TIEMPO	(2) DESTINO	(3) ACTIVIDAD ci	POT γ(W)	POT $\beta + \gamma$ (W)	γ/s GP1	γ/s GP2	γ/s GP3	γ/s GP4	(4) CANTIDAD gr
30 MINUTOS (5)	(6) ESCAPA	1544×10^{3}	3.449×10^{0}	7.845×10^{0}	3.620×10^{13}	4.839×10^{12}	1.386×10^{12}	5.180×10^{12}	9.606×10^{-1}
	(7) QUEDA en R de C.	3.603×10^{8}	1.182×10^{6}	2.235×10^{6}	4.024×10^{18}	5.329×10^{18}	1.385×10^{18}	8.044×10^{17}	1.756×10^{5}
1 HORA (8)	ESCAPA	2.756×10^{3}	6.544×10^{0}	1.324×10^{1}	7.142×10^{13}	9.146×10^{12}	2593×10^{12}	9659×10^{12}	1.920×10^{0}
	QUEDA en R de C.	3234×10^{8}	1.048×10^{6}	1.915×10^{6}	3.830×10^{18}	4.669×10^{18}	1.132×10^{18}	7.131×10^{17}	1.7569×10^{5}
2 HORAS	ESCAPA	4.937×10^{3}	1.187×10^{1}	2.214×10^{1}	1.392×10^{14}	1.654×10^{13}	4565×10^{12}	1.687×10^{13}	3.841×10^{0}
	QUEDA en R de C.	2.865×10^{8}	8.752×10^{5}	1.578×10^{6}	3.617×10^{18}	4.380×10^{18}	8.204×10^{17}	5.548×10^{17}	1.7558×10^{5}
24 HORAS	ESCAPA	3627×10^{4}	5.308×10^{1}	1.010×10^{2}	1.216×10^{15}	8.158×10^{13}	1.408×10^{13}	4.091×10^{13}	4.607×10^{1}
	QUEDA en R de C.	$1.776 \quad 10^{8}$	$4.310 \quad 10^{5}$	$7.740 \quad 10^{5}$	$2.637 \quad 10^{18}$	$2.828 \quad 10^{18}$	$3.253 \quad 10^{17}$	$6.515 \quad 10^{16}$	$1.7542 \quad 10^{5}$
48 HORAS	ESCAPA	5.852×10^{4}	7.015×10^{1}	1.385×10^{2}	1.999×10^{15}	1.119×10^{14}	1.707×10^{13}	4.148×10^{13}	9.210×10^{1}
	QUEDA en R. de C.	1.487×10^{8}	3.375×10^{5}	6.150×10^{5}	2.221×10^{18}	2.169×10^{18}	2.777×10^{17}	3.981×10^{16}	1.752×10^{5}

Table 2. Leakage of Radioactive Products

Key:

1. Time
2. End location
3. Activity
4. Quantity in grams
5. minutes
6. Leakage
7. Remaining in enclosure
8. hours

From a precise point of radiation, an isotope emitting gamma rays, the dosage per second at a distance of d meters, with no interference but the intervening air, is:

$$D\left(\frac{\text{rad}}{\text{sg}}\right) = .985 \times S_o \times F_p \times$$
$$\times P_o \times \mu_a \times d^{-2}[1 + K\mu d]\, e^{-\mu d} \times e^{-\lambda_i t} \qquad (1)$$

wherein:

S_o is the gamma ray source for the isotope under consideration

$$S_o = \frac{q_s}{P} \times 3.7 \times 10^{10} \times E_\gamma \text{ (MeV/sg. MW)}$$

q_s/P is the inventory of saturation (C_i/MW).

E_γ is the total gamma ray energy from disintegration (MeV/disintegration).

$3.7X10^{10}$ is the number disintegration per second in curies.

F_p is the fraction of the isotope under consideration which is released into the containment enclosure by the accident (1 for inert gases, 0.5 for iodines).

P_o is the thermic power of the reactor.

μ_a is the energy absorption coefficient for the air (m^{-1}).

μ is the linear absorption coefficient for the air (m^{-1}).

$$K = \frac{\mu - \mu_a}{\mu_a}$$

d is the distance in meters (m).

λ_r is the radioactive disintegration constant (sg^{-1}).

t is the time after the accident (in seconds).

Integrating the equation (1), one obtains the total dosage at the end of a time period t and at the distances desired, d.

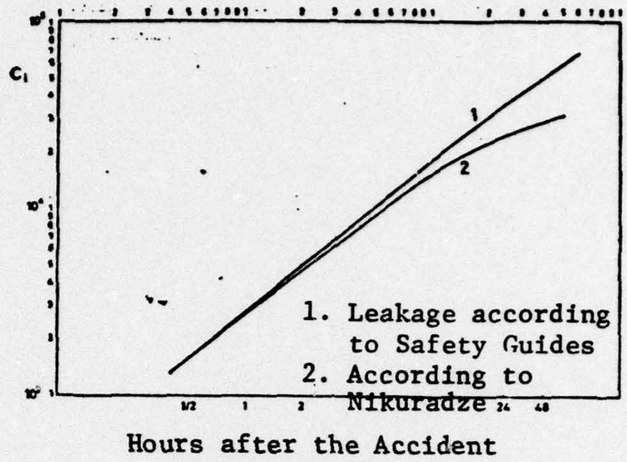
The equation (1) is integrated for each of the isotopes playing a role in the fission. For iodine and the inert gases, exponential radioactive decay is considered throughout the entire time t.

For the mixture of solid fission products, exponential decay is considered for the first two hours, and after that, decay of the type $t^{-0.21}$.

Adding together the results for each of the isotopes, the direct gamma ray dosage is obtained.

All of these calculations were done by computer, using a program written in FORTRAN terminology.

The study made using the Nikuradze formula shows us that the norms in the safety guides are generous for exposure times in excess of 2 hours after



Leakage Curves

Figure 7

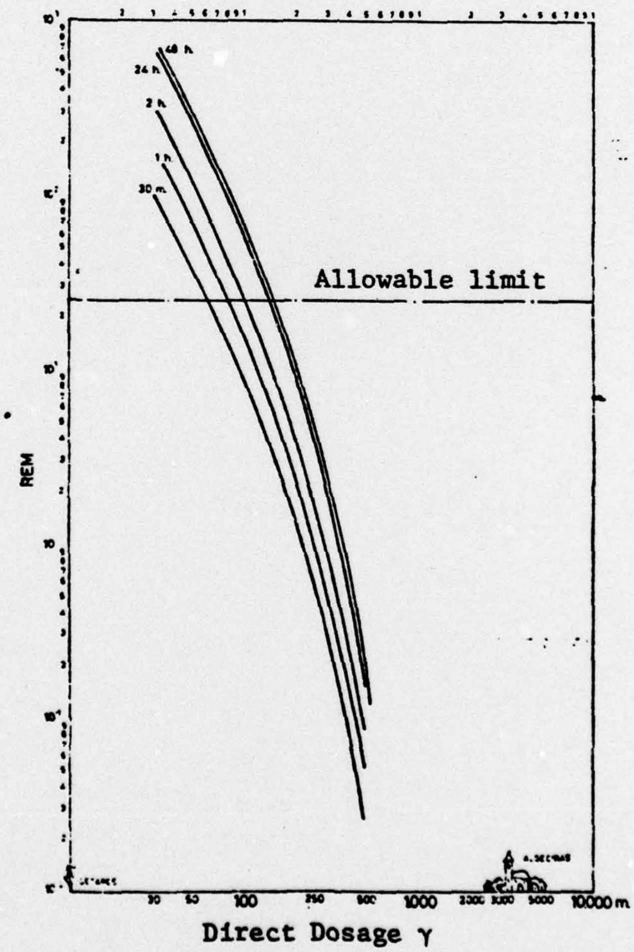


Figure 8

the occurrence of the accident. For times closer to the accident, the two criteria can be regarded as coinciding. Should the circumstances so dictate, we always have the advantage of being able to take the vessel (under its own power or in tow) to a distant anchorage, which would permit us to continue fully normal operations at the Getares wharf.

As possible emergency anchorages, we could use the Ensenada de la Parra or else the Ensenada del Tolmo (la Parra or Tolmo coves), depending on the seriousness of the accident and as the circumstances dictate.

We have represented the leakage functions in log-log graphs, where the difference can best be seen at the end of 48 hours.

A supplementary shields study was made enabling us to establish the decay undergone by direct radiation γ as a result of biological shielding estimated over three decades.

8. Conclusion

1. If an MAP were to occur at the Getares wharf the personnel of the vessel and workers near it would be exposed to nuclear radiation.

2. The dosages allowed by the administration would be exceeded in the following cases:

a. The allowable limit for the thyroid gland by inhalation is 150 rems, which would be reached following 24 hours of exposure at 165 meters from the vessel.

b. The allowable limit for body immersion is 25 rems, which would be reached following 24 hours of exposure at 100 meters from the vessel.

c. The allowable limit for direct gamma radiation on the body is 25 rems, which would be reached 30 minutes after the accident at a distance of 60 meters.

3. It can be seen that the most rigorous requirements pertain to the results of direct gamma rays, but it must be borne in mind that gamma radiation decays very drastically with distance, for at a distance of 150 meters from the vessel, 48 hours of exposure would be required to reach the maximum allowable (25 rems).

At a distance of more than 500 meters from the vessel, the allowable maxima would not be reached even after continuous exposure for 48 hours.

By way of conclusion to the above, we can say that in the event of an MAP, the vessel personnel should immediately abandon ship to avoid exposure to direct gamma rays, proceeding to the decontamination room at the port.

The port authorities should take charge of the situation, preventing anyone from remaining on or transmitting across the docks within a radius of 100 meters of the vessel, and organizing the team equipped with safety gear which would have to board the vessel to carry out the required operations.

The port authorities would take charge of such goods as might have been exposed on the wharf, removing such containers as they deem necessary.

There would be no risk to the workers not exposed to radiation and, naturally, none to the population of Algeciras.

In any case and as an alternative, plans call for the removal of the vessel from the port and its anchorage elsewhere.

BIBLIOGRAPHY

1. Alonso, A. "Introduction to Nuclear Safety," Nuclear Energy Board.

2. Chapter VIII of the 1960 SOLAS Convention.

3. Maritime Administration, Atomic Energy Commission, "Oak Ridge National Laboratory - Nuclear Safety Information Center -5 Norms."

4. USAEC, "Safety Guides."

5. Safety Division of the Nuclear Energy Board, "ESDORA Program and Code."

6. Vickers, "Nuclear Powered Container Ship."

7. British Department of Industry, "Second Report on the Nuclear Ship Study."

8. "Otto Hahn" Project.

9. USAEC, "Document TID-14844."