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HIGH DENSITY ASEISMIC SPENT FUEL STORAGE RACKS

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HIGH DENSITY ASEISMIC SPENT FUEL STORAGE RACKS

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. Why this FRAMATOME/LEMER development ?

. General Description

. Main components of the rack

. Applicable codes, standards and regulations

. Summary of analysis and qualification tests

. Significant results

. Main advantages of this technology

I would like to discuss today a development that has been occuring in France by FRAMATOME and its subsidiary LEMER on high density aseismic storage racks.

I have prepared a number of slides that will show :

. <u>one</u> : why FRAMATOME and LEMER developed this technology,

. <u>two</u> : a general description of the rack,

. <u>three</u> : the detailed main components of the racks and their general characteristics,

. <u>four</u> : the assumptions taken into account for the design,

. <u>five</u> : the analysis and the qualification tests which have been carried out,

. <u>six</u> : the significant results of these tests,

. <u>seven</u> : the main advantages of this technology

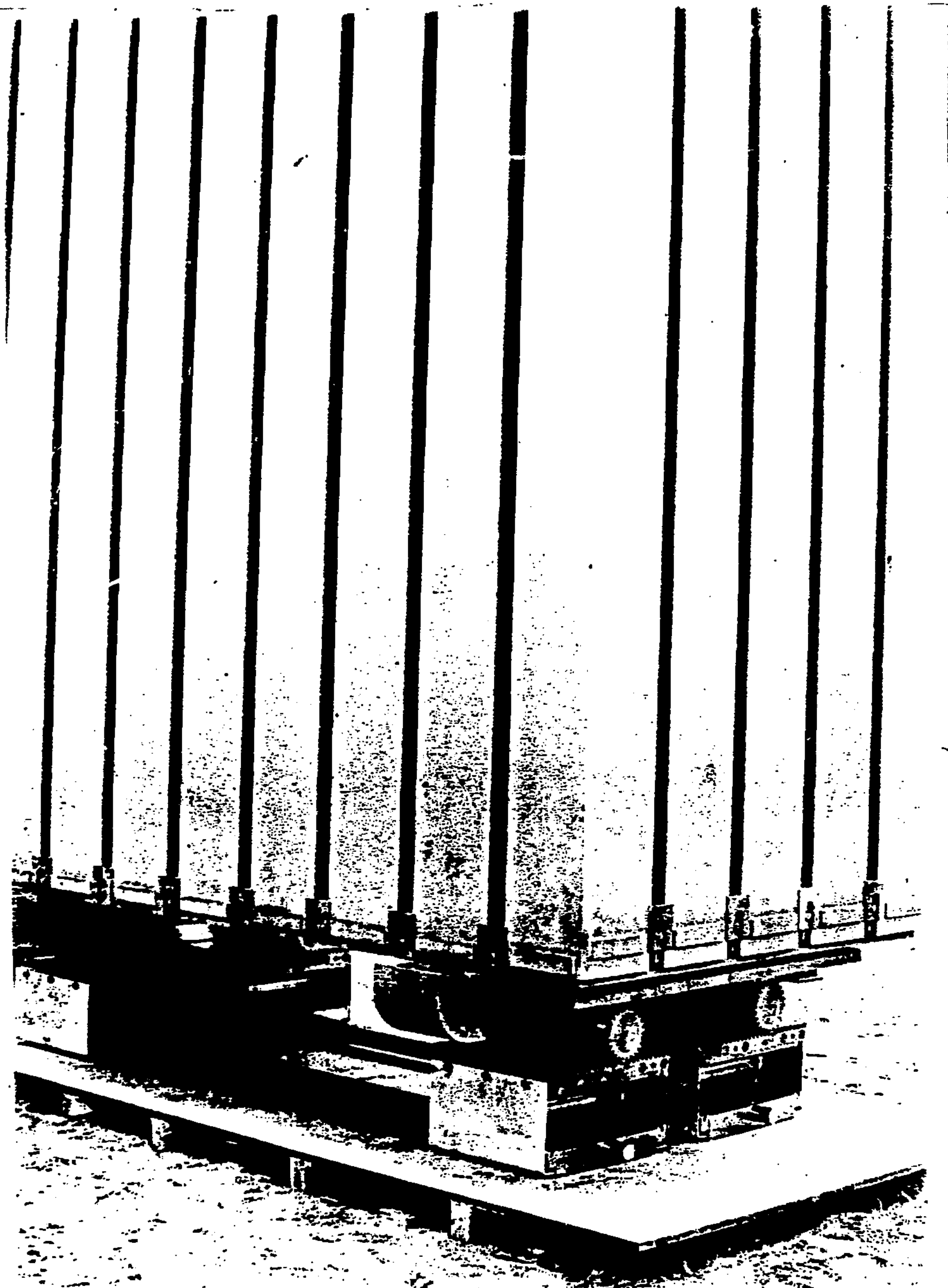
The first theme I would like to discuss is the reason of such a developement.

First, it was to increase cell resistance against adverse environment, because we knew that present day solution for compact rack using materials of a BORON 10 base for neutron absorption can prove to be unreliable when racks are exposed to fuel irradiation in the pool (i.e. corrosion, gas emmission or any kind of deformation due to deterioration of poison material).

Secondly, it was to increase pool storage capacity, targeting a maximum on site storage and designing a compatible solution with the rod consolidation,

Thirdly, it was to decrease loads on the pool walls and bottom, suppressing the rocking movement of the standard free standing racks,

Finally, it was to reduce fabrication, erection and maintenance costs.



In a general description, we can see on this slide that storage modules are made up of three main components :

- CELLS in Cadminox, which have the absorption properties of Cadmium.

- Beneath each module, four ASEISMIC BEARING DEVICES filter horizontal movements created by earthquakes.

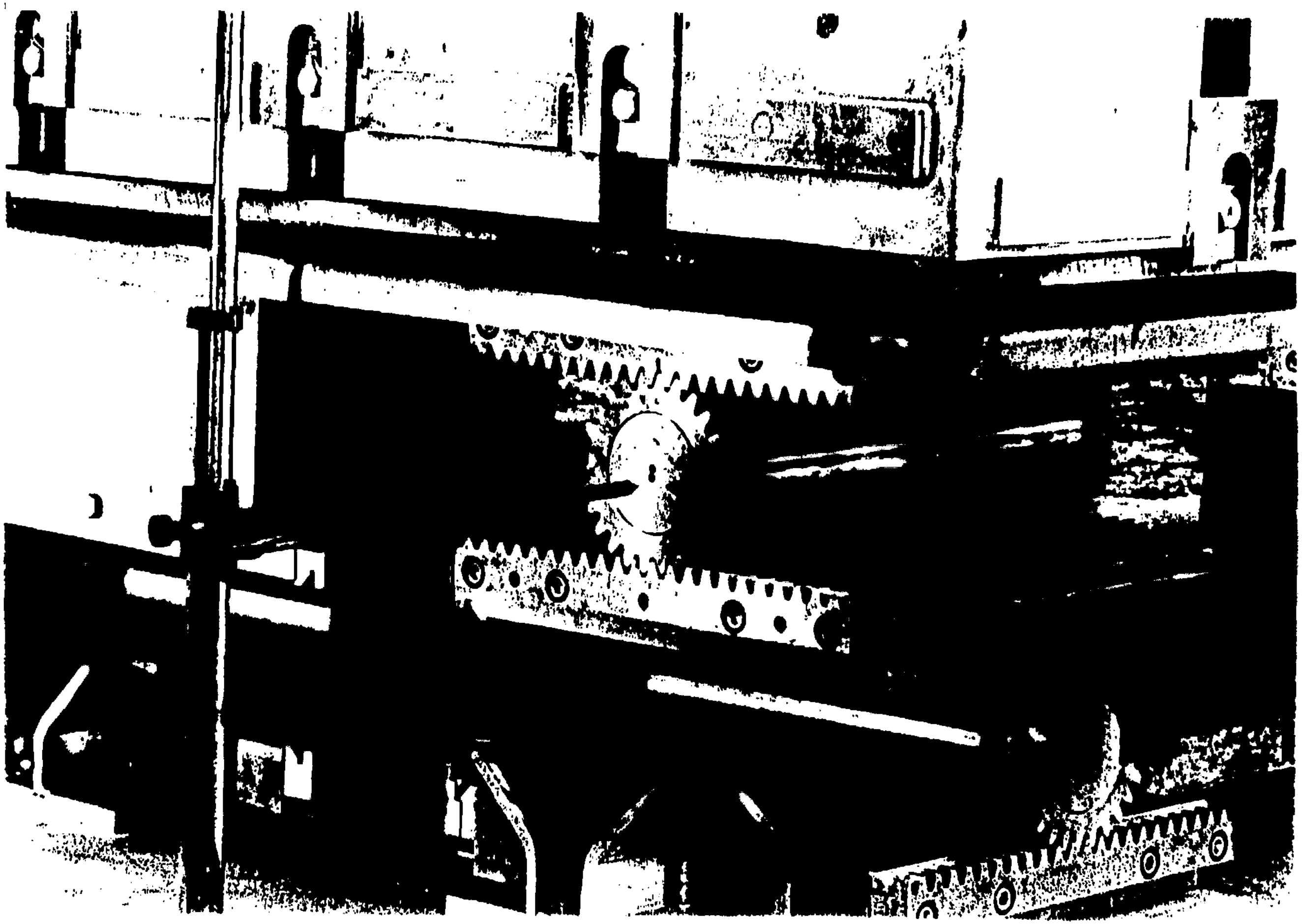
- a CELL LINKING STRUCTURE, in the form of a network of bars contributes to module rigidity and positions the fuel storage cells.

Talking about general characteristics, CADMINOX permits a storage pitch between 260 and 280 mm, to store 4.5 per cent enriched PWR fuel.

On the other hand, 304 L and 17.4.PH are the stainless steels used for rack fabrication.

The number of cells per module varies from 36 to 63, depending on the type of fuel, consolidated or not.

Finally, the aseismic bearing devices are designed with US NRC spectrum. The natural frequency of these devices is below 1 Hertz.



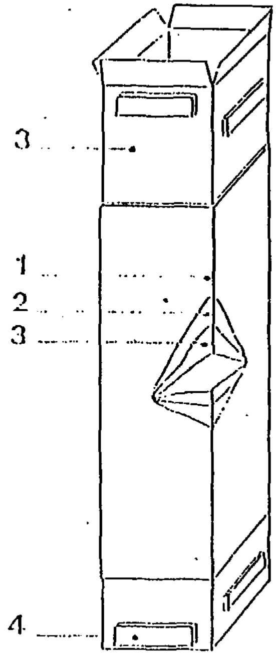
The bearing devices utilize the rolling motion of 2 rollers with orthogonal axes, in 2 horizontal plans.

The shape of the plates or rollers are such that the rolling provokes an increase of the potential energy and a return to the equilibrium due to recall forces.

Guide wheels and lateral stops prevent sliding in the direction of the roller axis. The rack and pinions prevent any change of the roller axis.

FRAMATOME

CELL



1 : OUTER STAINLESS STEEL SHEET
2 : CADMIUM STRIP
3 : INNER STAINLESS STEEL SHEET
4 : BRACKET

Another main component of the rack is the CADMINOX cell. This cell has a square section and a triple wall consisting of :

<u>One</u> : an internal stainless steel sheet.

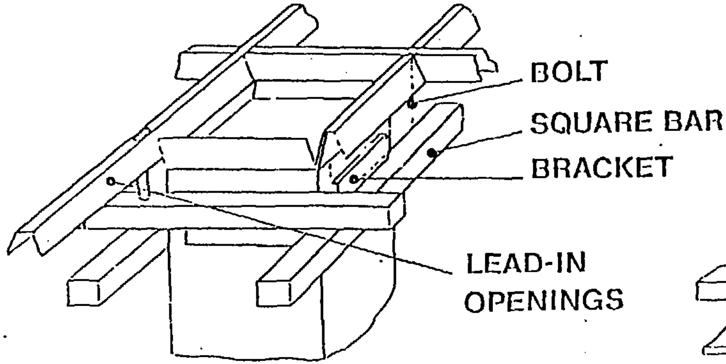
<u>Two</u> : an intermediate Cadmium wall.

<u>Three</u> : an outer stainless steel sheet, which, along with the internal wall, forms a leakproof envelope for the Cadmium.

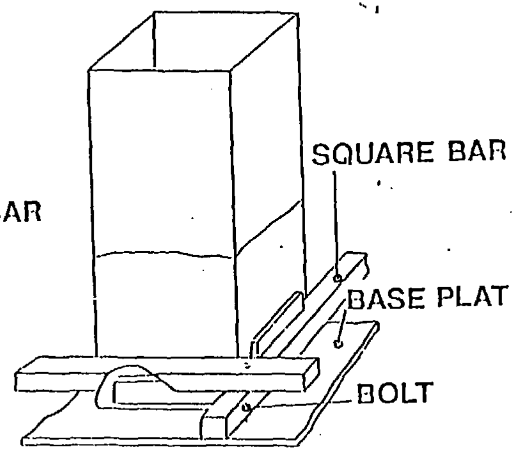
On each face of the cell, brackets are welded to insure the binding of the structure that we will see in the next slides.

ASSEMBLY PRINCIPLE

FRAMATOME



UPPER BAR ASSEMBLY



LOWER BAR ASSEMBLY

The module structure is composed of a base plate and 2 lower and upper bar assemblies.

At the top of the cells, the lead-in openings facilitate an excellent insertion of the fuel into the rack.

The structure is entirely mechanical and does not need any welding to assemble it.

The elements can be easily adapted to different sized modules, depending upon the surrounding factors.

FRAMATOME

APPLICABLE CODES, STANDARDS AND REGULATIONS

- 10 CFR 50 APPENDIX 2-61 AND 62
- ANSI 18.2 1973
- STANDARD REVIEW PLAN 9.1.2
- REGULATORY GUIDES 1.13 AND 1.29
- RCCM, APPENDIX H
  (EQUIVALENT TO ASME CODE SECTION III)

After this description, I would like to show you the codes, standards and regulations used to design this FRAMATOME compact storage rack.

As you can see, all these documents are well known by the specialists.

RCCM is a french code, equivalent to ASME III code.

Different design analysis have been performed.

We can see on this slide most of them :

First, a criticality analysis : Keff has been calculated with 2 computer codes, using the well known Monte Carlo method.

Calculated Keff is always below 0.95, for all different pitches, enrichments and for consolidated or non consolidated fuel.

The conception of the structure facilitates natural convection of water without any air or steam traps.

So, thermal-hydraulics analysis showed that there is no risk of water evaporation and no local increase of th fuel temperature.

Behavior of the rack during an earthquake has obviously been calculated with OBE and SSE spectrum.

Damping, natural frequency, rack displacements, hydrodynamic loads, and forces induced on the liner were determined by these calculations.

Finally, a structural analysis showed that stresses are always acceptable in all parts of the rack.

FRAMATOME and LEMER performed a lot of qualification tests with the French CEA.

The Monte Carlo method has been qualified by a set of critical experiments with 4 PWR elements.

To prove the reliability of the cells in the pool, samples have been irradiated 1 meter from a test reactor core axis by a neutron flux of 10^{13} neutrons per square centimeter, equivalent to a very long exposure to flux in a PWR pool.

Then, Cadminox samples were placed in borated water at a temperature up to 90°C, to test the behavior of Cadmium when an unlikely loss of leakproof condition occurs.

To check the theoretical dynamic characteristics of the aseismic bearing devices and determine their performance in any real earthquake situation, reduced scale models were built and tested in air and underwater on a three dimensionally vibrating table.

In all, more than 20 tests were carried out with diverse loading situations and different combinations of vibrations, even with the eventuality of earth settling into the bottom of the pool.

For example, you can see on this slide a 1/10 scale model of a pool, equipped with racks, which has been tested in air and underwater.

It was obviously of fundamental importance to understand the influence that water has on the performance of a storage facility equipped with aseismic bearing devices.

That is why FRAMATOME conducted full size tests in a pool. They made it possible to quantify the hydrodynamic linkage between the racks and the walls.

Now, I have to talk about the significant results of all these tests.

<u>One</u> : for criticality : the calculation is conservative in comparison with the experiment. The real value of the effective multiplication factor is situated in the interval Keff ± 2 sigma in 99.93 % of all cases. This agrees with the NRC position for review and acceptance of spent fuel storage applications.

<u>Two</u> : for irradiation, we measured that Cadminox activation is the same that for stainless steel.

There is no gas release and no deformation of the cell geometry.

Under normal conditions, corrosion of the cell is that of stainless steel. If an unlikely loss of leakproof condition occurs, we measured that :

- corrosion is possible only in the immediate proximity of the opening.

- rate of corrosion, for an accidental breach of 80 mm^2 remains below 4 microns per year at 25°C. Therefore, the Cadmium plate would dissolve after a period of 100 years.
- this rate of corrosion increases only by 10 % when temperature rises to 90°C and only by 60 % when the opening is multiplicated by 3.

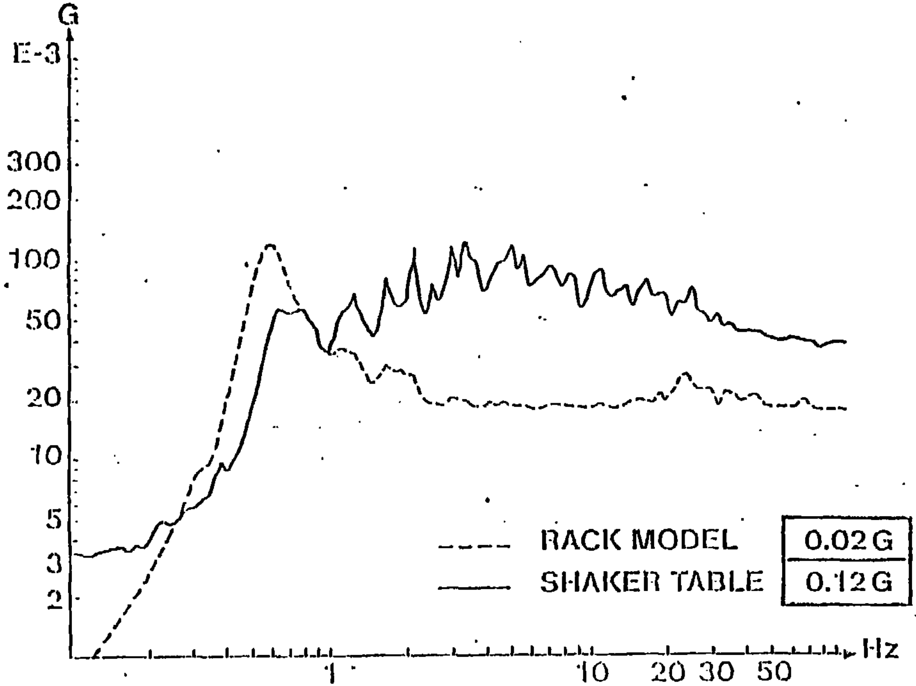
Concerning the seismic behavior, tests proved that :

- calculated and measured frequencies agree, whether or not water was present,
- horizontal accelerations are filtered in the order of 6, and vertical accelerations are not amplified.

Good filtering of horizontal accelerations can be seen on these curves.

Despite strong vertical vibrations, the horizontal movements and filtering capacity are absolutely unaffected.

HORIZONTAL ACCELERATION FILTERING



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In conclusion, I would like to bring out again the main advantages of this technology.

- Cadminox is very stable under radiations and in the pool water. Compared with the others, this neutron absorber put forward by FRAMATOME has a better behavior,
- If an unlikely breach occurs in the sandwich CADMINOX, salts of Cadmium are very quickly checked in the pool, that means an easy and non expensive in-service inspection as required by R.G. 113 proposed revision 2.
- If necessary, dismantling and reparation are simplified due to the assembly structure without welds.
- Then, by significantly reducing demands upon buildings and structures, it is, thus, more reliable and economical.
- Finally, this solution can be adapted to all new or existing installations, even when the utilizer takes into consideration the burn-up of fuel, thus dividing the pool into several sections, each having an adapted pitch and neutrophageous shields.

At the same time, storage of consolidated fuels is possible thanks to the aseismic bearing devices.