SAFETY REQUIREMENTS FOR FRENCH REACTORS

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I - BASIS OF SAFETY REQUIREMENTS

We have in France some legal prescriptions in order to assume the protection of the public against the risks from the nuclear reactors. Our basic safety health standards are precisely defined, but could change if new knowledge justifies it.

As for examination and authorization of nuclear reactors, legal texts are general enough to let a large place to the application by specialized Commission and Groups. Taking into account the studies and experience, we have now some requirements that I shall detail thereafter. But an evolution is always possible, and the severity depends on the context, especially on the population density. Concerning that point, we have taken till now to choose the most distant sites from towns (1).

II - AUTHORIZATION PROCEDURES RECALL (2)

From the December 11, 1963 order ("Décret du 11 novembre 1963") (3), the reactor "creation" is subjected to an authorization pronounced by an order (legal text for the government) after an advice from a
Commission where the different Ministries involved, the "Commissariat à l'Énergie Atomique" and the utility ("Electricité de France") are represented. This Commission may require to be assisted by all specialists needed, especially those from Nuclear Safety Department ("Département de Sûreté Nucléaire").

The "Authorization of Creation" is promulgated by an order specific for each reactor (4). The Practice is to precise in this order the technical prescriptions which are imposed and the documents that the utility will have to present. These are essentially the safety report, operating procedures and the tests results from the precedent step of the start-up, from which the responsible Authority allows the utility to start the next step, from the building completion until the commercial operation of the plant.

Inspectors verify the conformity to the technical prescriptions during the operation. Specialists from the Health Ministry ("Ministère de la Santé Publique") monitor the environment radioactive pollution.

**III - REQUIREMENTS CONCERNING THE RELEASES**

The irradiation of the public caused by the releases of radioactive nuclides is precisely limited by the order of June 20, 1966 (5). This order details also the maximum permissible concentrations of the different nuclides in air and water. Generally, the values are not very different from those given in the International Recommendations: for example 0.5 rem per year for the whole body, 1.5 rem per year for the thyroid.

We may observe that the limits for the public are given as yearly limits without requirements for the dose rate. The study (6) shows that the single intake of the radio-isotopes quantity, corresponding to a continuous exposure at the maximum permissible concentration during one year, does not lead beyond the permissible dose, on the condition that this massive absorption is the single one in the year, of course.
From the maximum permissible dose introduced in the preceding chapter, it is possible to judge if a plant can be authorized from the calculation of the propagation of the fission products. It is well understood that from the safety point of view the normal operation of the plant includes all the transients and the events, the frequency of which could be smaller than one per year, or more precisely accidents after which the re-starting does not require important repairs.

We do not impose a method to estimate the releases. We have in hand some detailed programs (7) in which the most present conservative values have to be utilized. We examine attentively each barrier against the fission products (8), and the eventuality of its failure leads to provide:

- an other barrier in parallel (for example we double some ventilation elements), or

- a scram of the plant and all the dispositions in order to assure that the failure has no remote effects.

We find here the particular importance of the scram and naturally of the cooling of the reactor in all circumstances.

If this scram and consecutive dispositions are not sufficient enough, and if the fission product release is important, we are in the case of severe accident which will be studied in the next chapter.

The seism is a special case. The common use is to consider that after a seism with the same intensity as the maximum known seism in the place, the plant could re-start after minor repairs. In other words we can say that the releases are not larger than those corresponding to incidents we spoke before. For an intensity higher of one unit in the Mercalli scale, we fall into the case of severe accidents studied in the fifth chapter.
The problem of the missiles has to be mentioned too. The internal missiles coming from rotation machines, pressure pipes, vessel closures, gas jets ... should leave undamaged the essential functions as scram, cooling of the reactor and fission products containment. Till now, we have not a systematic position concerning external missiles. Tornadoes are not very violent in France, and therefore only the fall of plane or of parts of a plane is to be considered. We have chosen our present sites far from the ways often frequented by planes, and we consider that the possibility of a crash on a part of a plant important for safety is too small to take that case as a possible accident. The necessity of new sites which could be less favourable will probably lead us to reconsider this position.

V - CASE OF SEVERE ACCIDENTS

As we said earlier, the failure of a barrier protecting the public from fission products could lead to situations where the scram of the core is not sufficient and where the dose legally permissible could be exceeded. For the study of the consequences of such a failure, it is necessary to consider the initial accident, because other elements could be damaged at the same time. The evaluation of fission products release is done, taking into account the accident conditions closest as possible to those previsible.

Practically, the choice of these typical accidents and of their development is made jointly by the project team and the Nuclear Safety Department ("Department de Sûreté Nucléaire"). Depending on the case, the characteristics of some safety devices could be voluntarily underestimated (filters for example); sometimes, even their misfunctioning is supposed.

Of course, and as the International Recommendations point out (9), we cannot fix limit doses for accidental irradiations, but only intervention levels to start the protective measures. These intervention levels vary with the characteristics of the site; reference levels are
nevertheless fixed in some countries and are mentionned in the TCRP's Recommendations.

Systematically, our aim is to reduce the consequences of the typical accidents for the public by using technical devices included in the plant. If these devices are adequate, i.e. if calculated doses are well below the reference level mentionned in the International Recommendations for the vicinity and the whole population, the project is accepted. A dose of the same order as the reference level already mentionned is accepted only if a few people are concerned (or a low agricultural production), i.e. if measures as evacuation or banning of food stuffs could be envisaged; these measures give a good confidence against the uncertainties of the real accident compared to the calculated one. The importance of the population density near the plant is found here. If these devices are not sufficient enough, or too expensive for the overall economy, the project must be re-considered.

VI - OUR POINT OF VIEW ON HTR's SAFEGUARDS

As an application of what we said, we shall give here our advice on different HTR's safeguards. Of course, we could change of mind if our knowledge of the subject changes.

VI.1. Reactor scram

In all cases, we have to be able to stop the nuclear reactions. This general aim could be assumed by a single type of device under the following conditions :

- the failure of the control rods power supply results in a scram; this is the case if the rods could fall under gravity

- the number of the modes of control should be sufficient and their failure results in a scram (actuated by loss of tension)

.../...
- total independance of the different rods or groups of rods
- the failure of the most efficient rod (or group of rods) should not prevent the scram.

A special attention should be paid to the rod introduction reliability: guiding, alignment of the moderator blocks, stability of the core under accident conditions (including seisms).

We notice that the High Temperature Reactors do not need a rapid scram (introducing of rods lasts from two to three minutes), which is an important safety advantage.

VI.2. Shutdown cooling

Independently of fuel re-utilization, keeping it at a sufficiently low temperature in order to retain fission products is an essential safety condition. So, shutdown cooling has to present a very high reliability; for this, we need on the site all that is necessary in superabondant quantity: power source, circulation and cooling of the gas, heat rejection, control of these functions, and their availability under all conditions, comprising earthquakes and previsible environmental disturbances, particularly radioactivity after an accident (control room especially).

We may consider two types of cooling:
- using the normal system, with adequate secondary sources; this resolves the periodic tests problem, but leads to other particular problems when we want to be sure of the independance of the different elements, taking into account the necessary commutations of the energy sources
- using special loopstotaly independant of the normal system; so we can reach a high reliability, but the isolation of these loops during normal operation is not easy.
For us, for a same degree of reliability, the choice should be economic, taking into account all that is necessary for the shutdown cooling, and including the lay-out (vessel concept allowing the loops installation, for example).

We note here that the shutdown cooling reliability is relatively easier to ensure on HTR core due to the good thermal resistance and the importance of corresponding starting delays.

VI.3. Vessel closure technology

The use of a primary circuit fully integrated in a prestressed concrete reactor vessel gives a good gas containment safety. It needs that the closures of the different penetrations offer a safety comparable to the vessel's one. More especially as the use of helium does not allow a loss of pressure through an equivalent orifice of a diameter larger than 0.2 or 0.3 meter, otherwise you risk important mechanical failures in the internal structures.

In order to have a good closure conception, some simple principles (10) reminding those of the prestressed concrete can be stated:

- tensile stressed pieces have to be long and superabondant, protected, inspectable if possible
- the corresponding forces should be transmitted to a resistant part of the vessel
- the massive pieces should undergo essentially compressive stresses
- the possible impact of an other piece should be considered.

If the study of the radioactive release shows that the tightness of the vessel is not essential for the safety when one takes into account the other devices, the above principles could be observed only for flow limitors in series with the tight closure (up stream if possible).
VI.4. Containment

In order to protect material and the staff from the bad weather and to sustain the cranes, a building around the reactor is necessary. So, it is evident to try using this building to contain fission products that could escape from the circuits.

From what we know concerning the fuel and from a recent study (H), it seems necessary to release the small leakages, occurring inside the containment from the circuits, only through a high stack, preferably after a filtration. For this, the ventilation circuit should maintain an under pressure in the building which is then required to be relatively tight. Two types of containment can be envisaged, depending on their behaviour under the pressure resulting from the release of all the primary gas:

- the containment sustaining this overpressure is the most classic. Apart its cost for building and maintenance, it leads to numerous subjections (12) during the building, the interventions or repairs on the reactor, the leaktightness tests... In order to get a real benefit, the actual leaks in accident conditions should be very small, which seems difficult to ensure, unless recovering the leaks, which leads to a double containment, even more expensive.

- the containment sustaining only a weak overpressure should be protected against a rapid loss of pressure from the primary circuit by exhaust flap systems on the roof of the building. It does not present the disadvantages we have seen, and the buoyancy of helium transports the fission products rather high in the atmosphere during a uncontrolled loss of coolant (13); this gives a dilution of the same order as the one of a high stack. It is not evident that the corresponding dose would be larger than the one from the non filtered leaks of a containment sustaining the overpressure.

In brief, and considering the rather favourable sites we dispose of for the moment, we think that a containment sufficiently leak-tight
to allow the ventilation is essential; the containment of all primary gas is not imperative if the release calculation is favourable.

VII - CONCLUSION

The evolution and the variety of the reactors studied in France have not permitted us till now to write precise criteria. From rather general rules in order to maintain the public irradiation within fixed limits, we have seen that the experience and the studies lead us to efficient dispositions.

Till now, and for each reactor, we managed a constant evolution of procedures and safety requirements. This evolution will be accelerated considering the estimated number of reactors and the future rarefaction of sites favourable to safety.
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