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ATOMIC ENERGY

The attached Note has been circulated in view of the growing significance of the possibilities of atomic energy for the generation of power and other peaceful uses in underdeveloped regions. The contents, which suggest that the use of atomic energy may well soon be brought within the reach of underdeveloped countries which are poor in natural energy resources, are made available so that Member States who may be interested can pursue further enquiries with experts from the organization which supplied the Note who will be available in Nairobi during the session to answer questions and explain more fully such technical aspects as delegations may wish to obtain.

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Memorandum

Concerning the question of pressure-vessels for reactors of great atomic power plants.

General Considerations

The production of electrical energy by reactors has been known for a long time and the production of electrical energy by nuclear energy is beyond all doubt. Therefore, the construction of atomic power plants will grow more and more important, not only in Europe but especially in those countries in which basic materials for energy gain like coal and water are not sufficiently on hand.

Therefore, the erection of atomic power stations, for instance in the African countries will be of increasing interest.

In the past atomic power stations have been built especially in America, Great Britain, France and Russia, the pressure-vessels of the reactors being constructed in steel. As the reactor efficiency grows, so grow the difficulties of the construction of such steel pressure-vessels. Consequently, one already changed over to build vessels in prestressed concrete instead of in steel.

The reactor sheathing is stressed on one hand by the temperature and on the other hand by the pressure in the reactor.

The necessity to develop great efficient reactors is strongly connected with the question of economy and so it will be necessary in the future to build efficient reactors according to new aspects.

If the known way to construct pressure-vessels will be continued the results of increasing reactor efficiency will be dimensions of structures which, considering the needed pressures and temperatures, can no longer be provided by steel or reinforced concrete structures. Considering this fact, prestressed concrete structures have already been built in Great Britain and France which, however, with increasing electrical output are no longer sufficient and have disadvantages with regard to economy.

Therefore, the European industrial countries are seeking since a considerable time for profitable solutions for the construction of more efficient and, therefore, more profitable pressure-vessels. The technical solution described in the technical exposé won the attention of EURATOM which promotes the further development until accomplishment maturity.

The advantage of the new structure is that for instance in the African countries the otherwise necessary imports of thickwalled steel-vessels will cease and modern prestressed concrete structures can be erected employing local products (cement, gravel and sand).

We are prepared to give governments interested in such reactors in connexion with our engineer consultation together with the inventor of the new type of prestressed reactor pressure-vessels, Herr Obering. Bremer, every technical support in building such reactors provided that the know how is available and no further research and development programmes have to be performed which would require additional expenditure.

Exposé

To a new type of prestressed reactor pressure-vessels

Known prestressed concrete pressure-vessels principally consist of a thickwalled standing or lying cylinder with an upper and lower plane or spherical slab.

At present the static calculation of such thickwalled short cylinders is extremely difficult owing to the fact that there are no exact analytical calculation methods. The prestressing cables necessary for production of compression tension are extremely heat-sensitive as an increase of heat leads to an expansion of the prestressing cables resulting in a quick decomposition of the compression tension. As to known solutions there must either be provided a very effective cooling on the inside of the vessel or the concrete strength must be increased so much that the temperature in the region of the prestressing cables does not result in an essential loss of compression tension. The design suggested eliminates the above described difficulties and confusions. It provides to dissolve the thick wall of a prestressed concrete pressure-vessel into one with several layers, each of which has its own special function. Thus the difficult problem of a correct static calculation is solved, the structure in comparison with the size of the vessel now being considered as thinwalled ones, the solutions of which are known. Also the control of the lateral disturbances at the transition to the upper and lower slab can now be more easily treated mathematically. The lateral disturbances at the transition to the upper and lower slab can be controlled employing programmed two-dimensional differential techniques. This does not only apply for tensions as a result of compression tension of the vessel but also for thermoelectric stresses, no matter if they are produced by heat radiation or nuclear induction. The possibility to be able now to calculate the compression process in a vessel, no doubt increases the safety of a vessel, respectively gives the possibility to judge it more clearly.

Principally the suggested solution is the following:

From the centre outwards the wall is dissolved into an approximately 1,50 m thick layer consisting of a special concrete the function of which is the photon absorption and partly also the neutron absorption, respectively, the energy changing of the neutrons. In order to achieve the gas and flual density the two outer skirt surfaces are furnished with a steel liner in the usual way. In order to decompose the temperature gradient occurring from the centre outwards, the outer skirt surface of the special concrete is lined with a temperature isolation which decomposes the gradient so much that the produced bending moments can be absorbed by unstressed reinforcement. Principally the temperature isolation, too, could be located at the inside of the vessel. Absolutely seen, the advantage would be a low medium temperature, the disadvantage, however, a higher temperature gradient owing to the ray-induced heat. Comparative calculations employing known gas-type reactors as reference reactors have shown that in the case of outward temperature isolation the gradient is about 12°C to 15°C lower than in the case of inner temperature isolation. The bending moments produced by the gradient, however, having to be kept as small as possible (because of optimum shielding effect) outward isolation must be preferred. Then indeed the medium total temperature in the inner cylinder is higher but it produces only compression tension, the increase in length in the vertical direction can be absorbed by movement gaps.

The special concrete suggested contains materials in the density spectrum of D = 1,00 to 5,0 gr/cm^3 in suitable composition. The linear temperature expansion of the tempered concrete is almost as great as that of steel. Thus unwanted separation of adherence between cement stone and steel does not occur in a high temperature field.

After this first inner shield follows a layer of water which is about 60 - 80 cm thick. This layer of water fulfills several functions. Over a special principally solved design it is under the same pressure as the inner vessel so that from this load condition the inner shield remains tensionless. The heat flowing through the inner shield and the thermal dam into the water is transferred to the outside by a secondary cooling system located in the water so that the water cannot heat itself beyond 50°C. This temperature which affects the outer real prestressed skirt, is, as learned by experience unimportant for the prestression. Here the thermal neutrons penetrating through the inner skirt into this layer of water are absorbed. The skirt represents the real prestressed part of the vessel. Owing to the suggested design it is not subject to any influences or stresses except the gas-pressure coming from the reactor and can be calculated, designed and built employing conventional techniques. Its only function is to absorb the operating pressure transferred from the inside through the layer of water.

It is the aim of this suggestion to design a vessel which because of the possibility to calculate all tensions rising from the reactor operations has a higher or better predictable safety grade and because of less material being used also has to be cheaper than vessels known up to now. As the dissolution into thin layers also means lower tension at constant pressure compared to a thickwalled vessel, higher operating pressure in the inner vessel is controlled.

For various reasons other thoughts can be taken for a basis for the safety considerations of the vessel than for very thickwalled vessels built and designed up to now. The now suggested solutions can be exactly mathematically controlled. This allows to include the much higher material solidity in the two - or three - dimensional tension fields in the safety research. All parts of the suggested vessel are at least in a two-dimensional tension condition. What concerns all prestressed concrete pressure-vessels built up to now, because of the calculation uncertainty for very thickwalled structures, the uncertain tension process owing to temperature, shrinkage and creep, safety factors between $v = 3 - 3,5$ have been chosen. Up to now common regulatives do not exist in any country.

It is clear that for a design for which for each reactor operating condition the tension can be exactly predicted lower safety values can be admitted, moreover even when producing smaller quantities a higher regularity of the material can be guaranteed.

Thus the suggested design for a prestressed concrete pressure-vessel must not only lead to safer but also to cheaper vessels.

The design can be applied to gas-cooled reactors as well as to high pressure water reactors.

Summary

All solutions for a prestressed reactor pressure-vessel built and known up to now principally consist of a thickwalled cylindrical skirt with a plane or spherical upper and a thickwalled lower slab. In order to prevent an excessive temperature gradient in the thickwalled structures, there must be an intensive cooling on the inside of the vessel. Moreover, too high a temperature in the region of the prestressing cables would lead to a very quick decomposition of the compression tension.

The static calculation of such thickwalled vessels is extremely difficult. Up to now exact solutions are not known.

It is planned, therefore, to design a vessel, the wall of which is dissolved into several independent layers. Each separate layer has its own specific function. From the centre outwards the following dissolution is planned:

An about 1,50 m. thick layer of a concrete of very high density with a high level of hydrogen. Its function is essentially the absorption of the gamma photons and the energy reduction of fast and medium fast neutrons. A layer of water, which is about 60 - 30 cm. thick follows. Its function is to transfer the heat flowing through the first layer to the outside and to absorb penetrating thermal neutrons via a special device it is in pressure

balance with the inner vessel so that the first layer of this load case alone is almost tensionless. Only after this layer of water outwards lies the 1,20 m. to 1,50 m. thick shell of the real prestressed concrete pressure-vessel. Now it is free of temperature and radiation influence and can be designed and calculated employing conventional and known techniques. In order to control the lateral disturbances at the transition to the upper and lower slab, known computer programmes for two-dimensional tension fields can be used.

There are new aspects for the safety considerations which allow now to build not only safe but also more profitable prestressed concrete pressure-vessels. This applies for gas-cooled reactors as well as for high pressure water reactors.

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