CONSIDERATION ON THE MECHANICAL DESIGN OF COMPONENTS FOR BWR-FUEL ELEMENTS 64 ROADS TYPE

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ABSTRACT

A description of the basilar criteria followed during the design of mechanical components for a BWR Fuel elements, is given.

These criteria are mainly mechanical and permitt to obtain some stresses that must be compared mitt the allowable maximum nuclear ones.

1. GENERAL REMARKS

An element of this type can be viewed as constitued by a set of 64 zircaloy tubes 2.900 mm Long, arranged on 8x8 square matrix. The external diameter of the tubes is 15 mm, as the pitch is 19,3 mm.. The tube nest is hold at the ends by two elements: a lower nozzle with mothpiece in the bottom plate of the reactor core, and an upper plate with coupling handle.

Because of the length of the fuel filled tubes, that in this case is 2.900 mm, elements are to be inserted between the tubes. Such elements must maintain unchanged the distance between the tubes, have a good thermohydraulic perfomance and prevent vibrations of the tubes themselves. In this kind of reactor these mechanical elements take a pretty compact shape, do not depend on the zircaloy rods and, from the resulting appearance, are usually named grids.

By referring to an elements of 64 rods B.W.R. fuel, for the different above mentioned components we shall discuss the design and realization criteria that have been adopted in order to obtain a reliable performance from the point of view of the mechanical strength.

The design of the zircaloy clads, which involve problems related to the release of fission gases, to the construction accuracy of the pellets and to the assemblage, will be excluded from this communication.

Therefore, for the zircaloy tubes will be assumed the thickness which furnished satisfactory pratical results in previously experimented reactors.

2. UPPER PLATE

Two conditions may be distinguished:

A) during the operation of the reactor, it has the task of keeping assembled the upper ends of the element, of supporting the 160x160 external protection clad and of allowing the flow of the cooling liquid with loss of pressure as little as possible. The metallic mass of this component should be as low as possible.

B) During the assemblage in the factory, transportation, installa tion and extraction from the reactor itself, it has to support the weight and the dynamic stresses of the whole element. The stresses come from 8 particular rods with threated ends, through which the weight of the whole element is released. In this case, the plate has the function of conveying this load towards the coupling by means of two stay rods (see fig.1 and 2).

From the above conditions, it comes that the stresses originate almost exclusively from point B).

The load conditions which require a certain mechanical dimensioing of the plate thickness are anthitetical to the requirements shown in the second section of point A).

The maximum design effectiveness is reached by bringing to Ø 16 mm the diameter of the holes for the passage of the liquid. With this diameter a passing section of the liquid is obtained that is approximatively equal to the section between the rods (fig.1).

The height of the plates results to be 20 mm from a cautious mechanical computation, made with reference to the more stressed section between two holes.

The distance of the two stay rods, that initially was 83 mm, has been increased to 137 mm, in order to come nearer to the plate edge, just where the loads are applied.

This kind of plate presents remarkable theoretical difficulties of computation, besides the high number of holes, it must be considered that the way the 8 loads are applied to the edge, makes it very different from the plate supported on the 4 sides (fig. 2).

Necessarily, our design has been of theoretical-experimental type. By using real dimensions test sections, a research has been developed, to note the agreement with the theoretical popo sed models (fig. 3).

In the more difficult cases, the initial yield has been recorded in the most stressed sections shape factors, dimensional and safety coefficients have been introduced in order to assure, also in these cases, the running safety necessary to such kind of components.

The construction of the upper plate can be easily carried out, starting from round or rectangular rods and subsequent mechanical processing. To the purpose , techniques have been developed that aim at reducing the material to be removed as much as possible (fig. 4). The holes according to their use, have different finishing and tolerance levels.

The holes for passig the liquid can be easily obtained using multiple drilling heads with the same passage are made also the peripheric holes and the cut along the diameter is carried on to obtain the bearings for the outside jacket.

3. GRID

Various types of spacing grids have been examined to determine the selection of the grid more satisfying the required characteristics (fig. 5).

In short, we can say that the points that were to be realized in the project and whose validity has to be shown, are the following:

1) The grid must be realized with lamellar elements arranged in the direction of motion of the liquid in order to minimize the loss of pressure (fig. 6).
2) The contact between zircaloy rods and grid elements must always be linear, i.e. between cylindrical surface with parallel axes in order to obtain low specific pressure (fig. 7).
3) The grid must be realized as a rigid body able to furnish rigid bearings and pressure springs in order to keep the fuel rods pressed against the rigid bearings.
4) The location of the rigid and elastic bearings must be realized according to triangular (not quadrangular) pattern having care that the triangle be near to balanced triangle (fig. 7).
5) Each alveolus where a zircaloy rod will be stuck, composed by two elastic and one rigid bearings, must have its own

rigidity indipendently from what surrounds it, in the sense that a safe locking must be found in each alveolus whether a zircaloy rod exists or not in the nearby alveoli.

6) Each time that structural parts of the grid get near to the rods, for instance acting as support, the angle between the zircaloy tube and the grid frame (as seen in plan) will be made as wide as possible in order to facilitate the downflow of the liquid (fig. 7, and angles).
7) The outside cage and the shape of the grid must assure the maximum uniformity of the velocity distribution of the liquid, avoiding as much as possible low downflow at the borders of the fuel element.
8) The grid must have a certain degree of asymmetry so that it may have at disposal contiguous grids that are mutually rotated of 90°, which will present advantages with regards to the vibrations and the velocity distribution.

As for the construction, two trends are to be followed. A first in which the material undergo to moderate plastic strains, due to the pressing. To this purpose for instance, it is necessary to perform a greater number of weldings in order to apply the rectangular tanks on the sheets where the rectangular holes have been shorn. This type of grid is made realizing the connections through E.B. (fig. 8).

Moreover a second construction technique has been experimented, that aims at reducing the number of weldings by obtaining the parts directly from the stamping, as much as possible. The pieces will be obtained through a deeper drawing but the connections will be realized with T.I.G. system or plasma (fig. 9).

The construction cycle for a grid may be briefly reduced to the following operations:

1) Preparing of the 8 elastic elements by welding 3 sheet pressed elements.
2) Preparing of 7 rigid elements by welding lamellar elements pressed with the rectangular boxes (sol. 1) or by directly pressing the whole element.
3) Preparing of the two types of body side.

The assembling of the groups realized that way is developed according to the following cycle:

I) Fitting up of the external part of the grid through the junction of the two body sides on a proper bearing box.
II) Installation by means of bearing guides of the elastic and rigid elements.

Mechanical cold tests performed on the grid, have confirmed the strength obtained from the design computations.

The parts made with AISI 304 steel are subjected to a maximum stress of 5-6 Kg/mm^2 during the assemblage, as the elastic element called corrugated frame spring, to be made in NIMONIC 80A, reaches stresses of about 30 Kg/mm, in the most serious conditions.

Hydraulic cold tests have shown a good behavior as for the pressure losses (Tab. I).

Also the velocity distribution has been satisfactory as for the level of local and general uniformity.

Fig. 10 show a characteristic curve obtained with small Pitot tubes running from one side to the other of the grid in a test fuel element entirely assembled on scale.

4. BOTTOM NOZZLE

In practice, stresses act on this element exclusively when it is installed in the reactor.

The weight of the rods, that is released on the bottom circular support through the body sides, bears on the drilled plate.

Moreover, during the operating conditions a pressure od 1 Kg/cm^2 with respect to the outside takes place on the inner body of the nozzle.

This state of stress and the requirement of minimizing the weight of this component have been considered to reach its realization through the welding junction of 3 intermediate forgings, which, after homogenizing, are finished within the prescribed tolerances (fig. 11).

Unlike the already mentioned upper plate, the nozzle plate has the same drilling scheme, but different load and constraint conditions. The load on the nozzle comes from the 64 rods bearing upon it; therefore, in a first approximation, the load can be assumed as being uniform. The constraint conditions apparently are those of a plate partially fixed on the boundary.

The theoretical-experimental computation has given 12 mm as value of the thickness of the drilled plate, and the maximum stress is 7÷8 Kg/mm^2.

The central part of the nozzle is realized with a square section tube whose minimum thickness is 6,5 mm.

It behaves as a plate fixed at the ends, subjected to a uniform load, as for the above mentioned inner pressure.

The stress results to be moderate enough, and therefore, also considering the thickness reduction due to the machining, a value of σ is obtained that is not greater than 5 Kg/mm^2.

TABLE I

Pressure drop on a grid

Flow rate gr/cm² sec	Δ P mm Hg
110	1,8
170	6,2
230	11
300	17

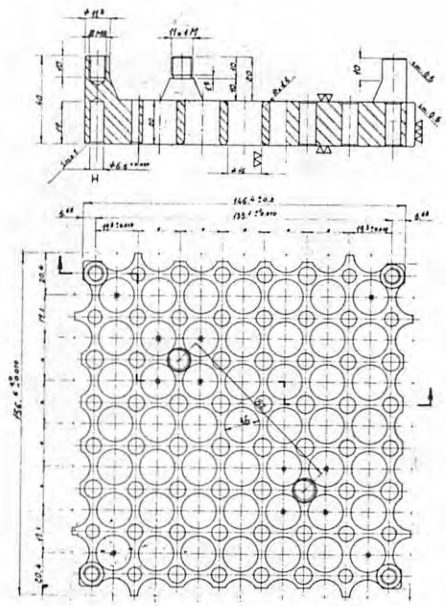

Fig. 1 - Upper holed plate (First solution).

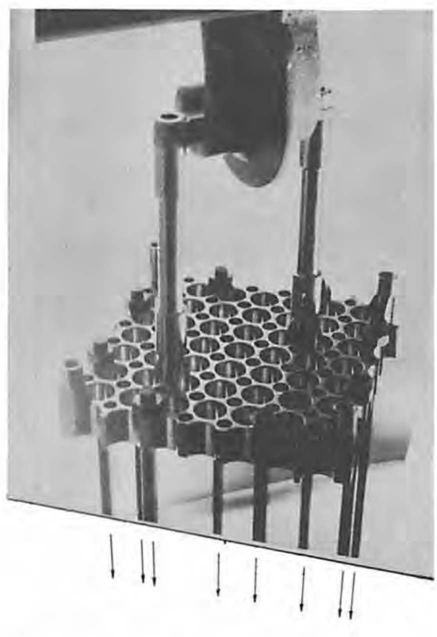

Fig. 2 - Upper holed plate and his 8 points of loading.

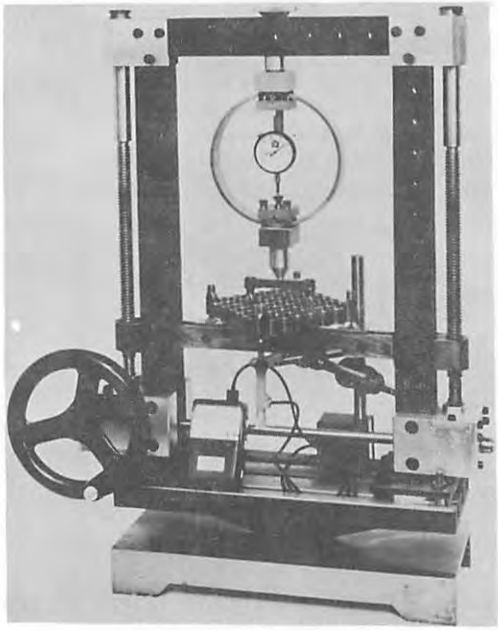

Fig. 3 - Apparatus for holed plates experimental testings.

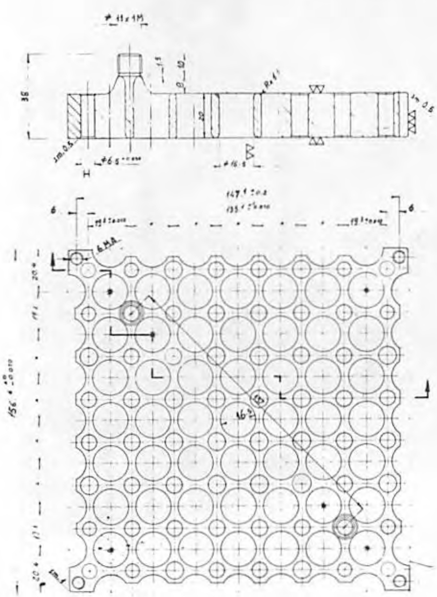

Fig. 4 - Upper holed plate (Second solution).

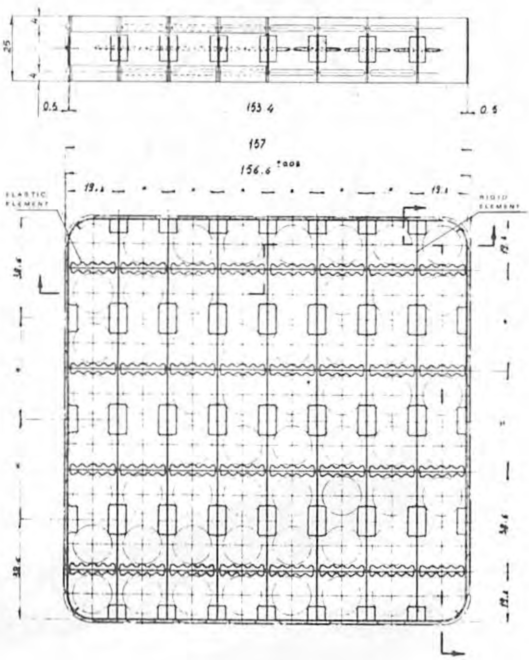

Fig. 5 - E.B. welded type spacer.

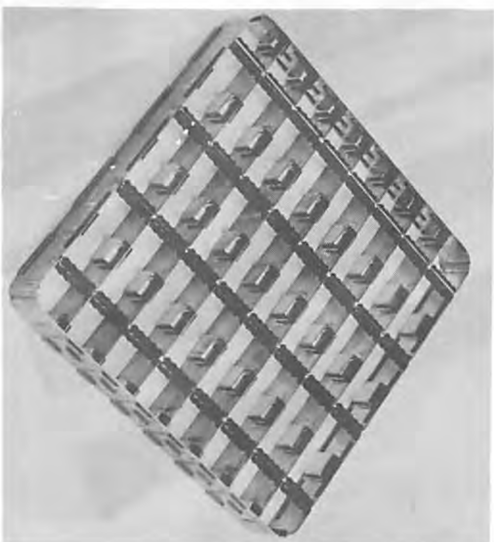

Fig. 6 - The grill in the first version.

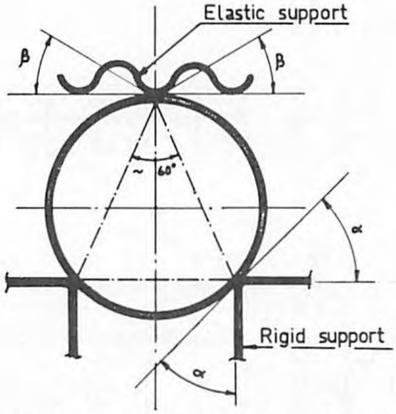

Fig. 7 - Low flow noise type contact in a linear extension.

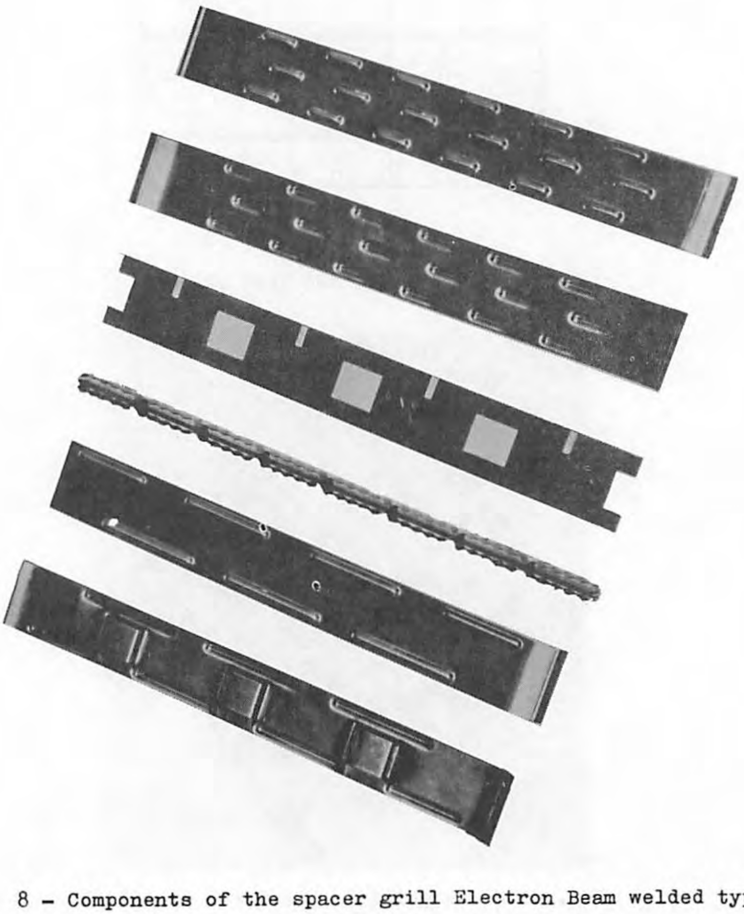

Fig. 8 - Components of the spacer grill Electron Beam welded type.

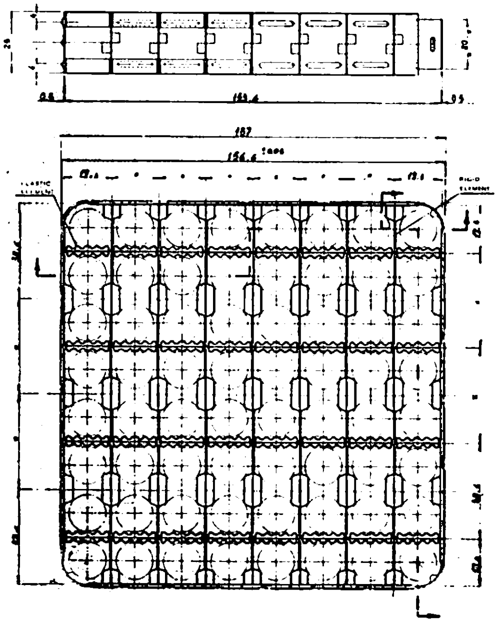

Fig. 9 - High pressing type spacer T.I.G. sistem welded.

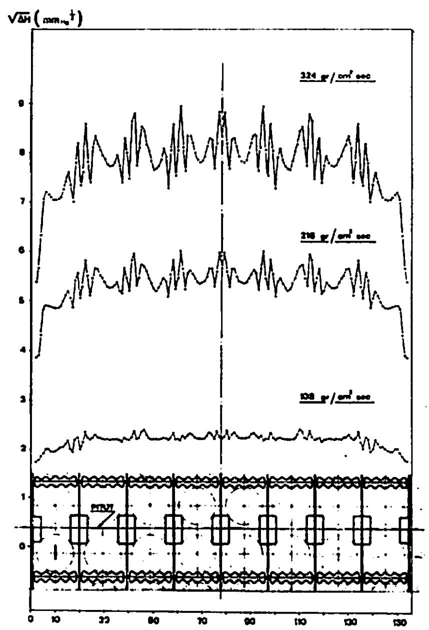

Fig. 10 - Velocity diagram in a section of a spacer type indicated in the fig. 5.

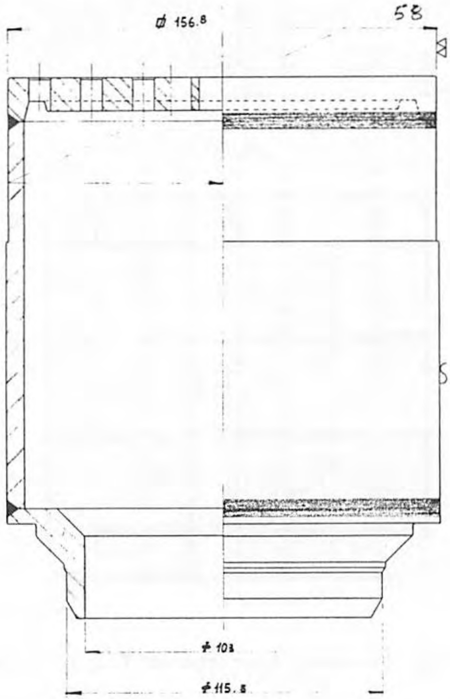

Fig. 11 - Botton holed plate with inlet nozzle.

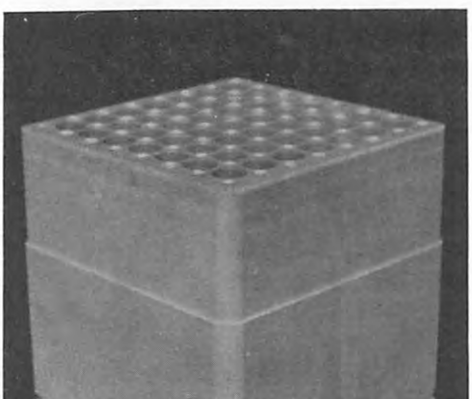

Fig. 12 - Bottom inlet nozzle of fig. 11.

DISCUSSION

Q J. REYNEN, JRC Ispra, Italy

What is the effect of decrease in pressure losses on the hydrodynamic stability of BWRs ?

A R. LEO, Italy

From the experiments we have performed in a water loop, where we have just the original fuel element functioning in the same conditions as in a reactor core, we have registered no case of hydrodynamic instability. So, we can deduce that the decrease in pressure losses is an improvement with respect to the type of fuel elements actually used in BWR power reactors and does not give any problem of hydrodynamic stability in our type of element.

Q R. A. VALENTIN, U. S. A.

1. Were any studies performed that would reveal the spectral characteristics of the flow field associated with this design ?
2. Were possible vibration problems of such "flow noise reducing supports" factored into the mechanical design process or were the vibration characteristics only tested after the mechanical design was decided ? I am asking about the degree of interaction between mechanical and fluid mechanics studies during the design process.

A R. LEO, Italy

1. Some initial theoretical considerations have been made to decide the best design from the point of view of the characteristics of the flow field. After the construction of the fuel element, we have performed an extensive experimentation for determining the flow characteristics for several values of the flow rate.
2. We have designed the spacers in such a way that we supposed from theoretical considerations they would give the best performance against vibrations of the fuel rods. But the last word we have let to the experiments, that have given good results.

Q J. L. HEAD, U. K.

Is there any loss of the pre-stress in the springs due to creep, and if so, does this seriously influence the vibration characteristics of the fuel element ?

A R. LEO, Italy

In not-in-core large experiments at the temperature of 350°C the NIMONIC 80A springs have given a very good performance against creep, working for many hours without appreciable loss of the pre-stress. We have not yet done experiments in core, but we expect good results also in presence of irradiation damages, as we can induce from others experiments.