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Worldwide Report

NUCLEAR DEVELOPMENT AND PROLIFERATION

(FOUO 3/82)

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CONTENTS

PEOPLES' REPUBLIC OF CHINA

PRC SEEKS AID IN SELLING ENRICHED URANIUM

OW281155 Tokyo MAINICHI SHIMBUN in Japanese 27 Feb 82 Morning Edition p 1

[Text] China, a nuclear power, seeks to export enriched uranium, heavy water and other nuclear-related material and has sought the help of Marubeni Corporation, Mitsui and Company, and several other major Japanese trading firms in selling them to third countries, it was disclosed on 26 February. According to the trading companies, the request was made recently by the Metals and Minerals Import and Export Corporation of China, which handles mineral resources, to their branch offices in China.

So far the trading companies have reacted passively to the request, saying: "We are afraid that these nuclear-related materials may be used to make nuclear bombs." In any case, this move by China, a country troubled by a shortage of foreign exchange, is likely to create a big international stir because it can be taken as an action aimed at joining the ranks of nuclear materials-exporting nations by capitalizing on its free position as a nonmember of the Nuclear Nonproliferation Treaty (NPT).

According to major trading company sources, China said in its request: "Since we have almost completed our atomic bomb production plans, we are requesting your help in selling heavy water and enriched uranium thatwe will produce in the future to those countries that have atomic energy powerplants." China sounded out Japanese trading firms handling multinational transactions on the export of the materials to user countries other than Japan because Japan already has contracts with the United States and other supplier countries for the supply of low enriched uranium for its nuclear powerplants sufficient to meet demand until 2003 and also because Japan has no power reactors of the Canadian-developed Candu type which use heavy water.

It is believed that the Japanese trading companies received the request because they play an important role in China's trade and have past records of trilateral trade, or of handling trade transactions between two foreign countries without involving Japan.

At one time in the past, a certain major trading company was making headway in its negotiations for the export of heavy water to India and Pakistan, which have Candu-type reactors, but it had to give up its plan of concluding the contracts when it met with intervention from the United States, which is keeping an eye on nuclear proliferation. Because of this, trading firms have so far shown no move to proceed with negotiations.

An official of a major company obviously expressed caution when he said: "It is possible that a deal may result in promoting nuclear proliferation and in trading companies risking being denounced as merchants of death." However, he also showed eagerness to positively strike a deal, saying: "If it can be guaranteed that the enriched uranium in question is used for peaceful purposes, I would say it is all right to approve the deal as resources trade."

According to an official atomic energy source, China has no atomic-power generating facilities, but it has conducted atomic bomb explosion tests on more than 100 occasions to date and reportedly has large-scale uranium enrichment facilities and plutonium production equipment for making atomic bombs in the Xinjiang Uygur Autonomous Region. It appears that high enriched uranium is being produced there and that a large quantity of heavy water is being used for making plutonium of high purity.

China appears to seek foreign exchange earnings by effectively utilizing these facilities and equipment to make enriched uranium and heavy water for export, now that it has completed its atomic bomb production plan for the time being. One of the major countries in the world blessed with natural uranium, thorium and other nuclear fuel resources, China also appears to be eager to make the most of its domestic resources.

However, since the products in question are made in the process of making atomic bombs, countries importing them can, with comparative ease, produce atomic bombs should they choose to develop nuclear arms. High enriched uranium in particular is a dangerous material because under certain conditions it can be easily turned into atomic bombs merely by attaching a triggering device.

For this reason, international trade involving these products is subject to strict checks by the International Atomic Energy Agency (IAEA). The Japanese group represented by Mitsui and the Power Reactor and Nuclear Fuel Development Corporation imported 2 tons of heavy water from China in November 1980 for use as moderator [gensokuzai] in the automatic transfer reactor "Fugen," but only after having convinced the IAEA of the peaceful nature of the purpose.

An important point about China's latest "export strategy," however, is that it is not necessarily for peaceful purposes, as one can see from its previous attempt to export heavy water to such countries as India and Pakistan, which both had a strong desire to make atomic bombs. Among the nations possessing nuclear arms, China is unique in that it has not ratified the NPT and is not a member of the IAEA. Those nations which are formally unable to obtain cooperation in their nuclear arms building efforts, either from the United States or from any European country bound by the NPT, will be greatly interested in the Chinese move.

CSO: 5100/2123

CZECHOSLOVAKIA

PRODUCTION TECHNIQUE FOR BREEDER REACTOR FUEL ELEMENTS DESCRIBED

Prague JADERNA ENERGIE in Czech No 11, 1981 pp 388-395

[Article in Czech by Hanus Landspersky and Milan Tympl, Institute of Nuclear Research, Rez, and Vaclav Pinkas, Institute of Nuclear Fuels, Prague: "A Laboratory Line for Preparation of Coarse-Fraction Sintered UO_2 Spherules by the Sol-Gel Method, and Preparation of Fuel Elements by Vibratory Compaction"]

[Text] Between 1970 and 1979, Czechoslovakia developed and tested on a laboratory scale a technology for the production of oxide fuel by the sol-gel method. As part of this research a semicontinuous laboratory line for the so-called "coarse fraction," with spherule sizes from 0.7 to 1.0 mm, was built, and efforts were made to develop and test a technology for producing the so-called "fine fraction," whose preparation involves a number of difficulties resulting from specifications regarding its properties. In conjunction with development of the sol-gel method for oxide fuel production, Czechoslovakia has also built an experimental facility for the preparation of fuel elements by vibratory compaction of sol-gel materials using the "sphere pack" process. In the process of research, the preparation of shortened model fuel elements with core lengths of 100 and 400 mm and densities about 80 percent of the theoretical maximum was tested.

1. Introduction

Almost since the very beginning of the development of nuclear power, pellets of sintered uranium oxide have been used as the starting fuel material in designing fuel elements for both thermal and breeder reactors. In the course of time, experience with pellet production has been acquired and pelletizing process technology has been well mastered.

However, at the beginning of the 1960's, more detailed investigation of the behavior of fuel material for breeder reactors indicated that the characteristics of the fuel cycle in such reactors does not allow straightforward application to them of the experience acquired with the first generation of reactors. In most breeder reactors, plutonium is the planned fissile material; because of its cost, it becomes necessary to increase burnup and assure the fastest possible recycling

of the fuel. These requirements lead to a number of major complications which were not considered critical in the fuel cycle of thermal reactors.

The high cost of plutonium, safety concerns in working with it, and the radioactive character of the material is to be recycled, requiring that the process be remote-controlled with maximum possible automation, have led to the development of new approaches to fuel preparation, including the so-called "sphere pack" process, which involves preparation of spherical fuel material by the sol-gel method and its vibration compaction.

The need for a lower density in the fuel for breeder reactors (80-85 percent of the theoretical maximum), the successful mastery of sphere preparation by the sol-gel method, the simplicity of the process, allowing remote control, and economic considerations, all contribute to the great promise of this process.

In recent years, the method of preparing dispersed fuels called the "sol-gel" method has been developed abroad; the method successfully solves certain problems stemming from the nature of the breeder reactor fuel cycle. This hydrometallurgical process is relatively simple and is amenable to remote control. The fuel is formed into microspherules of the oxide, carbide or carbonitride of fissionable or fertile materials, which are loaded into the fuel-element jackets and vibration-compacted to the required density. This process eliminates some of the mechanical complexity of the equipment, material consumption is the same as or less than that in classical pelletizing methods, dust production is decreased, and the filling of the jackets involves no risk of damaging their inner walls. Published results of radiation experiments conducted abroad have indicated that vibration-compacted fuel elements are suitable for use in reactor cores.

2. Preparation of Fuel Materials by the Sol-Gel Method

A variant of the sol-gel method called the "interior gelatinization method" has been developed in Czechoslovakia. During 1970-1978 the basic research was conducted and the problems of the chemistry of gelatinization, leaching of the gels, their conversion to xerogels and their heat processing into the final product, sintered uranium oxide, were solved [1-9]. The findings have made it possible to design and build a laboratory line which produces one 0.5-1 kg lot of the "coarse fraction" per shift.

The wet part of the procedure for producing uranium oxide spherules by interior gelatinization uses the principles of colloid chemistry [1,2]. Under certain circumstances, the colloidal solution is converted to a gel, i.e., a solid, elastic material with the characteristics of the solid state. The gel has the same volume and shape as the colloidal solution which preceded it.

In the first stage of the process, a solution of uranyl nitrate is produced, after which urea and urotropin [hexamethylenetetramine] are added to it. This mixture is temperature-unstable; at low temperatures it remains liquid for a long time, but when heated to 70-90°C it rapidly solidifies into a gel. If the gelatinization reaction takes place in a drop, the gel forms a solid sphere, from which impurities (residual urea, urotropin, ammonium nitrate and the like)

must be removed before further treatment. As a result, the particles are first rinsed to remove any adhering residue of the oil used as a dispersing medium, then leached in dilute ammonia water. This produces spherules consisting primarily of ammonium polyuranate. The rinsed spherules are then dried, calcined and finally sintered at a high temperature in a hydrogen or argon-hydrogen atmosphere to produce the final product: dense, solid spherules of uranium oxide of precisely spherical shape.

3. Preparation of Fuel Elements by Vibration Compaction

One promising method of preparing fuel elements for breeder reactors, called the "sphere pack" method, is a process involving low-energy vibration compaction of the material prepared by the sol-gel method [10-12]. The principle of this method is that by suitable choice of the particle size of the material to be compacted with reference to the diameter of the jackets and the vibration frequency and vibration process conditions, the ultimate density of the finished column of material can be controlled very precisely.

The choice of particle size and number of fractions is based on theoretical conceptions of optimal compaction conditions, according to which the size of the particles is controlled, compacting a certain number of size fractions of material to obtain the desired density.

Compaction can be classified in terms of the number of fractions, as described below.

a. Single Component

According to Ayer [13], the compaction effectiveness P is a function of the ratio D/D_1, where D is the inner diameter of the jacket and D_1 is the diameter of the spherical particles. The effective compaction volume P_1 is the part of the total volume of the element which is filled by the compacted material, in the present case, coarse-fraction spheres of diameter D_1. Figure 1 shows the packing effectiveness for spheres of diameter D_1 as a function of the ratio D/D_1. It is clear from the figure that when $D/D_1 \geq 10$ the curve becomes approximately linear, and its limiting value of 0.635 indicates that the maximum attainable density with spheres of one size is 63.5 percent of the theoretical maximum. This limiting density of a vibration-compacted column is of course insufficient for nuclear fuel, and accordingly two or more fractions of different sizes must be used.

b. Two-Component

Various graphic and mathematical models have been proposed and developed for multicomponent compaction and for the relationship between D, D_1 and D_2, where D_2 is the diameter of the spheres of the finer fraction. Following references 10 and 11, the limiting value for a two-component system is calcuated as 0.865, i.e., the maximum achievable density of a column of spheres of two sizes is 86.5 percent of the theoretical density. This value is satisfactory for breeder reactor fuel. Figure 2 shows one of the graphs published by Ayer [13] for

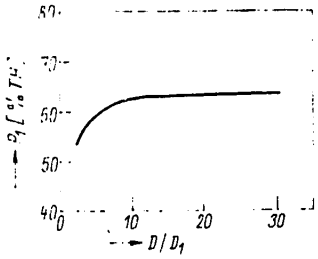


Figure 1. Relationship of P_1 (percent of theoretical maximum) to ratio D/D_1 for single-component compaction

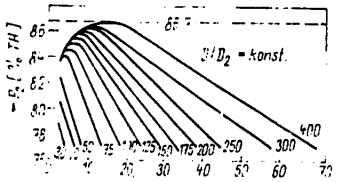


Figure 2. Relationship of P_1 (percentage of theoretical maximum) to D/D_1 with ratio D/D_2 constant (according to reference 13)

two-component packing, from which it is possible to read off sufficiently detailed relationships between the diameters D, D_1 and D_2.

4. A Laboratory Line for Preparing the Coarse Fraction

In accordance with the requirements of vibration compacting, trial preparation of the coarse fraction of compact uranium oxide spheres aimed at a diameter of approximately 0.8 mm. The principles of the preparation, drying and heat treatment of the gel materials have been described in a number of earlier publications [1-9]; here we are concerned with our experience in the construction of a line capable of producing 0.5-1 kg of sintered uranium oxide per shift.

Figure 3 is a diagram of a line for production of the coarse fraction, consisting of the following components: solution preparation, dispersion of drops, gelatinization, tempering of the gel, rinsing away of the gelatinizing medium, leaching, drying, calcination and sintering.

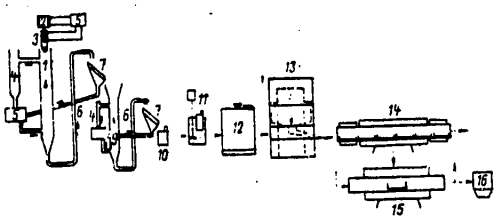


Figure 3. Design of line for preparation of coarse fraction

Key:
1. Gelatinization column
2. Gelatinizing solution tank
3. Dispersing head
4. Overflow
5. Constant-temperature vessel, pump
6. Hydrolift
7. Sphere separator
8. Constant-temperature vessel, pump
9. Tempering column
10. Baskets for rinsing and leaching gel particles
11. Rinsing unit
12. Washer
13. Distillation apparatus
14. Calcination furnace
15. Sintering furnace
16. Container for sintered UO_2 spherules

4.1 Preparation of Solution, Dispersion and Gelatinization

The gelatinization solution is prepared by dissolving weighed quantities or uranyl nitrate and urea in demineralized water in a stirred reaction vessel to produce a 2M concentration of uranium in the final solution and a 2:1 molar ratio of urea to uranium. After complete solution, filtration and cooling to a temperature of 10°C (e.g. in a bath of ethyl alcohol and dry ice), a weighed quantity of solid urotropin is added bit by bit so that the local temperature nowhere rises above 10°C while it is being dissolved by stirring. The solution of uranyl nitrate and urea is prepared in advance in large quantities and stored, while the gelatinization solution with dissolved urotropin is prepared in the quantity required for one batch; the ultimate molar ratio of urotropin to uranium is 1:5.

The quantity of gelatinization solution required for one batch is introduced all at one time into the cooled gelatinization solution tank, located above the dispersing head of the gelatinization and tempering columns. This arrangement can be seen from Figure 3, while the dimensions of the equipment, largely constructed from commercially available glass parts from the Kavalier concern enterprise in Sazava nad Sazavou, are shown in Figure 4. The individual components can be purchased directly according to the data given in the catalog. The dispersing head, a diagram of which is shown in Figure 5, consists of a cooled solution tank and a cooled tube with a stopcock, at the opening of which is a set of drop-producing jets mounted in a rubber holder which is attached to the opening. The temperature of the coolant is maintained at 5° in a constant-temperature vessel. The drip jets are stainless steel tubes, whose inner diameters, along with the density and viscosity of the solution, the height of the solvent column and the surface tension on the surface of the spheres determines the drop size. The approximate relationship between drop size and the inner diameter of the drop jets in our system is given in Table 1.

Table 1. Inner Diameter of Jets Used To Prepare Coarse-Fraction Particles

Jet diameter, mm	Diameter of sintered spherules, mm
0.24	0.7
0.52	0.87
0.79	1.0

The drop jets are inserted into the head of the gelatinizing column above the level of the gelatinizing medium. The gelatinizing medium, in the present case a silicone oil, passes from a constant-temperature vessel through cock 5 (Figure 4) and flows both into the gelatinizing column itself, where the gelatinization occurs, and into branch 10, through which the gel spheres exit. As a result of the surface tension between the two liquid phases, the individual drops of gelatinizing solution become spherical in shape and are gelatinized by rapid heating to 89°C in the column. The time required for gelatinization is about 20 seconds. Hydrolift 8 carries the spheres away to device 16 which separates them from the liquid. The separator [14], which is diagrammed in Figure 6, consists of a funnel across which are stretched steel wires which trap the spheres

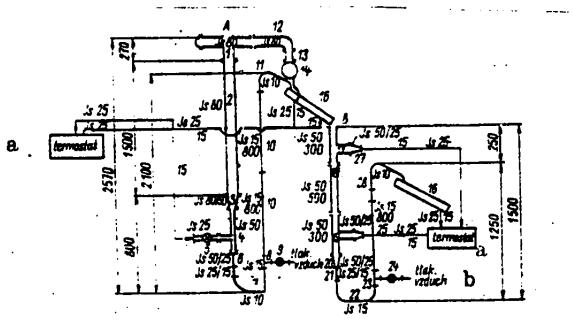


Figure 4. Gelatinizing and Tempering Columns

Key:
1. Cross, Js [nominal inside diameter] 80
2. Tube, Js 80, length 1,500 mm
3. Reducer, Js 80/50
4. T piece, Js_1 50, Js_2 25, length 300 mm
5. Stopcock, Js 25
6. Reducer, Js 50/25
7. U tube, Js 25/15
8. T piece, Js 15, length 100 mm
9. Laboratory stopcock, inner diamter 3 mm
10. Tube, Js 15, length 800 mm
11. Curved tubing, Js 10
12. Elbow, Js 80
13. Reducer, 80/25
14. Modified filter with reducer, Js 80/25
15. Intake and return tubes for oil, Js 25
16. Particle separator of tempering column
17. T piece, Js 50, length 300 mm
18. Tube, Js 50, length 500 mm
19. T piece, Js 50, length 300 mm
20. Reducer, Js 50/25
21. Reducer, Js 25/15
22. U tube, Js 15
23. T piece, Js 15, length 100 mm
24. Laboratory stopcock, inner diameter 3 mm
25. Tube, Js 15, length 800 mm
26. Bent tube, Js 10
27. Reducer, Js 50/25

a. Constant temperature vessel
b. Compressed air

Note: Total height of gelatinization column 2,570 mm (without drip equipment, about 500 mm high); total height of tempering column 1,550 mm.

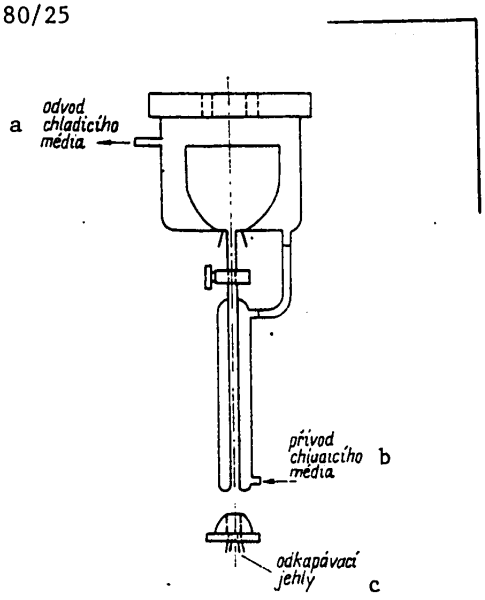


Figure 5. Dispersing head

Key: a. Coolant outlet
b. Coolant inlet
c. Dispersing jets

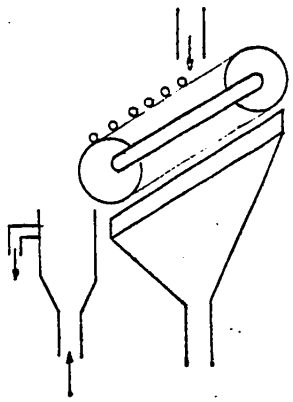


Figure 6. Drop separator

and allow the liquid to flow through and return to the constant-temperature vessel. The spheres roll by their own weight along the inclined, stretched wires, and fall into the tempering column. This column works by the same principle as the gelatinizing column, but the temperature is 35°C and its purpose is uniform, slow cooling of the spheres to a temperature lower than that of the gelatinizing column so that the gel will mature into solid spheres. This homogenization of the gel into solid spheres is the essential condition for their further successful processing. If the spheres are not made internally homogeneous, they powder during further processing, particularly during drying and calcination, spoiling the entire batch. It is not necessary, of course, that the tempering column be filled with the same medium as the gelatinization column. After separation of the phases in a second continuous separator, the spheres fall into a basket in which further processing takes place.*

4.2 Rinsing and Leaching of the Gel

The gel material from the separator is accumulated in baskets (Figure 7).

These baskets have walls made of sheet stainless steel with openings measuring 0.1 mm and are filled to a specified height. After filling, the basket is submerged in a tank containing carbon tetrachloride or some other medium, which rinses away silicone oil adhering to the surfaces of the spherules. After all of the gelatinizing solution is converted to gel, silicone oil is completely

*Note: Cocks 9 and 24 feed air into the hydrolift; the air bubbles make possible transport of the spheres at high gelatinization column outputs. The silicon oil is fed to the gelatinization and tempering columns by a gear pump in the temperature-controlled vessel, and the flow rate can be regulated. The silicone oil Lukooil M100 is used as the gelatinizing medium.

removed from the spheres by successive immersion of the basket into three containers of carbon tetrachloride.

Studies of the kinetics of the rinsing process indicated that the minimum amount of time required for satisfactory rinsing at room temperature is 15 minutes. At a temperature of about 40°C, the rinsing time can be decreased to about 5 minutes without any evident changes in the mechanical properties of the gel [3]. After draining and drying for about 15 minutes the baskets and their contents are placed in the leaching solution.

Following gelatinization, the gel contains all the components which were present in the liquid phase. All of the unreacted substances, such as excess urotropin and urea, and all products of the reaction, primarily ammonium nitrate, must be removed from the gel before it is further processed into a xerogel. These products are eliminated by leaching the batch in 2.5 percent ammonia solution in a leaching unit.

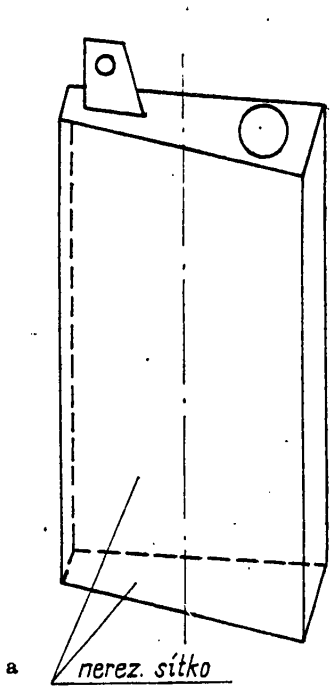


Figure 7. Basket for rinsing and leaching of gel
Key: a. stainless steel mesh

For the laboratory line we modified a commercially available agitator-type washing machine with a screw agitator by installing a holder for the baskets in the upper part. After all of the baskets holding the spheres from one batch of gelatinization solution were placed in the machine, it was filled with ammonia solution and a timer was used to turn the agitator on briefly at preselected, pretested intervals. The time required for adequate leaching of the gel was determined as a function of the intensity of agitation, the solution temperature, and the quantities of gel and leaching solution. In general the time required at room temperature was less than an hour.

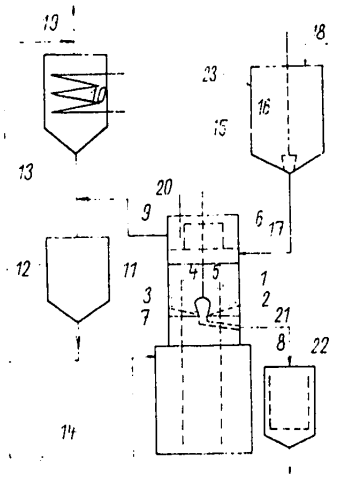
After leaching, the baskets were allowed to drain, then each was emptied into a feed container from which the gel was introduced into the dryer.

4.3 Calcination and Drying

Great attention was devoted to the drying process as one of the most sensitive operations in the processing of the gel. The initial drying method, at a temperature of 220°C [4,5] in a controlled atmosphere of the decomposition products of the material, was abandoned because of the time required. We selected a basic drying method using the principle of azeotropic distillation

of water with chlorinated hydrocarbons [5-7]. The first apparatus for drying the gel particles by azeotropic distillation consisted of a heating vessel, a reverse-flow cooler and a separator unit to separate the organic and water phases. This design was not satisfactory. Some of the product was contaminated by drops of water which dropped from the coolest locations into the heating vessel. It proved impossible to eliminate this problem by installing baffles, and accordingly a column with a perforated bottom was installed in the apparatus. The vapors of the organic liquid penetrated the layer of spheres, where they partially condensed. In some locations a continuous layer of condensate was formed, at the top of which the water phase separated out; however, this produced peptization of the particles. Use of a column with an overflow plate proved to be the best method.

This device, whose function has been described in detail in earlier publications [6,7], also uses the principle of azeotropic distillation, but introduction of the overflow plate assures homogeneous drying conditions for the entire batch of particles. In addition, it also allows control of the speed of the process. A diagram of the device is given in Figure 8 (according to reference 6). The operating principle is as follows. The gel particles are poured from the tank into column 1, where they are trapped by perforated plate 4. Vapor from the



Key:
1. Column with overflow plate
2. Perforated bottom
3. Overflow
4. Mesh
5. Cone valve
6. Head
7. Particle exit from column
8. Vapor generator
9. Vapor mixture outlet
10. Condenser
11. Phase separator
12. Water phase outlet
13. Pressure=equalizer
14. U-overflow
15. Container for gel particles
16. Cone valve
17. Transport of gel particles to column
18. Transport of gel particles to container
19. Exhaust
20. Temperature sensor
21. Removal of dried particles
22. Separator

Figure 8. Schematic of equipment for drying by azeotropic distillation in column with overflow plate as described in reference 6

vapor generator 8 accumulates above the plate, where it condenses. The column fills with liquid as far as the opening of the overflow plate, over which the liquid flows back to the vapor generator. The spheres are dried on the plate

by azeotropic distillation until outlet tube 9 reaches the constant temperature of the azeotropic mixture of steam and the vapor of the organic phase. The vapors are condensed in condenser 10, and the water and organic phases are separated in separator 11. The water phase is removed from the apparatus, while the organic phase is returned to the vapor generator. Initially, carbon tetrachloride was used as the organic phase, but it was later replaced by perchloroethylene because of the latter's higher boiling point, producing more rapid drying.

The distilling column was 160 mm in diameter, and 5 liters of perchloroethylene was used to dry about 1 kg of gel; drying required 40 minutes. After drying the material was collected in a holder, from which the xerogel was loaded into stainless steel boats and placed in the calcining apparatus.

The calcining has two main functions: it allows the grain size of the final material to be regulated and assures uniformity and homogeneity throughout the batch, as well as eliminating most of the volatiles, which must be removed from the material before treatment in the sintering furnace. These highly corrosive decomposition products would destroy the inner walls of the furnace and the heating elements, as well as the sintering boats.

The calcining unit is a pass-through furnace made of stainless steel tubing 70 mm in diameter, with a resistance-heated heating zone (zone of maximum temperature) about 40 cm long. The furnace has chambers at each end to assure uniform heating and cooling of the entire batch and permitting removal of gaseous decomposition products from the furnace and their condensation outside. The calcination was carried out at 550°C [8, 15] in a current of air flowing in the opposite direction from the boats. The boats consisted of cylinders cut in half longitudinally with perforated bottoms to allow easier entrance of gas and rapid removal of the decomposition products from the material. The layer of charge was 2-3 cm thick and the material was held in the maximum-temperature zone for 2 hours. The boats were transported mechanically, and after removal from the furnace and complete cooling the material was stored in polyethylene containers for sintering.

4.4 Sintering Process and Properties of the Final Product

The sintering was performed in batches, using molybdenum boats measuring 7x3x3 cm in a high-temperature Heraeus tubular furnace, where the heating element was the molybdenum tube itself. The process consisted of two parts: reduction of the calcinate to uranium oxide, and sintering proper. The sintering conditions had to be adjusted so that the heating would first produce complete reduction of the entire volume of the charge, after which sintering would proceed. The sintering conditions were as follows: heating by 500 deg/hr to a maximum temperature of 1,450-1,550°C, maintenance of this temperature for 2 hours, and cooling at a rate of 500 deg/hr. The entire reduction and sintering process was carried out in hydrogen. If a better furnace design, assuring complete, rapid removal of the reaction products and steam from the charge were used, a mixture of hydrogen and argon or hydrogen and nitrogen could be safely used. The sintered material was collected in a polyethylene container. The product of this process was sintered spherules of uranium oxide with a density 96-99 percent of the theoretical value, with sizes ranging from 0.7 to 1.0 mm

depending on the size of the jets in the dispersing head, with a maximum deviation of ≤5 percent from the average size, and with an average compression strength only slightly dependent on the sphere size, equal to 220±30 N/sphere for spheres about 0.8 mm in diameter. The composition was $UO_{2.010-2.016}$, with less than 100 ppm of carbon, with the grains uniformly distributed through the entire sphere; their size depended on the calcination and sintering temperature and was equal to about 20 microns for a calcination temperature of 550° and a sintering temperature and was equal to about 20 microns for a calcination temperature of 550° and a sintering temperature of 1,500°C, and they had a characteristic residual intergranular porosity and a pore size of 1 micron. Residual chlorine was below the detection threshold of 10 micron [as published].

5. Preparation of the Fine Fraction

Preparation of the fine fraction proved considerably more difficult than initially expected [16, 3]. Although the starting solutions were essentially the same as for the coarse fraction, dispersion was an important stage of preparation whose achievement was a demanding undertaking.

The preparation of dimensionally homogeneous, relatively concentrated dispersions with gel particle sizes about 150-250 microns required the use of a special dispersing unit. Designing a high-quality dispersing device which meets the required tolerances was not a simple task, and the manufacture of certain parts, particularly the jets, was difficult. Since at the same time that the gels were being prepared and processed it was also necessary to develop a vibration apparatus for the final compacting of the elements, it was decided to prepare small quantities of fine-fraction sintered spherules for this purpose by a provisional method. In this case, the fine fraction was produced by stirring in a simple device, a reactor with a heated surface, in which an emulsion of gelatinizing solution in a suitable organic medium had first been prepared. This emulsion was then converted to a gel by heating to 80-90°C, after which a polydispersed mixture was obtained by a method similar to that described above, and the required size fraction was prepared from it by sieving. This entire procedure has been described in detail in earlier publications [16,17] and will not be discussed further here. After finalization of a design for the line of production of the fine fraction with a narrow size interval (maximum deviation ±20 percent of average size), the results will be published in the same form as has been done for the coarse fraction.

6. A Line for the Preparation of Fuel Elements by Vibration Compaction

In the experiments, we used a coarse fraction D_1 with an average size of 0.80±0.040 mm and a fine fraction D_2 with a size of 0.060±0.012 mm. The research work was intended to determine the optimal conditions for compacting a column of material 400 mm long and 5.4 mm in diameter. The line consists of the following assemblies: an electrodynamic vibration apparatus for compacting the column of spherules, an SM212 measuring unit to mointor the compaction conditions, units for assembling the elements, including filling them with helium (at a pressure of about 0.2 MPa) and sealing them, and units for testing tightness and density distribution along the elements.

6.1 Vibration and Infiltration Equipment

For the experiment we used an SVUSS [State Research Institute for Machinery Construction] vibration device whose design and production are described in detail in reference 18. This device consists of an electrodynamic vibrator, to whose working platform is attached a fuel element jacket, a power supply and an SM2i2 monitoring unit. The main specifications of the unit are: maximum amplitude of sinusoidal force 2,000 N, frequency range 500-5,000 Hz, maximum available acceleration 1,000 m/sec^2, maximum load on table 5 kg. To limit noise and to control dust from the uranium-containing material, the entire electrodynamic vibrator is located in a sound-deadening, dust-tight box. Figure 9 shows an overall view of the device. In tests of two-component compaction, initially the particles of the D_1 and D_2 fractions tended to separate, which had a negative effect on the final homogeneity of the column of fuel material and thus on the final density and density distribution. This problem was solved by adding an infiltration device [19, 20], which involved introducing a bed of D_1 particles with a filling tube before infiltration of the fine-fraction spheres. The end of the filling tube, which was to be inserted into the fuel element jacket, was perforated with holes smaller than the dimension of the D_1 fraction spheres. A diagram of the infiltration device is given in Figure 10, and a photograph in Figure 11.

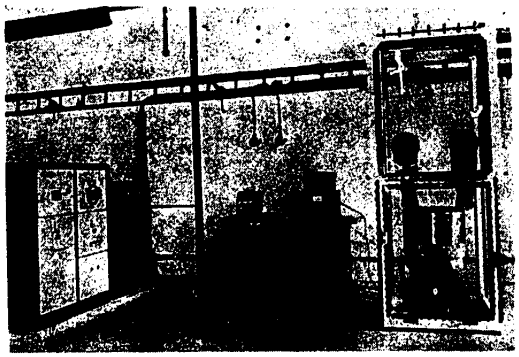


Figure 9. SVUSS Vibration device (reference 18)

The infiltration unit is attached to the vibration equipment by a base plate. After the D_1 fraction is loaded into the jackets and compacted, the resulting bed is held in place by the filling tube, which is inserted as far as the top of the compacted column of coarse-fraction particles. The calculated quantity of fine-fraction particles is introduced into the jacket through the filling tube, after which the vibration causes it to pass into the spaces between the compressed coarse-fraction spheres. In addition the infiltration devices makes it possible to read out the height of the compressed column to within ±0.5 mm.

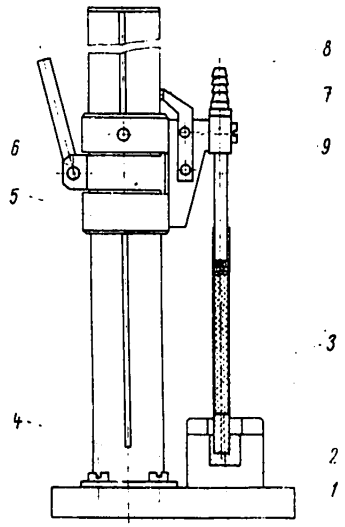


Figure 10. Infiltrator unit

Key: 1. Base
2. Fuel element holder
3. Model fuel element
4. Guide column
5. Infiltration unit holder
6. Stop
7. Infiltration unit holder
8. Height indicator
9. Infiltration unit

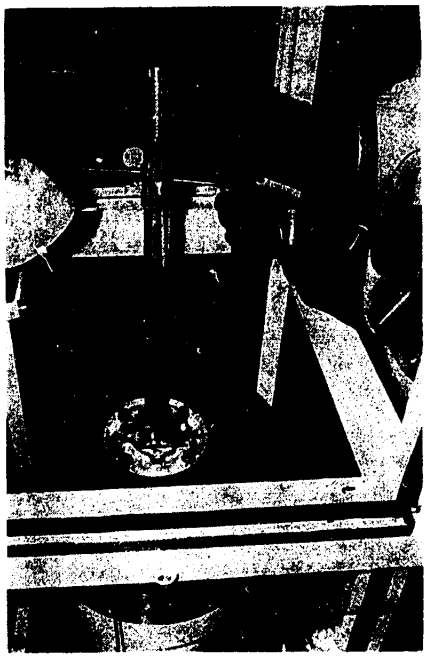


Figure 11. Infiltration unit

6.2 Assembly of Fuel Elements and Density Tests

The procedure described was used in a series of experiments which allowed us to check the apparatus and determine the basic compaction parameters. The ultimate density proved to be affected by a series of parameters such as the rate at which the fractions were introduced, the infiltration time, the vibration frequency and the acceleration. Under the conditions described above, a vibration frequency of 80 sec^{-1} and an acceleration of 75 m/sec^2 proved to be the most suitable.

Using the experimental results which we had obtained, we prepared model fuel elements with compacted columns 100 and 400 mm high. A cross-sectional diagram of a compacted element is shown in Figure 12.

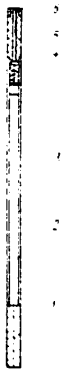


Figure 12. Diagram of model fuel element

Key:
1. Lower cap
2. Column of compressed particles
3. Jacket
4. Retaining tablet
5. Spring
6. Upper cap
7. Sealing plate

The elements were assembled as follows: the lower cap was welded onto the jacket and the weld tested for tightness. After the compaction and testing, the column was secured in place by a short pellet of uranium oxide, the spring was inserted, the upper cap was welded on and the element was evacuated and filled with inert gas (helium). The filling opening was covered with the top piece of the cap, which was welded on. The tightness of the element was tested using an Ultratest B helium detector.

The density and density distribution along the element were tested with a densimeter [19,21]. Figure 13 shows the density measurements made on a fuel column with this device. The graph shows a good density distribution curve, with a slight drop in density at the top of the compacted column. This phenomenon is typical of vibration-compacted elements and has been described in the literature. The density of the elements prepared by the method described was generally over 80 percent of the theoretical maximum, and thus was in the lower part of the range of densities required for breeder reactors. Preparation of a higher-quality fine fraction will make it possible to further increase this density to a satisfactory degree.

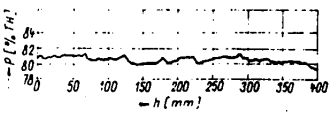


Figure 13. Density distribution along 400-mm compacted column

7. Conclusions

In summary, we may state that Czechoslovakia has mastered the laboratory preparation of coarse-fraction spherical material by the sol-gel method and has constructed an experimental facility and designed and tested nonstandard apparatus for preparing fuel elements by vibration compaction. The vibration compaction technique and test methods have been successfully mastered and have been tested by the preparation of model fuel elements. A fine fraction of mediocre quality was used to test the preparation of the fuel elements because the preparation method described is still in the laboratory development stage. Nonetheless, the densities for two-component compaction exceeded 80 percent of the theoretical maximum and accordingly were already in the lower part of the density range required for breeder reactors. The techniques described yielded sufficient information and data for industrial application.

In addition to the results described in this article, it should be noted that the sol-gel method has also been applied to a number of nonnuclear materials and that positive compaction results were achieved. Application of vibration compaction to dusty materials has produced an experimental base for the more extensive use of this technique in nonnuclear sectors.

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8480
CSO: 5100/3009

CAORSO PLANT RESTARTED AFTER SHUTDOWN

Rome ATOMO E INDUSTRIA in Italian 15 Dec 81 p 1

[Text] At noon on 14 December the Caorso nuclear power plant entered the starting up and power build-up phases after another shutdown lasting several days due to the need to repair a circulation pump for the primary circuit. By the evening of Monday 14 December it was producing 300 MW and was on the way to full power output. Its managers are confident: Engineer Guido Morante, director of the plant, said: "I'm optimistic; the blockage (of the pump) does not jeopardize the plan; there shouldn't be any delay in achieving full power output."

Operating at full power, the Caorso plant produces about 20 million kwh per day, putting more than 5 billion kwh into the network per year; this corresponds to an input worth about 300 billion lire for Enel [National Electric Power Agency]. Subtracting 50 billion for nuclear fuel and another 50 billion for maintenance, personnel and depreciation, Enel will receive a net profit of 200 billion lire per year. The plant cost 450 billion, so it will pay for itself in a little over 2 years.

Engineer Giovanni Naschi, central director of safety and health protection for CNEN [National Nuclear Energy Commission], commented on the Caorso situation and made some remarks about safety regulations in an interview with ENERGIA, the bulletin of the ADN agency, on 3 December.

The interviewer asked Engineer Naschi why it took 4 years for the power plant to begin operating. His answer: "I think this is the price our country has to pay for its relative experience in the nuclear field.

Also, there are some gaps in Italian legislation about nuclear plants and their safety, especially regarding the procedures to be followed in bringing a plant into operation. After the approximately 10 months of so-called "cold trials" there is a period of testing with the fuel called "hot trials" or "nuclear trials," whose main purpose is to enable the technicians to check the operation of the power plant under various conditions.

Once these two test cycles are over, the plant has to be shut down to enable the relevant commission--in our case that of CNEN--to make a final judgement of the operation of the plant. In other countries, on the other hand, as has been the case for several years in the United States, for example, the opinion of the commission is formed during the second trial period, that of nuclear trials, since the commission grants the plant a temporary license which more or less covers the period of "hot trials."

In this way as soon as the nuclear trial period is over, if everything is going well the operating license can be granted immediately and the plant can come on line and produce electricity very soon. This is practically impossible in Italy with the present procedure.

The delay with Caorso enabled the CNEN commission to analyze and study all the problems which surfaced during the intermittent operation of the plant.

The Caorso plant has finally become operational now that the commission has given a favorable judgement and the Ministry of Industry has signed the operating license, but only until September-October of next year, i.e., until the end of the hot trial period and until the next batch of fuel comes, at about that time.

If our country were to adopt a system like the one used in the United States, it would be possible to have the end of the hot trial period coincide with the commission's judgement, so the plant would not have to shut down after these trials with fuel to have the situation assessed."

9855
CSO: 5100/2088

CAORSO POWER PLANT STARTS OPERATION

Rome ATOMO E INDUSTRIA in English 15 Jan 82 p 12

[Text]

On 21 December 1981 the nuclear power station of Caorso, having completed the technical tests, started its normal operational activity. This was announced on 22 December by the Minister of Industry himself, Sen. Giovanni Marcora, at a crowded press conference held in Rome, at which the major exponents of the energy agencies and industry were present, in addition to the journalists.

Among others there were Prof. Giuseppe Ammassari, Director General of Energy Sources and of Basic Industries at the Ministry of Industry; Ing. Grancesco Corbellini, President of Enel; Dr Franco Viezzoli, President of Finmeccanica, Prof. Umberto Colombo, President of CNEN, Dr Fabiano Fabiani, Director General of Finmeccanica, Ing. Giovanni Massimi, Director General of Enel and Dr Fabio Pistella, Director General of CNEN.

« Today is a positive day for our country — Marcora began — *since the nuclear power station at Caorso has produced in 24 hours 20.3 million kWh of electricity, permitting a saving of 895 million lire in fuel oil which it was not necessary to burn; a reduction, therefore, of about 365 billion lire a year in the oil bill. If we had constructed five other power stations of this type, eletricity rates could have cost 30% less ».*

The Minister then stressed the effort required form all the participants in the enterprise, Enel, CNEN, Industry and, in particular, the task force set up last summer to overcome the last difficulties before the start-up of the plant.

With regard to future power stations, Marcora promised that an effort will be made to reduce as much as possible the times of site qualification: Apulia will probably be the first region in which the authorization procedure will be completed, then there will come in order Piedmont and Lombardy. As for construction times, the Minister said that this will depend also on the possibilities of a rapid and adequate financing of Enel and in connection with this problem he announced the inevitable imminent increase in electricity rates. CIPE will conclude, moreover, before the end of Juanary a study on tariff changes outside the so-called « social strip ».

In particular, as regards Enel's financial endowment, Marcora said that 3,800 billion lire can already be considered available: 1,000 billion with laws to be approved, 800 billion for laws already in force such as the rise in the price of petrol; another 1000 billion from the FIO Fund (Western Investment Fund) and the last 1000 billion from above-mentioned increase in tariffs.

The Minister said furthermore that there are good prospects of drawing up to the extent of 60% from NIC (Ortoli Fund), the endowment of which was increased from 1 to 3.9 billion EUA on 26 November last, by the conference of Heads of State and Government of the European Community.

The personalities present whom we mentioned at the beginning also intervened at the press conference. The President of CNEN Co-

lombo spoke of the prospects of solving also in Italy the problem of spent fuel reprocessing, now experimented in our country on the pilot plant scale. By 1985, he announced, a start will be made on the industrial plant by AGIP Nucleare. Prof. Colombo also recalled the necessity that the Parliament should approve rapidly, as the conditioning fact, CNEN's restructuring law, already passed in the Senate and now being examined at the Industry Committee of the Chamber of Deputies.

In his turn the President of Enel Corbellini recalled the importance, for the purposes of supplies of electric power, of the application of the multi-hour rates to industry, which has already yielded its first results, making a contribution of 1000 MWe of capacity: a real and proper « ghost power station ».

Finally Minister Marcora gave journalists a series of news items on the Caorso power station which we summarize here.

On the completion of the technical tests, the nuclear poer station at Caorso began its activity of real and proper operation, introducing energy into the national grid.

Caorso, with a capacity of 840 MW, produces at full power an average of 21 million kWh a day; even taking into account some interruptions or some moments of operation at reduced capacity, the power station will be able to supply about 520 million kWh a month, that is, no less than 5,850 million kWh a year.

THE OFFICIAL COMMUNIQUE'

The Caorso Power Station has become operational and introduces into the grid 840 MWe equal to 5 billion kWh a year.

The Caorso power station cost 450 billion lire in all.

In a year's activity it will produce, as has been said, 5 billion kWh, equal to a revenue for Enel of about 300 billion lire. If 50 billion are deducted for atomic fuel, and 50 billion for maintenance, personnel and amortization, Enel will have a net annual income of 200 billion lire.

That means that in just over 2 years the power station is paid for.

Caorso produces from 16 to 20 million kWh a day of electricity, equal to saving 1 billion lire a day of fuel oil, which leads to a reduction of 365 billion lire a year in the oil bill. Had Italy constructed 5 other power stations of this type, tariffs could have cost 30% less.

To produce the same quantity of power having recourse to oil, it would be necessary to burn 4,600 t. of fuel a day, 116,000 t. a month, 1,300.000 t. a year, equal, to give an idea, to the load of 13 super tankers of 100,000 t. each. In practice, it would be necessary to have more than one tanker of 100,000 t. arrive every month, spending about 300 billion lire every year.

This saving is obtained without paying a price in terms of risk. The Caorso station has at its disposal, in fact, the most sophisticated and advanced safety measures imaginable today. The power station has been built to emerge unharmed, or at least not to represent a danger for the surroundings' from any type of foreseeable accident or calamity.

Nevertheless, out of a further scruple, the operation licence issued by the Ministry of Industry was limited to the first phase of operation, which will be completed with the first recharge of nuclear fuel. The final licence for a long period will be subordinated to a new series of very severe tests.

The risks of possible black-outs should be considered greatly reduced if not completely overcome with the start-up of Caorso.

Having passed the third week of December which usually constitutes the peak point of energy demand in the country, with the contribution of Caorso Italy should have a sufficient margin to avoid the drawbacks of last winter.

There would be even greater certainty if, alongside Caorso, the thermo-electric station at Porto Tolle, already completed, could become operative. It is able to provide a capacity of 1,280 MW.

Enel is examining the requests put forward by local bodies. Issue of building licences to lay the oil pipeline that supplies the power station and authorizations for the mooring of lighters, are subordinate to their acceptance. In the meantime it has been established that work will begin on the first part of the pipeline from Porto Tolle to Asinara.

CSO: 5100/2121

PUGLIA REGION APPROVES TWO POSSIBLE SITES FOR POWER PLANT

Rome ATOMO E INDUSTRIA in Italian 15 Dec 81 p 1

[Text] Puglia is the first region which, pursuant to law 393 of 1975, has indicated the two sites where one of the nuclear power plants provided for by the National Energy Plan might be built.

They are on the Ionian coast near Avetrana (east of Taranto, on the boundary of the province of Lecce) and on the Adriatic coast north of Brindisi, near Carovigno. The decision was made, according to a communique from the Puglia region, by the regional Giunta and took into account studies made by CNEN and by the former chairman of the engineering department of the University of Bari, Professor Vincenzo Cotecchia, the suggestions of the Regional Energy Plan, and the final act of the joint committee region-Enel-CNEN. The Giunta also considered it necessary to come to an agreement with the communities concerned (Manduria, Avetrana, Porto Cesareo and Carovigno) before taking a final decision, as provided for by law 393.

San Benedetto Po, Viadana, and Bozzolo--in the province of Mantova--are the three sites where it would be possible to build nuclear power plants in Lombardy; these will probably be the places suggested by the region to the government by 4 February 1982, the end of the 60 day period set by CIPE [International Committee for Economic Planning]. That period started on 4 December when the measure was approved by PEN. This has been announced by Guido Sasso, regional assessor of energy, and Luciano Forcellini, president of the standing commission for energy problems and the protection of the environment. According to these indications, before the end of January the Regional Council will have to give the government a series of detailed answers. This will be a first concrete step toward the construction of a nuclear power plant, but it is not a final step, as the two representatives of the region explained. For now Enel must collect technical data about the areas concerned to provide a basis for a judgement about the qualifications of the sites.

The assessor and the president of the commission will arrange a series of meetings with the inhabitants of the three areas concerned in order to explain the protection of the environment and other things involved in the construction of a nuclear power plant.

Finally, for Piemonte, the Honorable Giorgio La Malfa, minister of the budget, who has been asked by the president of the Council to find a solution--together with the region--to the serious economic problems besetting Piemonte, has appealed

explicitly to Piemontese political groups "To halve the time-table for the construction of a nuclear power plant, while keeping the schedule for appropriate safety studies unchanged."

The sites on the Po are at Trino Vercellese and Filippona.

9855
CSO: 5100/2088

NIRA STEAM GENERATOR PROTOTYPE

Rome ATOMO E INDUSTRIA in English 15 Jan 82 p 12

[Text]

On the design of NIRA (Nucleare Italiana Reattori Avanzati), the Steam Generation Division of Ansaldo has constructed, crowning fifteen years of research and experimentation carried out by NIRA and CNEN, a prototype of steam generator for fast sodium-heated reactors.

The prototype, which has a capacity of 50 MW, has undergone operation tests in France, at the sodium component test Station at Les Renardières of Electricité de NFrance (EDF). The post-operational examinations of the plant, which was completely dismantled to study it in every particular, and the success of the tests have qualified Italian industry for operations of this type, putting it in the small number of industrial countries capable of designing and constructing steam generators for fast sodium-heated reactors.

Although it is not a specifically nuclear component, the steam generator represents, as is konwn, one of the most delicate parts of a fast reactor with liquid metal, owing to its function of producing steam at a high pressure and temperature to send to the turbines of the power station receiving, in form of heat, energy from the liquid sodium coming from the reactor.

Thus the plant is subject to very great stresses, having to operate at high temperature with two fluids, water and sodium, which must be kept absolutely separate.

The operation of a power stations is therefore directly conditioned by the correct operation of the steam generator, since an accident to the generator, while it does not raise problems of safety, can cause long shutdowns of the whole plant. That makes necessary the application of non-conventional technologies, the conformity of the design to the strictest regulations in force today, the use of highly selected materials and the adoption of sophisticated control techniques.

CSO: 5100/2121 END