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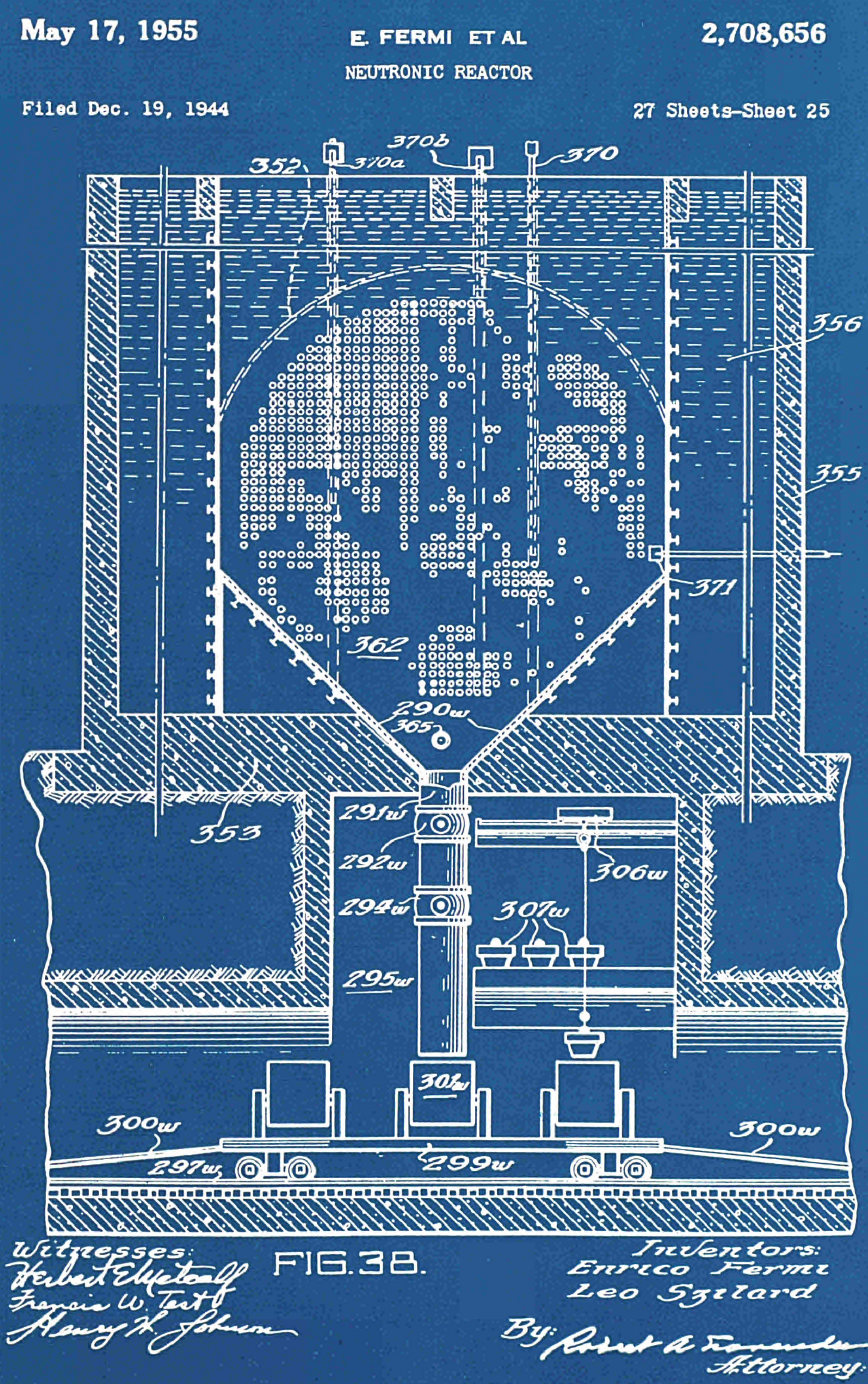

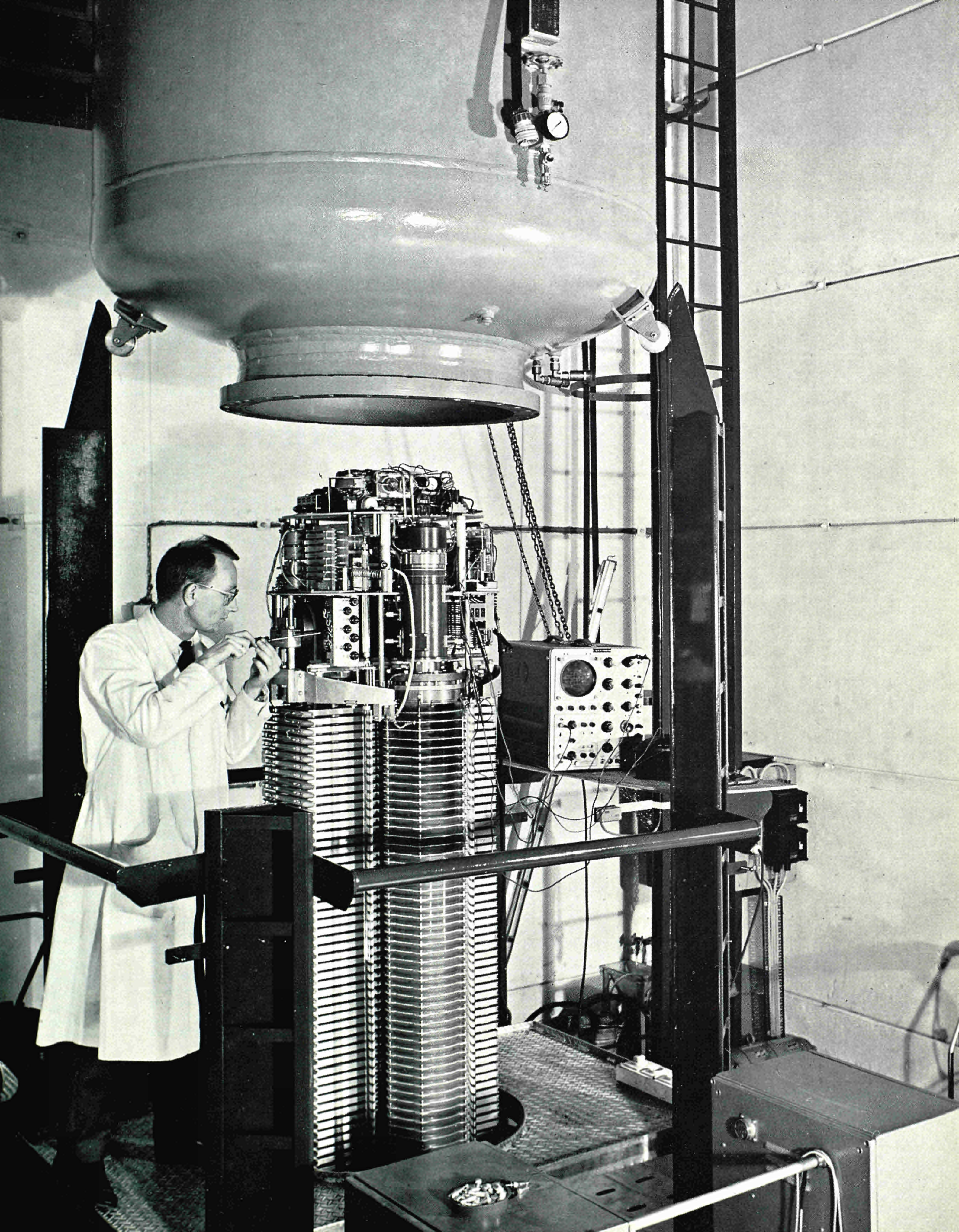

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◀ *Van de Graaff accelerator at the Joint Research Centre's Geel Establishment (Belgium).*

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The Community's mission is to create the conditions necessary for the speedy establishment and growth of nuclear industries in the member States and thereby contribute to the raising of living standards and the development of exchanges with other countries (Article 1 of the Treaty instituting the European Atomic Energy Community).

To maintain that fresh water is essential to man, for his own consumption, for domestic purposes and for use in agriculture and industry, would be to state the obvious. However, it is by no means so obvious that recourse will have to be made to desalination of sea-water and brackish water in order to obtain it in sufficient quantities.

The general opinion is that this is true in certain areas of the world which have a dry climate and where economic growth would be impossible without desalination, but our countries, with their temperate climate . . .? The fact that the Euratom Bulletin has called upon the services of an eminent expert from Israel in order to outline the desalination problem in this number almost provides confirmation of this attitude.

However, the truth of the matter, as things stand at present, is that in about ten years' time desalination will have to be carried out on a large scale in certain parts of the Community. This, at least, is the conclusion to be drawn from a series of studies recently launched by Euratom.

An example to illustrate this is the growing industrial zone in the Bari-Brindisi-Taranto triangle, where it is estimated that the daily demand for fresh water will have increased by several hundred thousand cubic metres in ten years' time, it being likely that this quantity can only be produced at a reasonable cost by means of desalination. North Germany at present adds to its local resources by piping in water from mountainous areas situated about one hundred and fifty miles from the point at which it is consumed, so that desalination holds out promise of offering a less expensive means of obtaining fresh water. In Belgium, public opinion is hostile to the erection of dams, which are nonetheless necessary for meeting water supply requirements, on account of which desalination offers an attractive alternative.

It is a known fact that the best economic prospects lie in the construction of large combined plants, in which nuclear energy could be used to produce both electricity and fresh water. We will return to this aspect of the matter once the studies mentioned above are completed.

Desalination today and tomorrow

I.E. STREIFLER-SHAVIT, *Project Manager, The Joint Sea-Water Desalting Project, Israel*

Water resources are running out

The existence of unlimited water resources was taken for granted in the past, and little attention has therefore been paid in most parts of the world to the management of regional water supplies. Allocation of water resources in arid zones has been and continues nowadays to be a cause of dispute among neighbouring nations.
Cities like New York already experience severe water shortages, while others are threatened and most concerned about their future.
The state of California faces in its north the problem of harnessing run off water, which causes loss of life and property, while in the arid south water resources are becoming depleted. Large water conveyance and pumping schemes are therefore being contemplated and are expected to meet the projected water need for the next two decades.

Water is becoming a raw material

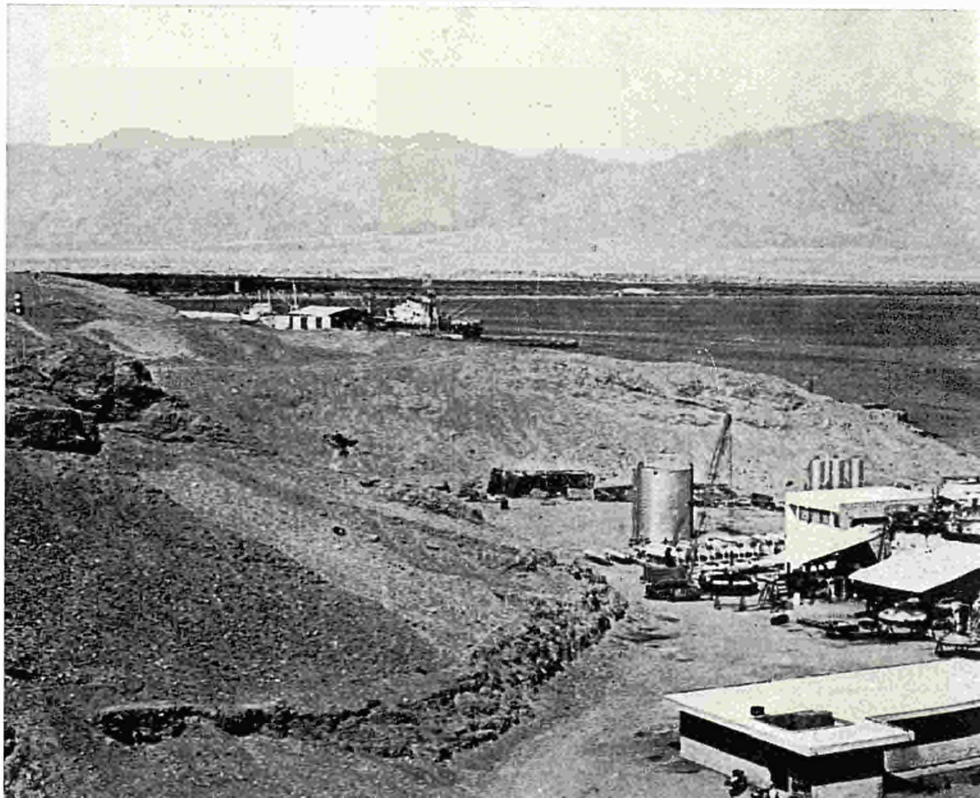
In short, water will soon have to be regarded, not as a commodity in unlimited supply, but as a raw material to which an adequate value will have to be assigned.
This will call for certain economic adjustments. The development and management of water resources will be an important factor of international co-operation on a scale determined by climatic zones. The water conversion industry will emerge from its present inconspicuity and constitute an integrated part of our environment, helped by the increasing availability of cheap energy from large power plants. Admittedly, sea-water conversion technology will have to be developed at the price of considerable efforts, but it holds out great promise for the satisfaction of mankind's future water needs.

Main desalination processes

Present desalination processes can be divided into four main types: electrodialysis, reverse osmosis, freezing and evaporation. In all these processes, which either separate solvent (water) from solute (salt) or vice-versa, a theoretical minimum amount of thermodynamic energy must be invested. The minimum energy requirement is relatively small (e.g. 0.7 kilowatt-hours per cubic metre for a salinity of 3.43% at 25°) and is the same for all processes.

Electrodialysis

Electrodialytic desalting is carried out in a series of water-filled compartments separated by special "permselective" membranes, of two different types. If an electric current is passed through the water, one type of membrane lets through water and cations, but stops anions; the other lets through water and anions only. As can be seen from figure 2, the membranes are arranged so that the salt concentration rises in half of the compartments and sinks correspondingly in the others.
A feature of electrodialysis is that it does not involve a change of phase of the water. When the method was first introduced,



it was thought that this would constitute an advantage, because it seemed that, thanks to the reduction of frictional energy losses to negligible proportions, energy consumption would approach the theoretical minimum. However, here as in other methods, energy is wasted: polarisation and electrical resistance must be compensated; scaling and filtration problems must be solved, back diffusion of salt must be overcome and membranes replaced.

As energy consumption with this method is proportional to the salt content of water, electrodialysis should logically be used for conversion of slightly brackish water or waste only, although attempts to use it for sea-water desalting, by itself, or in combination with other methods, are being made.

Only one plant in the range of 2000 cubic metres per day is in operation today (on brackish water), and it is therefore difficult to evaluate actual costs of this process. Extensive research in this field is being conducted by the *Negev Institute for Arid Zone Research* in Israel. One 500 cubic metres per day experimental plant is in operation and a production plant for 5000 cubic metres per day is in its final planning stages. The water cost for this case amounts to 20 cents per cubic metre.

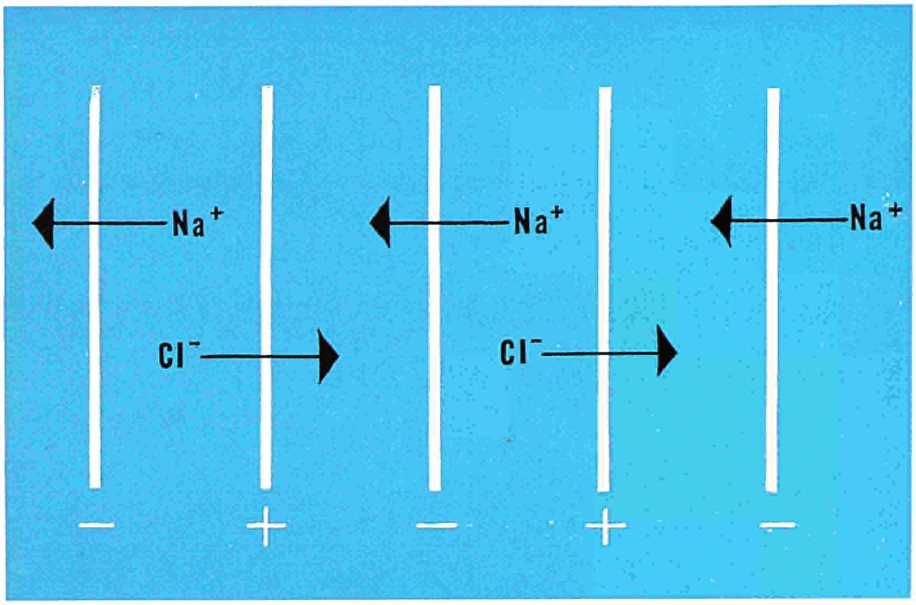


Figure 2: Working principle of electrodialysis

This projected figure refers to the local brackish water with a salinity content of 2000 ppm and a 500 ppm salinity of product water. Capital costs for electrodialysis are estimated at about $ 1.00 per litre product per hour for a 30% reduction in salinity. A reduction from 3,000 ppm brackish water to 500 ppm product water would require five steps, amounting to an investment of $ 5.00 per litre product per hour.

Electrodialysis today can hardly be considered a suitable method for upscaling into large production plants for the treatment of brackish water, and far less for sea-water desalting.

Reverse osmosis

The phenomenon of osmosis occurs when two solutions of different concentrations are separated by a membrane. If the membrane is "semi-permeable", i.e. if it is permeable to the solvent (water) and not to the solute (salt), a flow of solvent occurs from the more dilute into the more concentrated solution until the concentration becomes the same for both solutions or until the pressure of the more concentrated solution rises to a certain value.

However, if extra pressure is applied to the more concentrated solution, the phenomenon is reversed and the solvent can be made to flow through the membrane from the more concentrated to the less concentrated solution; hence the name "reverse osmosis".

Efforts have been devoted to the improvement of the membranes used (they are made of porous acetyl cellulose) to make them suitable for the conversion of sea-water and brackish water and the purification of waste water.

Reverse osmosis has recently emerged from the laboratory stage. Pilot plants designed for several cubic metres per day are in operation at present and one for 200 cubic metres per day has been planned. The application of reverse osmosis to sea-water requires a pressure of more than 100 atmospheres, which places a rigorous demand on the membranes. As large membrane surfaces are required for sea-water desalting, special ways had to be found of accommodating them into limited volumes and of providing the necessary resistance to high pressure. Membranes yield about 200 litres of product water per square metre of surface per day. As membranes constitute the main cost factor and still have to be frequently replaced, cost estimates are difficult to arrive at. The current estimate of water produced is 25 cents per cubic metre in a visualised reverse osmosis plant consisting of five major systems: intake, filtration and acid treatment units, high-pressure pumps, reverse osmosis units, power recovery turbines and water discharge systems.

Figure 1: Bird's eye view of the Vacuum Vapour Compression Freezing Plant in Eilat.

Freezing

The freezing process, which is currently under development in various directions, is similar to electrodialysis in that it is very promising on paper but has encountered many limitations in practice. It is basically a process involving three phase changes and operates at the "triple point" where the liquid, vapour and solid phases coexist. At the "triple point" of –1.9°C under a vacuum of 3.94 mm Hg, 7.5 kilograms of ice are formed for 1 kilogram of vapour from introduced sea-water, according to the corresponding caloric values of evaporation and freezing. Dissolved salts remain in the concentrated brine, which in part strongly adheres to the ice crystals formed, and has to be washed away with product water.

The "vacuum vapour compression freezing process" has been developed to a most advanced stage by *Desalting Engineering of Israel (Zarchin Process) Ltd.*, partly in co-operation with *Colt Industries Inc.* of the United States. It consists of five major systems: intake, freezer and compressor (hydroconverter), counterwasher, heat exchangers and process pumps.

A combination of these relatively simple elements into a production plant has been recently finalised and a pilot plant producing 4 × 250 cubic metres per day is now in operation on the Red Sea shore in Israel, supplying drinking water to the town of Eilat (figure 1).

In this process the vapour mass flow is approximately 13% of the ice produced; however, its low density results in very large flow volumes (approximately 10,000 cubic metres per minute for a 400 cubic metres per day plant.) Handling of such huge volumes thus presents a technical limitation to possible upscaling of this process.

The energy requirement is about 12 kilowatt-hours per cubic metre and capital investment is $ 500 per cubic metre in a plant consisting of 4 modules of 400 cubic metres each. The estimated water cost for a plant producing 2000 cubic metres per day, assuming a cost of 10 mills per kilowatt-hour and a 10% fixed charge rate, is 33 cents per cubic metre.

Power only — *200 MWe (net)*

Water only — *120 million m³/year*

Dual-purpose — *200 MWe (net)* and *120 million m³/year*

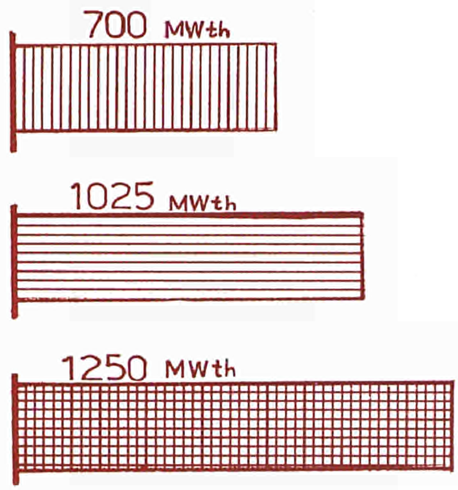


Figure 4: Energy requirements of a dual-purpose plant

Multiple stage flash process

Evaporation processes have been in practical use for some decades and have been developed in various forms. The multiple stage flash process is at its present stage of development the most suitable for use in large scale units. The process consists of three major sections: heat input, heat recovery, and heat rejection.

It is a regenerative evaporating process in which latent heat of the vapour leaving the flashing brine is recovered by the recycle brine flowing inside the heat transfer tubes (see figure 3). Flow of the

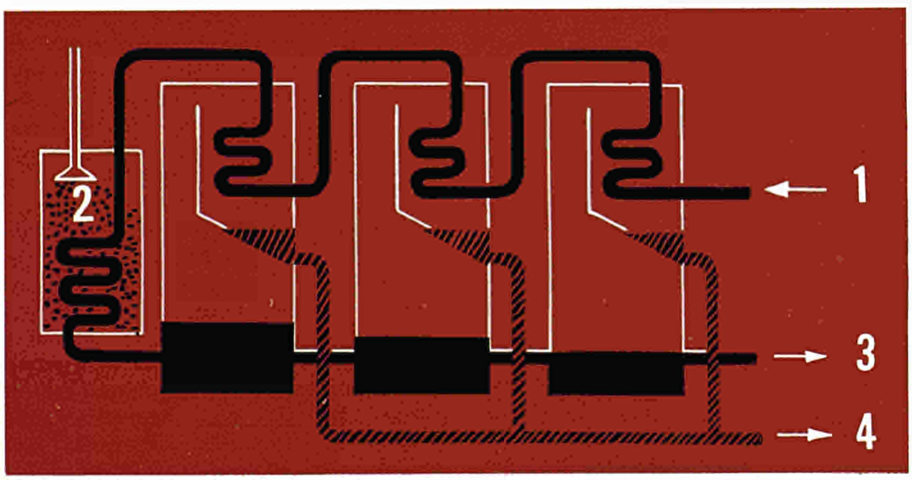


Figure 3: Working principle of the multiple stage flash process.
1. sea-water + recycled brine
2. steam heater
3. brine from flashing chambers
4. condensed vapour from flashing chambers (product water)

two brine streams, inside and along the flashing chamber, is countercurrent, and a temperature difference between the vapour and the recycle brine is maintained by division into stages. In each stage a pressure is established as a function of flashing brine temperature. Air and other non-condensable gases are continuously removed by an evacuation system to maintain the desired pressure drop along the stages. Heat has to be added to the process to compensate for heat removed by cooling water, blow-down and product water. It is added by steam from an external source condensing in the brine heater. The process has two temperature limits, that of the sea-water and that of the maximum brine temperature which is attainable without risking scale formation. The maximum temperature practical today is about 120°C and depends on the composition of the sea-water and the chemical treatment used.
A minimum pressure difference between adjacent stages is required, which limits the number of stages possible for any fixed temperature range. The number of flashing chambers employed, in turn, fixes the economy of the process. The "economy ratio" is defined as kilograms of product water produced per kilogram of steam added to the brine heater.
Economy ratio and water costs are closely related and affected mainly by the capital investment and energy cost applied. If the unit cost of steam is fixed, a higher fixed charge rate will lead to a plant which has fewer flashing chambers but uses more steam and vice versa.
Many improvements, most of them in detail engineering, have been applied to the multiple stage flash evaporating process during the last decade. Further radical technical improvements to decrease the water cost in this method are limited, owing to the linear relationship of most of its parameters; nevertheless many technical advances are expected.
An analysis of capital investment of a large multiple stage flash evaporator demonstrates the following division:

- Heat transfer area 35%
- Steel-work 37%
- Pumps and other equipment 28%

The most promising area for future economy in investment costs is heat transfer technology. Direct contact heat transfer, when more developed, will open additional far-reaching prospects for this process, as both capital and operating costs will drop sharply.
Even within the framework of present design principles, many elements can be improved by further research and development work. (The objectives for improvement are: optimum flashing chamber geometry including maximum possible mass flow of brine, maximum vapour disengaging rate, minimum temperature and pressure drops between two adjacent stages and adequate flashing devices, improvements in scale prevention methods, and

Figure 5: Dual-purpose power and water desalting plant.

1 *Nuclear reactor*
2 *Steam generator*
3 *Turbo-generator*
4 *Electrical energy output*
5 *Brine heater*
6 *Multi-stage flash evaporator*
7 *Brine recycle pump*
8 *Brine blow-down*
9 *Sea-water for cooling*
10 *Cooling water pump*
11 *Sea-water make-up*
12 *Heat reject stage*
13 *Fresh water*
14 *Cooling water to the sea*

Incoming sea-water shown in the lower right is used as coolant in the heat reject stage - and a portion of this sea-water coolant is added to the recycling brine as make-up. The recycled brine and sea-water make-up are cooled to 32°C by flashing in the heat reject stage, from where they are pumped into the tube bundles crossing the top part of the multi-stage flash evaporator, causing the vapour produced in the evaporator to condense. The recycled brine, which recovers heat in the process, emerges from the tubes at over 90°C and is further heated by the condensing steam from the turbine exhaust to about 104°C. As the heated brine enters the first chamber of the multi-stage flash evaporator, flashing occurs (because of the reduced pressure in the chamber), thereby reducing the temperature of the brine. As the brine flows from chamber to chamber, the pressure is progressively lower so that flashing occurs in each succeeding chamber. During this flow about 10% of the water in the brine solution is vaporised and subsequently condensed to form fresh water. The brine recycle is further cooled in the reject stage and with the addition of sea-water make-up repeats the circuit.
The recycle stream has a flow seven to ten times the fresh water production rate and a salt concentration about twice that of sea-water. It is thanks to the blow-down of brine to the sea and the addition of the sea-water make-up that the recycle concentration and flash chamber levels are maintained. The high purity product water emerges from the heat reject stage at about 32°C. Figure 7 represents a cross-section of two stages in the multi-stage flash evaporator.

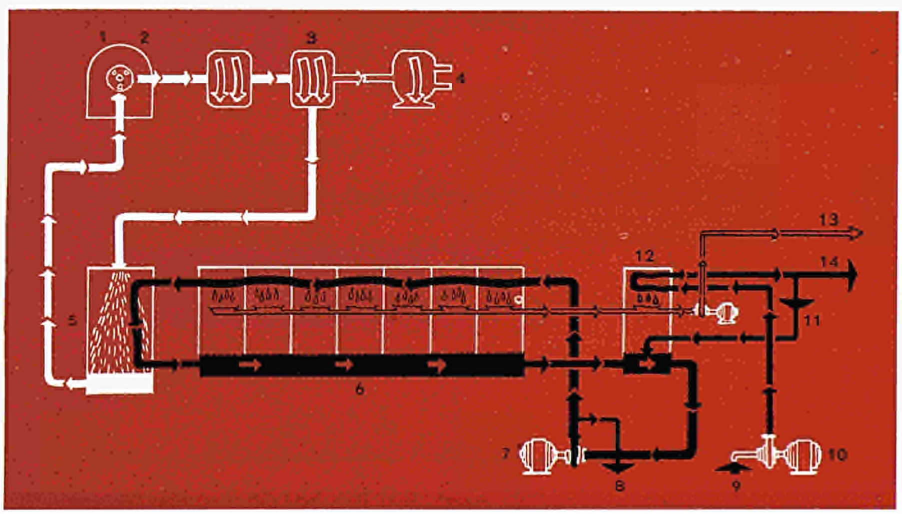
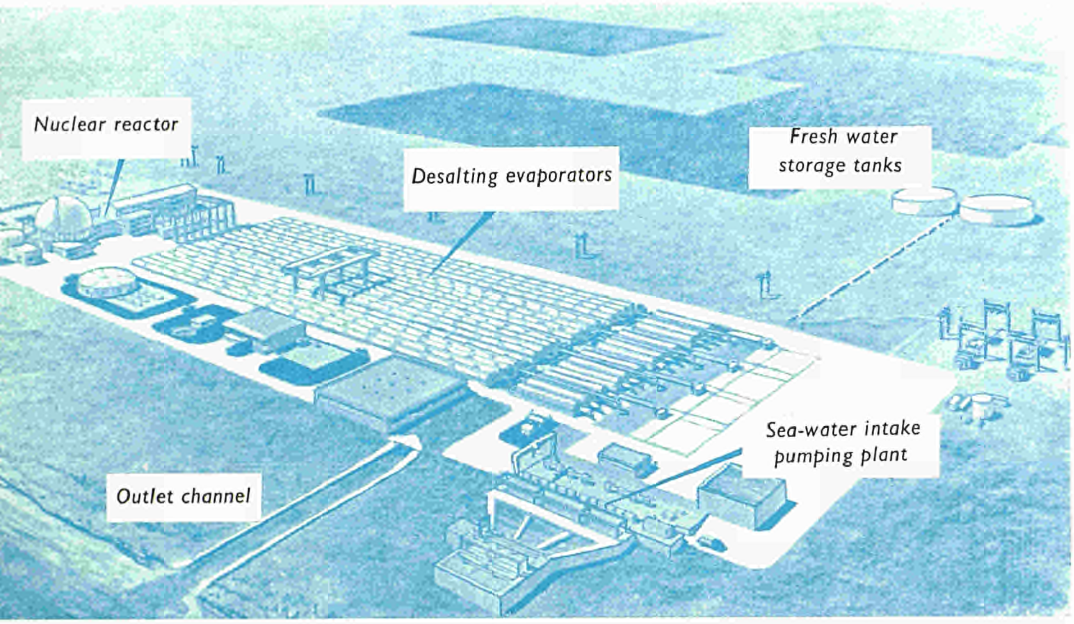


Figure 6: *Dual-purpose power and water-desalting plant for Israel (study sponsored jointly by the United States and Israel Governments. -Prime contractor*: Kaiser Engineers. - *Subcontractor*: Catalytic Construction Company.)



Capacity	*120 million m^3/ year (at 85% plant factor)*
Trains	*4 (4 modules each)*
Stages	*31*
Maximum brine temperature	*220°F (104.4°C)*
Economy ratio	*10.3 lb water/ 1,000 Btu heat (18,4 kg/1,000 kilocalories)*
Steam flow to brine heater	*3.4 million lb/hr (1.54 million kg/ hr)*
Steam pressure at brine heater	*25 psia (1.7 ata)*
Tube bundles	*7/8 inch diameter 90-10 copper/ nickel alloy*
Chlorine consumption	*140 metric tons/ year*
Sulfuric acid	*33,000 metric tons/year.*

more efficient deaeration devices).
Another way of reducing water cost significantly consists in combining water and power production in a dual-purpose plant. The economy ratio of a single-purpose water plant is low, owing to the above-mentioned temperature limitations, but the combined facility will utilise the energy input over a wider temperature range and therefore yield a higher overall efficiency.
A small dual-purpose water/power producing plant has been erected in the town of Eilat. This single plant, whose capacities are 6000 kilowatts and 1.1 million cubic metres per year, provides the main water supply for Eilat. Provision has been made for a second unit of the same capacity.

Large dual-purpose plant study

A recently completed feasibility study for a nuclear fired dual-purpose power/water plant for Israel illustrates, among other findings, the advantage of a large combined plant (see figure 4). An important additional saving accrues from the fact that only one energy source is required, instead of two smaller ones, and that the two plants can be run by a joint operational staff.
The above-mentioned study was undertaken by an *U.S./Israel Joint Board*. In December 1964, *Kaiser Engineers* and its main subcontractor, *Catalytic Construction Co.* of Philadelphia, were awarded a contract for a detailed feasibility study of a dual-purpose power and water producing plant.
The basis for the study were:
— a plant capacity of 175-200 megawatts of net salable electricity and 100-150 million cubic metres of water per year;
— a plant ready for operation in 1971 and commercial production in 1972.

The selected plant

The feasibility study resulted in the "selected plant" which is a nuclear power/desalination complex using a light water reactor, a back-pressure turbine and a multi-stage flash evaporator with capacities of 200 electrical megawatts (net salable) and 120 million cubic metres per year of water

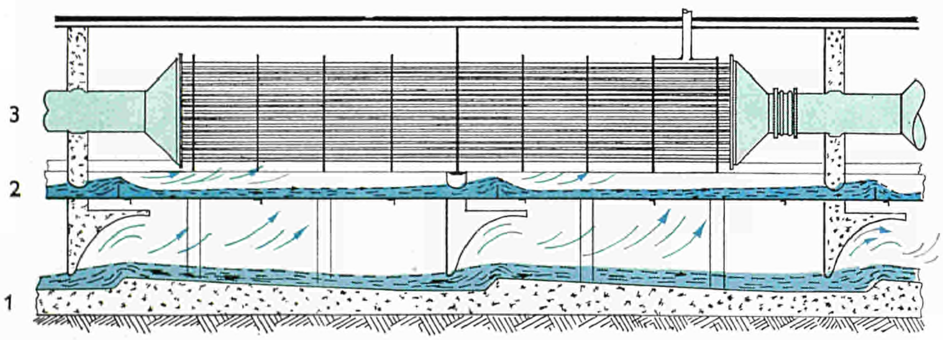


Figure 7: Cross-section of two stages in the multi-stage flash evaporator.
The heated brine (1) flashes and the vapour which it releases is condensed into fresh water (2) by the tube-bundle (3), through which cooled brine is recirculated. The partition between the two chambers is so arranged that the water seals them off from each other.

Figure 8: Israel dual-purpose plant investment (in millions of dollars) Total investment $187,000,000

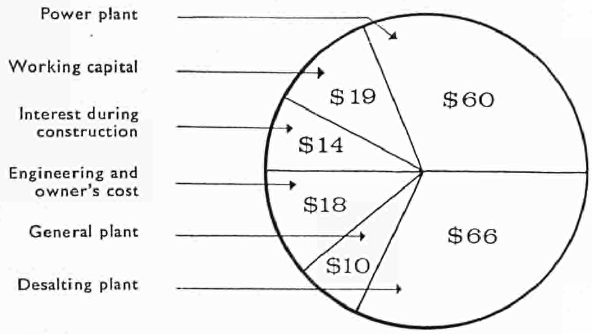
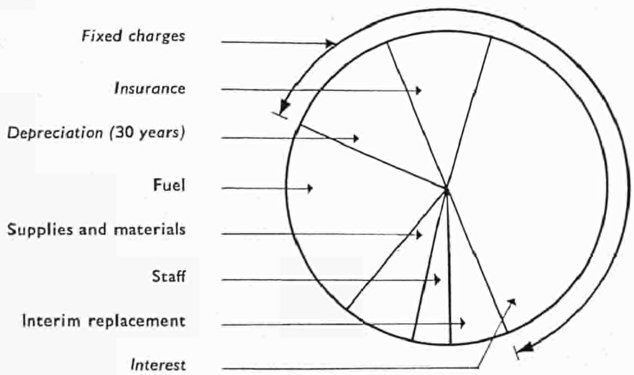


Figure 9: Split-up of Israel dual-purpose plant annual costs



production at an 85% plant operating factor. Figure 5 represents the basic flow sheet for this dual-purpose system.
Main elements of this system (see figure 6) include the nuclear reactor and power plant, desalination evaporators, sea-water intake and acid treatment facilities, product water storage and facilities for the disposal of waste brine. The flow streams connecting these elements are arranged to produce electrical power and desalted water at minimum cost. Steam generated in the nuclear reactor plant, depicted in the upper left of Figure 5, drives the turbo-generator. The steam exhaust from the turbine transfers make-up heat to recycled brine preparatory to the multi-stage evaporation and desalting operation. As the flash evaporator uses the brine recycle principle, this restricts boiling to the open flash chambers and avoids scaling of tube surfaces.

Optimisation studies

Because of the need to examine plants over a large range of physical and economic parameters, a computer programme was devised to permit the evaluation of several thousand alternative plants in a reasonable time and to determine the combination of characteristics yielding the lowest unit water cost. The reference plant consists of four trains each having a capacity of 30 million cubic metres per year and each capable of operating independently of each other. Within each train there are four module-trains operating in parallel, each having a capacity of some 7.5 million cubic metres per year and representing a four-fold capacity scale-up of existing plants of this kind.
Site erection is assumed for evaporator structures, which are made of either reinforced concrete or steel, while such equipment as brine heaters, removable evaporator heat exchange bundles, pumps, air ejectors, gantry crane, etc. are shop fabricated. Design is such that, if the turbo-generator of the power plant is shut down, the water plant can continue to operate; conversely, if the water plant must be shut down, the turbo-generator can continue to generate power.
It was on the basis of the computer optimisation that a nuclear plant of 1.250 megawatts thermal, with a 250 megawatts electrical (200 net salable) turbo-generator, supplying steam at 25 psia to the desalting plant, was chosen.

Nuclear versus fossil fuel

After selection of the nuclear dual-purpose plant, a fossil fuel dual-purpose plant was studied and compared with respect to characteristics and cost. The study showed that the cost of water produced in a nuclear dual-purpose plant was lower than that produced in a fossil fuel dual-purpose plant for all fixed charge rates (5%, 7% and 10%) considered, when the water plant capacity was 120 million cubic metres per year. In a companion study at 100 million cubic metres per year the nuclear plant yielded cheaper water for all fixed charge rates below 9%.

Estimated capital and unit water costs

The estimated capital cost for the selected dual-purpose plant constructed in Israel is $ 187 million based on 1965 costs and reflects Israeli construction costs. Allowance has been made for maximum practical utilisation of Israeli skills, construction labour, materials and products.
This capital cost estimate is delineated in figure 8; it does not include electrical transmission and water conveyance facilities required to bridge the gap from the dual-purpose plant boundaries to the main Israel distribution network. Therefore, to this $ 187 million estimate we may add $ 5 million for electrical transmission and 25 million dollars for water conveyance facilities.
The unit water cost estimates are based on 1965 costs with respect to operating labour, materials and credit for power sold (assumed at 5.3 mills per kilowatt-hour) and with respect to the capital costs upon which the fixed charges have been calculated. As noted in figure 9, fixed charges constitute a large portion of the total annual costs. Assuming an 85% plant operating factor, product water at the plant boundary is estimated to cost:

	Fixed charge rates		
	5%	7%	10%
Cents per 1000 gallons	28.6	43.4	67.0
Cents per cubic metre	7.6	11.5	17.7

Thus, it is noted that a change of one percentage point in fixed charges results in a difference of about 7.5 cents per 1000 gallons (2.0 cents per cubic metre) in water cost. Interest and sinking fund depreciation (with its heavy dependence on interest rate) constitute almost the entire fixed charge. For example, with a fixed charge rate of 7%, interest is 4.6% and depreciation on a 30-year sinking-fund basis is 1.6% —together constituting 90% of the total

fixed charges. Insurance and in lieu taxes compose another 10%.
A development programme has been recommended. This programme will "prove out" those features not currently in commercial operation and provide data on means of reducing desalination plant costs.
Results from a similar feasibility study for the *Metropolitan Water District of Southern California* are in agreement with the *Kaiser-Catalytic* study.

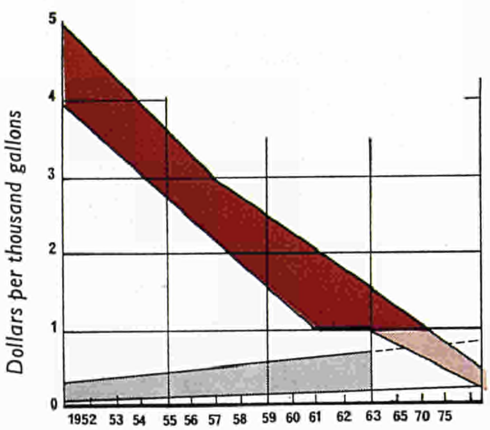
Potential applicants for large plants

Water costs quoted in these studies are very encouraging, compared with water costs for desalted sea-water prevailing some years ago, but are still extremely high considering general prevailing water prices.
Future large size desalting plants of billions of cubic metres per year may develop to single-purpose plants, owing to the enormous power blocks involved which few areas could absorb, but the forthcoming generation of intermediate size plants in the range of 100 million cubic metres per year will certainly be dual-purpose power and water producing plants.
These plants will put to the test the scale-up economies which are possible for desalting technology. As for the actual application of product water from dual-purpose plants for municipal, industrial and agricultural supply, it will provide information for plants of the more distant future.
There are many questions which should be considered carefully before deciding on the erection of a dual-purpose plant. Here are some of them:

— Have the regional natural water resources been already fully exploited?
— Are there no alternative water supplies near by?
— Is the economic structure too rigid to permit shifting of agricultural water to industrial and municipal usage?
— Is an integrated water grid available?
— Can the electricity network absorb the output of a large base-load power-producing unit?
— Can a high value be allocated to the low salinity of the product water?
— Is there an adequate technical and administrative staff capable of coping with advanced technology?
— Are there facilities for interseasonal storage of large quantities of water?

The number of potential applicants for these intermediate size units under present desalting technology is certainly limited, especially those who could arrive at an economic and technical evaluation of the multi-purpose use of product water.

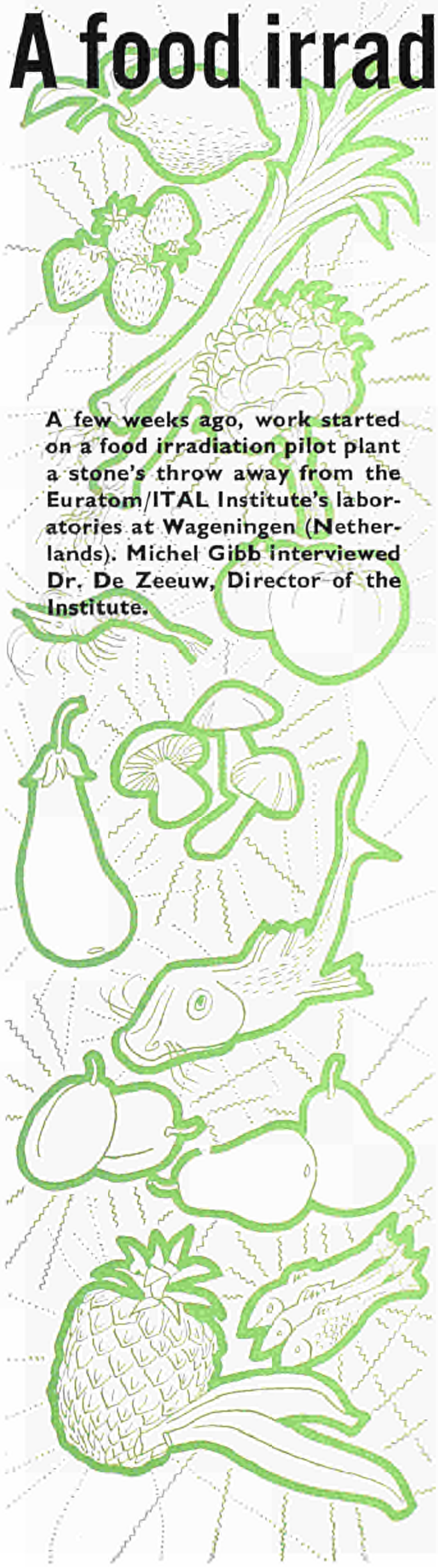
Figure 10: Future trend of water costs from conventional sources (in grey) and from the water conversion industry (in colour)— from U.S. Dept. of the Interior Office of Saline Water, *1962 Report.*



First plants—a stimulant for more

Yet those first operating plants will become a stimulant for those who prefer not to be first but will have to tap the sea soon for additional water supply. In turn, industry will join the present predominantly governmental research and development efforts and become a dominant factor in the progress of desalination technology. It must be borne in mind that a few years of superiority may be decisive and that there is no better way of learning than by doing.
Improved technology will lead to lower desalted water costs and this factor, combined with the reassessment of water "value" which is taking place, will make desalting plants more and more attractive as time goes on. However, the initial steps will have to be padded by an unconventional investment policy in large plants. This will prevent social and economic "friction".

A food irradiation pilot plant



A few weeks ago, work started on a food irradiation pilot plant a stone's throw away from the Euratom/ITAL Institute's laboratories at Wageningen (Netherlands). Michel Gibb interviewed Dr. De Zeeuw, Director of the Institute.

Dr. De Zeeuw, what are the prospects of conservation of food by irradiation? Are they good enough to justify the construction of a pilot plant?

I think there can be no doubt that, generally speaking, they are good. But irradiation is not a panacea for all our food conservation problems. The whole point of the pilot plant is precisely to make it possible for the marketing organisations to gain detailed practical experience on *how* good the prospects of irradiation are for the conservation of *particular* foodstuffs.

Are there no useful research results available in this connection?

The interaction between ionising radiation and living matter has been studied extensively for the past twenty years and the results of this work have clearly demonstrated that foodstuffs can be preserved by irradiation.
The problem is how to pass on to food manufacturers the know-how acquired. It should be realised on the one hand that it is not the rôle of a research institute to provide industry with a ready-made process; on the other hand the food manufacturing sector is usually not able to try out on a commercial scale the results obtained in the laboratory. It is to bridge this gap that it has been decided to build a pilot plant.

How is it that irradiation improves the keeping qualities of food-stuffs?

It is primarily the action of micro-organisms which causes all our food to deteriorate shortly after it has been harvested, gathered or slaughtered. The effect of irradiation is to destroy a large number of these micro-organisms.

I believe this is true of several other conservation methods. What advantages has irradiation to offer over these methods?

The process I have been referring to is a kind of *cold* pasteurisation. It therefore offers the advantage over the traditional pasteurisation methods, which involve the use of heat to destroy the micro-organisms, that the properties characteristic of the fresh product are retained.
This is of course not the whole story. Although irradiation leads to the microbiological stability of a product, it does not follow that complete storage stability will be obtained. In order to arrive at this result it may be necessary to destroy certain enzymes, in which case irradiation has to be combined with other methods, or else the radiation dose must be considerably increased.
However, this perfectionism is often not necessary. In many cases the elimination of the most harmful groups of micro-organisms will stabilise the product sufficiently to extend its storage life by a few days. From a marketing point of view - I am thinking here of fruit and vegetables especially - even such a short extension can be very valuable.

Can you give us a few practical examples?

Irradiation of fruit, vegetables, fish and meat offers the most obvious prospects because these products have today a very limited storage life. It should be added that cold storage and disinfectants have not always produced the desired results. Since 1961 research work on fruit and vegetables has been carried out by the *Euratom/ITAL Association* in co-operation with the *Institute for Research on Storage and Processing of Horticultural Produce* at Wageningen. In the course of these investigations, use was made chiefly of low-penetration rays with the object of treating the surface of the fruit only. The reason for this is that the deterioration of such soft fruit as strawberries, raspberries, cherries and plums is accelerated by the formation of moulds and yeasts on the surface of the fruit. Consequently a surface treatment is often sufficient.
The results of more fundamental research

on the influence of radiation on the physiology of the fruit have shown that the ripening mechanism is also affected. Hence irradiation in this case succeeds not only in inactivating the micro-organisms already present but it has an effect on the natural decay of the fruit.

These findings are particularly interesting: they open up the possibility of handling, marketing and distributing produce over longer periods of time than is now the practice.

I will give you just one other example, which shows up a different set of problems: the conservation of fish. The very low storage stability of fish is due to the natural microflora of the skin and in the intestines. It consists mainly of organisms of the Pseudomonas-Achromobacter group, which develop rapidly at low temperatures. The storage of fish in ice therefore does not prevent decay. The maximum storage life of white fish is about 14 days at 0°C and at 4.4°C it is only 6 days.

The most recent development in this field is irradiation. It is possible to irradiate fresh fish in order to obtain a stable product, but the sterilisation dose required leads

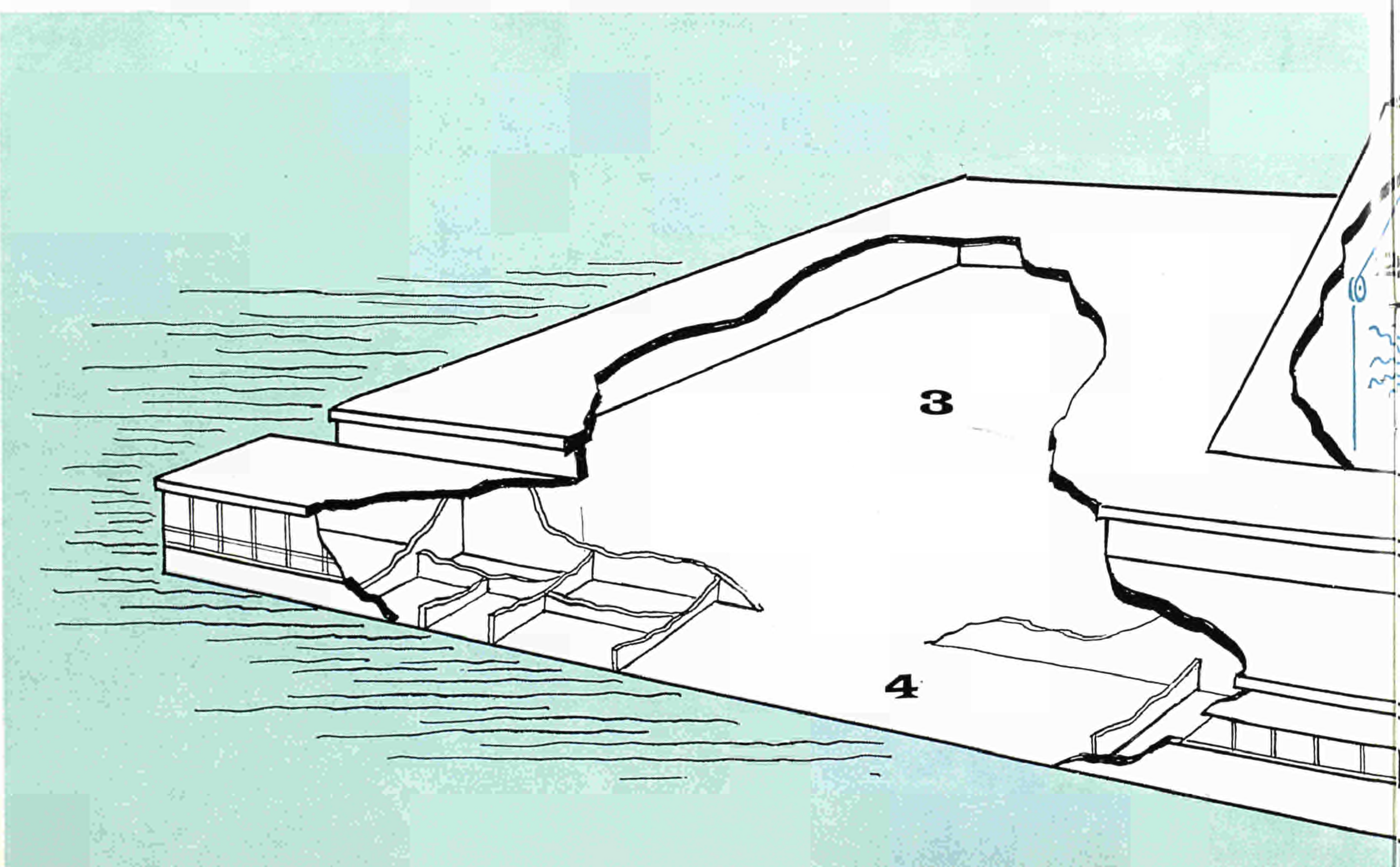
As can be seen from the plan, the food-irradiation pilot plant in Wageningen will be equipped with two radiation sources. In one of the source-rooms will be housed a 85,000 curies cobalt-60 source, and in the other a 3 MeV Van de Graaff electron-accelerator.

The cobalt-60 source is a dry source, equipped with a fully automatic multi-pass system for exposing the material to be irradiated on four different planes. A loading and offloading conveyor will also be provided, capable of storing 8 hours of product. The speed control for the conveyor system will be infinitely variable. The Van de Graaff accelerator, which is a normal standard K machine, will be vertically mounted. Products to be irradiated will be transported to and from the source on conveyors, adapted to the kind of product.

The working area is divided into two parts. The largest area is for those products which can be handled at ambient temperature, while the smaller room can be kept at a constant low temperature, for handling products such as fish, meat etc.

Next to the main entrance of the plant are situated the administration offices and a small laboratory for dosimetry.

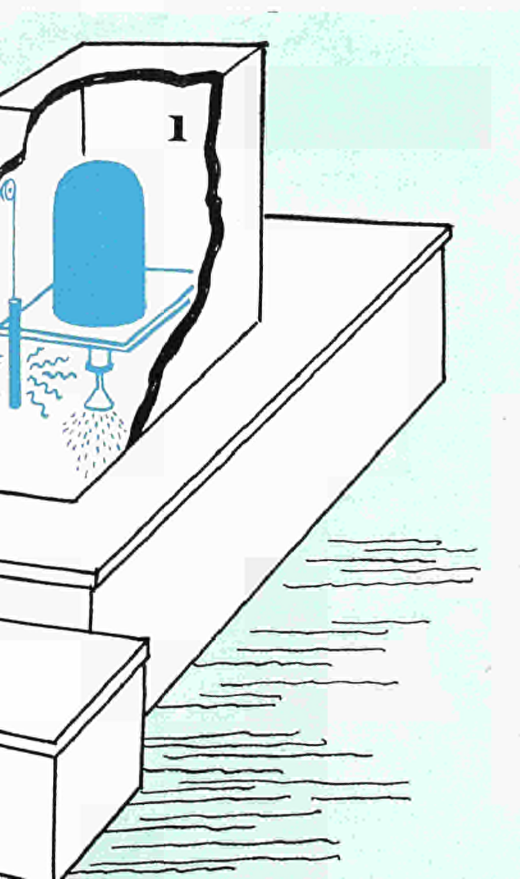
1. Van de Graaff accelerator
2. Cobalt-60 source
3. Working area (ambient temperature)
4. Working area (low temperature)



to unacceptable changes in consistency, flavour and taste. On the other hand irradiation *combined with cold storage* at relatively moderate temperatures (of the order of 0 to 4° C) offers good prospects. As an illustration it may be stated that fillets of plaice wrapped in plastic can be stored at 4.4°C for at least 20 days after irradiation.

I will ask you the inevitable question: is there any possibility that irradiated food could be a threat to health?

Considerable research efforts have been devoted to this problem. It is accepted today that irradiation is safe for most foodstuffs: no toxins, no carcinogenic elements, no induced radioactivity are produced.
However irradiation can entail a shift in the microbiological balance: the most resistant micro-organisms stay alive and can, because of the absence of competition, develop into larger colonies than would otherwise have been the case; if some of these micro-organisms happen to produce toxins, then a threat to health exists, because they will be produced in abnormally large amounts. This fact does not constitute an objection to the use of radiation. It just means that before embarking on the large-scale treatment of a particular product from a particular area, tests will have to be carried out and, if necessary, adjustments be made to the treatment conditions.



To come back to the pilot plant: why did your choice fall on two types of radiation source, namely a γ-emitting isotope and an electron-emitting machine, instead of only a γ-source as is generally done?

Our institute has always had a keen interest in the possibilities offered by an electron accelerator for both shallow and penetrating treatment. When such a machine is used in a straightforward manner it produces electrons, which have a low penetration. On the other hand, if a gold target, for instance, is placed in the path of the electron beam, high-penetration electromagnetic radiation (*Bremsstrahlung*) is produced.
In an electron accelerator it is possible to vary both the energy of the emitted particles and the density of the beam, which makes for great flexibility. Moreover the machine can be, unlike a γ-source, switched on and off, so that no radiation energy is lost when it is not being used.
However, it was decided to instal a high penetration γ-source as well, in order to make more complete the experience which could be derived from the pilot plant. In any case this arrangement has additional advantages: two different treatments can be given at the same time and furthermore the flexibility of the whole is increased.

What capacity will the plant have?

It will be capable of treating 1000 kg per hour.

Is this not a fairly high output for what is after all only a pilot plant?

Not if you consider that it is meant to be the immediate precursor of future commercial facilities. If information had been wanted only on such parameters as dose-rate, required radiation dose, etc., then it is true that a plant with a capacity of some 200 kg/hr would have been adequate.
But the purpose of this pilot plant goes further. It is meant to provide technical data on the actual processing and on various other aspects such as the storage of the irradiated products. It is also meant to supply information on production costs and on the best ways of planning and running a commercial facility. Finally sufficient amounts of irradiated food must be produced to make it possible to supply the market and sound public opinion.

Who are the sponsors of the pilot plant?

There are several sponsors. It has been proposed that a quarter of the investment cost be borne by the Common Market's European Agricultural Guidance and Guarantee Fund. The remainder of the cost will be shared by the Dutch Government and the Dutch marketing organisations.

And who will actually run it?

The plant will be run by a board of governors, *all* of whom will be representatives of the marketing organisations. I think this is a unique feature. The Wageningen food irradiation pilot plant cannot be said to be entirely unique from the technical point of view: similar plants are being planned or under construction in other countries and a few are already operating. But as a rule commercial organisations, although they have a voice on the governing boards of these plants, do not bear complete responsibility, as their counterparts will do in Wageningen.
The marketing organisations will of course not be left altogether to their own devices. Two representatives from the Dutch Ministry of Agriculture and two representatives from the *Euratom/ITAL Association* will be appointed to assist the board of governors.
The board will also be assisted by an advisory committee whose members will include public health experts, representatives of the Press, housewives, etc.

You explained earlier how the investment costs would be covered. What about the running costs?

Basically it will be up to the board of governors to conclude contracts with firms who wish to avail themselves of the pilot plant's facilities. Tailor-made experimental programmes can then be drawn up, the results of which will be the firms' property.

EUBU 5-12

Euratom and patents

JACQUES RENAUDIE, *Head of Patents Bureau, Directorate General for Dissemination of Information, Euratom.*

Somewhat paradoxically, it is nowhere laid down in the Euratom Treaty that the European Atomic Energy Community *must* patent the fruits of its research, and yet it does so; by 1 August 1966 a total of 2201 patent applications had been filed in Euratom's name and 1214 in the name of parties associated with or under contract to Euratom, covering 812 inventions in 26 countries.

It is the purpose of this article to explain how and why Euratom is building up a portfolio of patents.

The purpose of patents

A patent is a title delivered by a government to an inventor or his assign, generally his employer, to establish his temporary exclusive right to exploit his invention for profit. Offsetting this exclusive right, the government, representing society, sees to it that the invention is made known by publishing the patent. This system ensures that any benefits stemming from the invention will not be lost to society.

Pindar is said to have written that "The merit belongs to the first inventor" and this seems fair, reasonable and practically beyond all question. But before such merit can be widely recognised, one practical condition must be met—the invention must be made public.

Thus at the heart of the problem we find alternatives: if the invention is revealed (through lectures, publication, marketing) without due precaution, it is surrendered to the public. This procedure may, indeed, be an act of humanity but at the same time it can be a gift to rivals. On the other hand, if the invention is kept secret, the inventor cannot make any public claim to merit and often finds difficulty in turning it to profit.

In former days the only way an inventor could defend himself against imitators and competitors was by jealously guarding the secrets of his craft. This system had very serious disadvantages: in the first place it was unreliable (the simple explanation of the dispute over the invention of printing, for example, is probably that one of Coster's former workmen was taken on at Gutenberg's works); secondly, it slowed down or prevented those exchanges of knowledge which are the yeast of technical progress; and lastly, there was always the danger that the use of some invention might be lost to mankind for ever (for instance, no one has ever succeeded in reproducing certain pigments used in the stained-glass windows of the Middle Ages).

Not everything is patentable, however. The legal criteria vary from country to country, but two of them are universal—the invention must be new (though there are limits of space or time to this "novelty" condition in some countries) and it must be of industrial application (the term "industrial" being understood in its widest etymological sense). We should note, incidentally, that the novelty may be annihilated by the inventor himself if he discloses his invention before filing a patent application. The other most usual criteria are the technical progress contributed by the invention, and the "level of invention", a subtle concept involving a fictitious character called the "person skilled in the art", who is assumed to be thoroughly acquainted with the state of the art in question but of very moderate inventive ability.

Certain countries insist on a preliminary examination, that is to say they will not grant a patent until they have ascertained that the patent application satisfies all the requirements. This investigation usually takes two or three years, but exceptional cases can be cited, such as the celebrated Joliot patents, which went through more than twenty years of bitter argument before they saw the light in certain countries. Other countries grant the patent automatically but without guaranteeing that the invention is new; this is why French law obliges the patentee to specify "S.G.D.G." (not guaranteed by the Government).

Another important point is that under the Union Convention signed in Paris in 1883, to which more than 70 countries acceded (including the USSR in 1965), anyone who files a patent application in one of the countries of the Union is allowed one year to effect the "corresponding applications" in other Union countries, claiming the date of the first application as priority. After that time he forfeits this advantage; as the effective date of filing in a particular country is the only one legally recognised, he then runs a considerably higher risk that someone else will get in first with his invention, if only because of his initial patent application if it has been published in the meantime.

We should note here that each patent is therefore valid in one country only, with one exception—the African and Malagasy Office for the Protection of Industrial Property grants a patent which is valid in the twelve member countries of the African and Malagasy Union. There are, moreover, several very advanced international patent schemes ("European patents", for the six Common Market countries, "Nordic patents" for the Scandinavian countries), and this tendency to internationalise the patents system is spreading. It has reached the United States, witness the speech delivered by Mr. Edward J. Brenner, Commissioner of Patents, on the occasion of the 175th anniversary of the United States patents legislation. Mr. Brenner acknowledged the advantages of extensive co-operation by all countries in the "preliminary examination" so as to avoid unnecessary repetition of the "searches for prior publication and use".

Another important point is that the law in all countries deals very sternly with infringers—those who use a patented invention without the consent of the patentee.

Lastly, we should mention that as well as being exploited by its owner, an invention protected by a patent can either be "assigned" (sold) or leased under a "licence" which may be gratuitous or subject to various fees, the best-known of which are the dues called "royalties".

Why does Euratom take out patents?

Let us examine the reasons that prompted the Euratom Commission to apply for patents.

Article 2 of the Treaty of Rome says that the Community must "develop research and ensure the dissemination of technical knowledge". It is obvious, however, that unless certain safeguards accompany this dissemination any third party will be able to make free use of the discoveries made in the course of research financed by the Community budget. But Article 1 of the Treaty specifies that "it shall be the aim of the Community to contribute to the raising of the standard of living in Member States and to the development of commercial exchanges with other countries by the creation of conditions necessary for the speedy establishment and growth of nuclear industries".

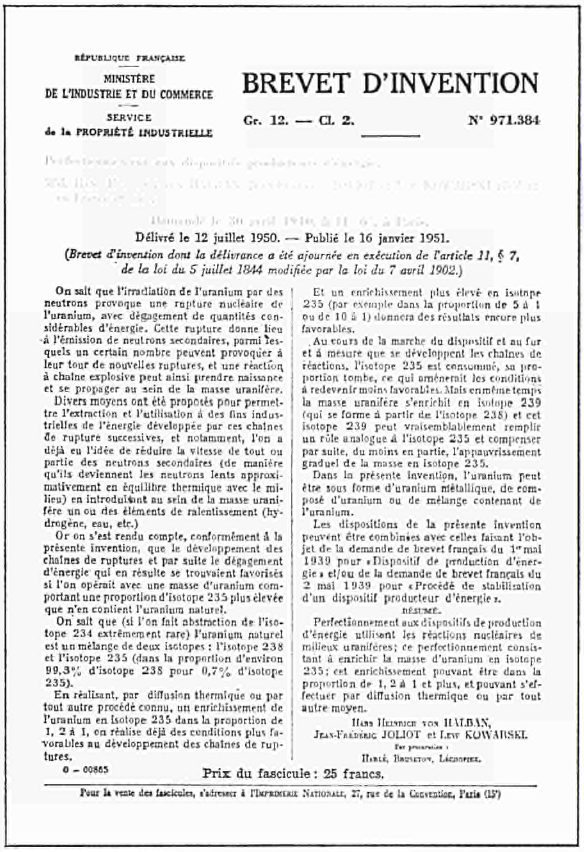
The ownership of a patents portfolio serves precisely that aim, in that it helps the Community to give preference to the industries of Member States and strengthens its hand in exchange agreements with other countries.

Furthermore, since Article 12 of the Treaty regulates the use of "patents, provisionally protected patent rights, utility models or patent applications, which *are the property* of the Community", their existence is officially, though indirectly, recognised.

In its main task of promoting research, the Commission has two means of action—the Joint Research Centre establishments and contracts or association agreements concluded with enterprises in the Community. In either case the studies are financed by public funds provided by the Member States; it is therefore normal that the first fruits of Community research should go to those States and their industries (or their citizens).

Such priority may take two practical forms. According to whether the information is patentable or not, it is issued either (Article 12 of Treaty) under a preferential licence system, which was defined in a statement by the Commission to the Council of Ministers, or (Article 13) by restricted dissemination, confined to persons and enterprises in the Community.

Again, it was in the light of these basic principles that the Commission decided who was to own the patents. Obviously, for inventions produced by the Joint Research Centre, the Community applies for them in its own name; but for inventions issuing from contracts or association agreements, this right belongs in the first place to the contractor or associate of the Community, subject to his allowing the latter a free and irrevocable licence with the right


RÉPUBLIQUE FRANÇAISE
MINISTÈRE DE L'INDUSTRIE ET DU COMMERCE
SERVICE de la PROPRIÉTÉ INDUSTRIELLE

BREVET D'INVENTION

Gr. 12. — Cl. 2. N° 971.384

Délivré le 12 juillet 1950. — Publié le 16 janvier 1951.

(Brevet d'invention dont la délivrance a été ajournée en exécution de l'article 11, § 7, de la loi du 5 juillet 1844 modifiée par la loi du 7 avril 1902.)

On sait que l'irradiation de l'uranium par des neutrons provoque une rupture nucléaire de l'uranium, avec dégagement de quantités considérables d'énergie. Cette rupture donne lieu à l'émission de neutrons secondaires, parmi lesquels un certain nombre peuvent provoquer à leur tour de nouvelles ruptures, et une réaction à chaine explosive peut ainsi prendre naissance et se propager au sein de la masse uranifère.

Divers moyens ont été proposés pour permettre l'extraction et l'utilisation à des fins industrielles de l'énergie développée par ces chaines de rupture successives, et notamment, l'on a déjà eu l'idée de réduire la vitesse de tout ou partie des neutrons secondaires (de manière qu'ils deviennent les neutrons lents approximativement en équilibre thermique avec le milieu) en introduisant au sein de la masse uranifère un ou des éléments de ralentissement (hydrogène, eau, etc.)

Or on s'est rendu compte, conformément à la présente invention, que le développement des chaines de ruptures et par suite le dégagement d'énergie qui en résulte se trouvaient favorisés si l'on opérait avec une masse d'uranium comportant une proportion d'isotope 235 plus élevée que n'en contient l'uranium naturel.

On sait que (si l'on fait abstraction de l'isotope 234 extrêmement rare) l'uranium naturel est un mélange de deux isotopes : l'isotope 238 et l'isotope 235 (dans la proportion d'environ 99,3% d'isotope 238 pour 0,7% d'isotope 235).

En réalisant, par diffusion thermique ou par tout autre procédé connu, un enrichissement de l'uranium en isotope 235 dans la proportion de 1, 2 à 1, on réalise déjà des conditions plus favorables au développement des chaines de ruptures.

Et un enrichissement plus élevé en isotope 235 (par exemple dans la proportion de 5 à 1 ou de 10 à 1) donnera des résultats encore plus favorables.

Au cours de la marche du dispositif et au fur et à mesure que se développent les chaines de réactions, l'isotope 235 est consommé, sa proportion tombe, ce qui amènerait les conditions à redevenir moins favorables. Mais en même temps la masse uranifère s'enrichit en isotope 239 (qui se forme à partir de l'isotope 238) et cet isotope 239 peut vraisemblablement remplir un rôle analogue à l'isotope 235 et compenser par suite, du moins en partie, l'appauvrissement graduel de la masse en isotope 235.

Dans la présente invention, l'uranium peut être sous forme d'uranium métallique, de composé d'uranium ou de mélange contenant de l'uranium.

Les dispositions de la présente invention peuvent être combinées avec celles faisant l'objet de la demande de brevet français du 1er mai 1939 pour « Dispositif de production d'énergie » et/ou de la demande de brevet français du 2 mai 1939 pour « Procédé de stabilisation d'un dispositif producteur d'énergie ».

RÉSUMÉ.

Perfectionnement aux dispositifs de production d'énergie utilisant les réactions nucléaires de milieux uranifères; ce perfectionnement consistant à enrichir la masse d'uranium en isotope 235; cet enrichissement pouvant être dans la proportion de 1, 2 à 1 et plus, et pouvant s'effectuer par diffusion thermique ou par tout autre moyen.

Hans Heinrich von HALBAN,
Jean-Frédéric JOLIOT et Lew KOWARSKI.
Par procuration :
Harlé, Bruneton, Lécuyer.

0 – 00865

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to grant sub-licences under certain conditions.

We come now to the key question—the "profitability" of patents. Without going so far as to write, as someone did, that it is "easier to turn money into patents than patents into money", it must be admitted that it is far easier to calculate the amount of expenditure incurred for patents than the amount of profits they bring in. It is a fact that the profit reaped from a patent cannot always be reckoned in figures, and the receipt of royalties for licences is only one of the possible benefits.

To borrow an analogy from real estate, we might ask if the rational way of using a house is to occupy it, let it, . . . or sell it! In the last two cases the profit is readily apparent in the sale price or the rent received, less expenses; but in the case of owner occupation, can a price be put on the direct advantage thus obtained (security of tenure, stability of charges, planning of

May 17, 1955 E. FERMI ET AL **2,708,656**

NEUTRONIC REACTOR

Filed Dec. 19, 1944 27 Sheets-Sheet 20

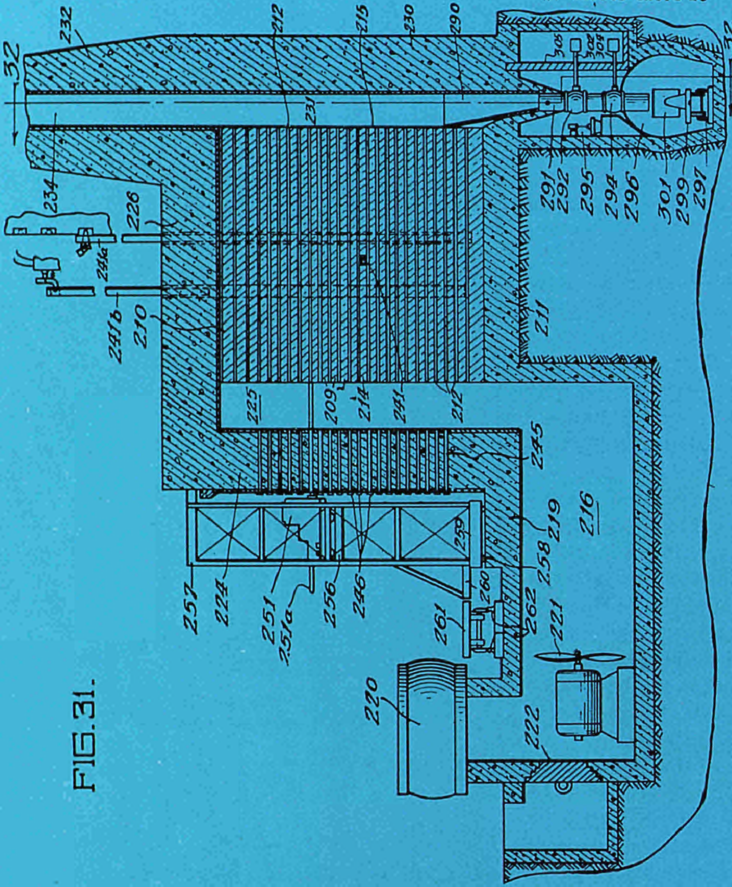


FIG. 31.

Witnesses:
Herbert E. Metcalf
Francis W. Test
Henry H. Johnson

Inventors:
Enrico Fermi
Leo Szilard

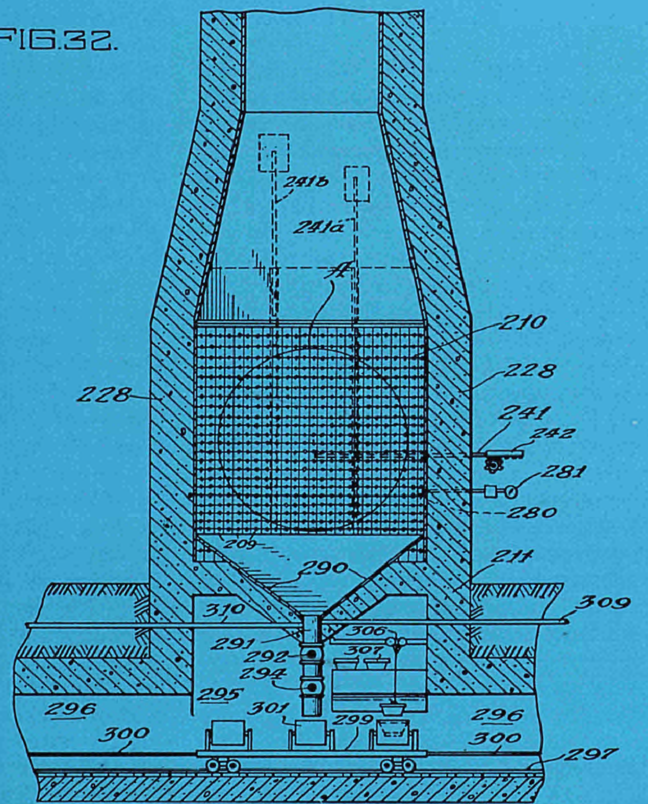
By: Robert A. Lavender
Attorney

May 17, 1955 E. FERMI ET AL **2,708,656**

NEUTRONIC REACTOR

Filed Dec. 19, 1944 27 Sheets-Sheet 21

FIG. 32.



Witnesses:
Herbert E. Metcalf
Francis W. Test
Henry H. Johnson

Inventors:
Enrico Fermi
Leo Szilard

By: Robert A. Lavender
Attorney

Extracts from the patent granted to Enrico Fermi and Leo Szilard for the 'neutronic reactor'. The application was filed on 19 December 1944.

maintenance and improvements) . . . or the higher credit status of the owner, should he wish to obtain credit? The only items that can be expressed in figures are the maintenance expenses and the market value of the house, which varies. It remains to be shown that patents are necessary in the same way as a house. One could, conceivably, run an enterprise without resorting to the protection of industrial property rights, in the same way as nomads do not worry about buying or renting a piece of land. Obviously, however, the industrialist who does this would be exposing himself to serious hazards; if he does not patent the processes and devices which he has developed and utilises, a competitor may very well do so in his place . . . and then claim royalties from him or even sue him for infringement.
When we realise the constant watch kept by many firms on the patents granted to their rivals, and all the tricks used to baffle them, we see the "aggressive" rôle patents may play in the world of business. The Belgian Patent Office furnishes an excellent example of this, for Belgium usually grants patents six months after the date of filing; hence one American firm can keep watch on another in *Brussels*, as the Belgian patent will be published long before the American. As to the counter-ruses adopted, one, for instance, consists in patenting a number of products simultaneously, only one of which is *the* article which the firm is preparing to launch on the market.

It is impossible to tell whether a new partner, before sitting down at the negotiating table, has already attempted - and at what cost - to get round a patent whose value you tended to underestimate. You never know, either, what indirect benefit you may have reaped from an exclusive exploiting right, were it only temporary. That is why it is wiser to speak of the efficiency of patents as one speaks of the (offensive) efficiency of an advertisement or the (defensive) efficiency of a lock without being able to calculate this exactly. . except by statistics effected after the event.
The fact that the Soviet Union has come round to the patents system, after years of regarding it as one of the evil results of capitalism, proves that it is valuable even in economies of widely differing structure.

How is a patent application filed?

The foregoing is enough to suggest that the problems of industrial property rights are often complex; lying midway between the law and applied science, they have to be dealt with by engineers with a good knowledge of the law and lawyers acquainted with the technical difficulties. The Euratom Directorate for Industrial Property Rights, like the patent agents' offices or the patent departments in large firms, has a number of these "rare birds", carefully proportioned as to the various branches (chemistry, electronics, mechanics etc.) and the five languages needed (the four official Community languages and English).
The engineers in the Patents Office study all the scientific reports drawn up either by the Joint Research Centre or by Euratom's contracting or associated partners, before they are published, in order to detect any patentable information (by 1 August 1966 a total of 7097 reports and articles had been "screened" in this way). Each patent application demands a clear text (legal requirement), filing formalities that differ from country to country (and the many inventors who have had to travel scores of miles to swear before a consul that they were indeed the inventors know something about this), examinations by the national Offices which go on for years, and so forth.

It has been frequently said and written that there are no real inventions any more, only improvements; certainly the modern inventor does start from very broad technical and scientific foundations which constitute what is called the state of the art. In new fields, however, such as that of nuclear energy some years ago or space research today, this statement is not quite true. As Dr. J.M. Hill, member of the United Kingdom Atomic Energy Authority, said at the *Foratom* Congress at Frankfurt "In the early days of nuclear energy, every time two or three physicists went out for a drink together they invented a new reactor".
Many new reactors have been invented . . . and others will certainly follow. They must, if nuclear science is to go forward, even though apparently promising prototypes have been abandoned. How many of us remember, in another context, that the first automobile to reach a speed of 60 mph was electric? (Possibly those who, like the author, read it in the *Euratom Bulletin*, No. 4/64, p.3).
In practice, it is often difficult to decide whether to patent an invention and, if so, in which countries to file corresponding patent applications. The happy medium must be struck each time, by good judgement, for it cannot be calculated, between expenses of filing, which are known precisely in advance, and the potential advantages, which can only be estimated. The estimate, like the navigator's reckoning, *must* be compared afterwards with the facts so as to ascertain the error, analyse it and reduce it the next time. Unfortunately this empirical method is ill suited where there are rapidly-developing techniques, fledgling markets and bodies which have only been in existence for a few years, as in the nuclear field.
Faced with these difficulties, one must "cast one's mind into the future and thus bring into play a certain degree of foresight, of prophetic instinct, and also a certain shrewdness"[1].

By way of conclusion . . .

In every hive - that model of organisation in nature - there are guardian bees who safeguard the ownership of the honey made by the thousands of workers; biologically similar to the workers, the guardians may seem to be vexatious and unnecessary, but it is they who keep thieves away from the laboriously gathered heritage. Until the day the beekeeper comes . . .

1. A. Bertin, "Le secret en matière d'invention", Editions du Tambourinaire, Paris.

Low-energy nuclear physics and the development of nuclear applications

PROFESSOR UGO FACCHINI, *Centro Informazioni Studi Esperienze (CISE), Milan.*

General vieuw of the CISE Nuclear Laboratories, Milan, with Van de Graaff tower in background.

From the time when Rutherford triggered off the first nuclear reactions on light nuclei down to the present day, all the known nuclei have been bombarded and disintegrated in all manner of ways and the thousands of nuclear reactions of various types induced have been studied from every possible angle. Even so, many problems remain unsolved and, as far as applications are concerned, the demand for nuclear information is continually growing — in the nuclear engineering and applied physics laboratories, which are increasingly engaged in the design of new types of reactor, in the laboratories attached to nuclear power-plants, in thermonuclear fusion laboratories, and also in the radioactivity monitoring centres and in all the various fields of application of radioactivity and radiation in industry, medicine and agriculture. The development, especially, of fast reactor and thermonuclear fusion studies indicates that in Europe and the Euratom countries, as elsewhere, the next few years will bring a wide and growing market for such information.

Nuclear reactions galore!

But if an engineer looks for some item of nuclear information, what does he find? A list ad infinitum of the most widely assorted nuclear reactions, obtained with various particles and energies, and often missing out the very data he wants and skating over the very problem he is interested in. And how is he to find his way around in this welter of detail, how distinguish the right from the wrong or the out-of-date, what system shall he adopt in his quest through the various atlases of nuclear data? What the engineer needs is a clear picture of nuclear physics as a whole, that is, he needs to know the fundamental rules governing nuclear properties so that he can build up a correct mental framework within which he can move around without effort.

But at the moment there is no such thing as an unequivocal and complete picture of nuclear physics, such as we have of electromagnetism for example; the laws governing nuclear forces are still far from clear, so that we have no firm foundation on which to build up a system of nuclear physics in the same way as the science of electromagnetism is based on Maxwell's laws. The physicists themselves are still studying the atomic nuclei, exploring individual details and seeking new nuclear reactions.

From all these experimental data it is hoped to evolve a theoretical description of nuclear properties. For this purpose physicists generally resort to various models of the nucleus, each of which brings out some particular aspect of nuclear phenomena.

Thus we have the liquid drop model, which is self-explanatory, the gas and the shell models which, on the other hand, demonstrate the fact that the movements of the many nucleons contained in the nucleus are practically independent; the optical model, used to describe the property which the nuclei have of diffracting nucleons, and the statistical model, used to describe the thermodynamic properties of the nuclei. These models are highly useful tools for expanding the frontiers of knowledge in the sub-atomic world.

In recent years we have begun to grasp a number of facts and shed light on the energy-level properties of nuclei, on nuclear forces and on the mechanism of nuclear reactions.

Let us briefly consider the line of enquiry which the nuclear physicists are at present pursuing.

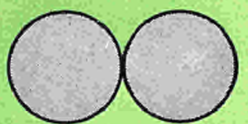
Reactions on light nuclei

The study of the reactions produced by deuterons, protons, alpha particles and gamma quanta on deuterium, lithium, etc., and on

Fig. 1: The α particle consists of two protons and two neutrons.

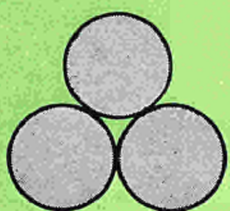
^{4}He

Structures composed of α particles are found in some light nuclei; e.g. ^{8}Be consists of two α particles



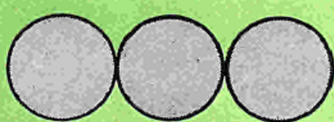
^{8}Be

and ^{12}C of three α particles;



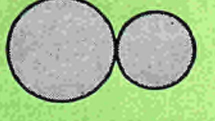
^{12}C

in certain excited states it appears that the three α particles can adopt a linear arrangement.



$^{12}C^{*}$

^{6}Li, on the other hand, consists of one α particle and one deuteron.



^{6}Li

very light nuclides in general, is aimed at providing simple direct data on the nuclear forces acting among small numbers of nucleons and at revealing the structure of the light nuclei.

We still know little about nuclear forces; it is clear that there are repulsive Coulomb forces between protons and far stronger attractive nuclear forces acting over a short range, i.e. at distances of the order of one nucleus diameter, between all the nucleons – neutrons and protons. At yet shorter distances the nuclear forces likewise become repulsive and this is what prevents the "collapse" of the nucleons in the nucleus. Not much more is known about the nuclear forces, and the current meson theories liable to explain their origins and properties are still by no means clear or complete. Nevertheless, study of nuclear reactions and the radiations emitted by light nuclei has made it possible in recent years to outline a new structural theory on these nuclei, from which it appears that they are composed of agglomerations of alpha particles, deuterons and single nucleons (Fig. 1).

Reactions with light nuclei are also of great interest from the standpoint of fusion physics and the harnessing of fusion for power generation; for, as is generally known, typical fusion reactions are those which produce the synthesis of two deuterons or of one deuteron and one nucleus of tritium, and in the sun, for instance, nuclear energy is produced by a series of reactions involving a well-defined group of light nuclei.

Nuclear shapes and motions

Information as to the shape of the nuclei can be derived from detailed analysis of the properties of certain typical nuclear reactions; among the most important of these are Coulomb excitation, in which a proton or alpha particle passing close to a nucleus transmits a definite quantity of energy to it by Coulomb effect, and the reactions induced by 10-100 MeV gamma-rays. Some of the shape properties of various nuclei can also be deduced by study of their beta and gamma emission.

We know nowadays that nuclei are not just little spheres of nuclear matter but differ in shape and structure and vary in complexity.

Certain of them—the nuclides with the so-called magic numbers of protons or neutrons—are indeed spherical. Others, the intermediate nuclei, generally consist of a spherical kernel surrounded by a more or less ellipsoidal cloud of nucleons (Fig. 2).

Nuclei are similar to all microscopic systems, atoms, crystal lattices, etc., in that the energy that can be imparted to them can only have certain well-defined quantic values, the sum total of which constitutes the nuclear energy levels.

Spectroscopic analysis of the first energy levels of nuclei has proved particularly rewarding. In the case of spherical nuclei the first levels correspond to the excitation of one or a few of the nucleons contained in the surface of the nucleus, whereas in the deformed nuclei levels are observed which denote movements of the whole nuclear cloud—vibrations and rotations with definite rules and strong analogies with the properties of molecular movements (Fig. 3).

At higher energies (over 5-6 MeV) the nuclear levels become extremely numerous. This multiplicity is explained by assuming that many nucleons are excited individually and carried into higher energy orbits in various combinations. The resonances produced by thermal neutrons can be assigned to this level.

At excitation energies of 12-18 MeV there are also particular levels which represent well-defined modes of vibration of the nuclear kernel; in these motions the whole of the neutrons and protons enter into a kind of reciprocal vibration. These motions are studied more particularly by means of the reactions induced by gamma rays.

Mechanism of nuclear reactions

At the present time nuclear reactions are the only means available to us for penetrating the mysteries of the nuclear world. Generally speaking, we have in the nuclear reaction a particle (proton, neutron, alpha particle) colliding with the nucleus, as a result of which the nucleus breaks up, emitting one or more nuclear particles. Although the process of interaction between incident particles and nucleus involves many of the nucleons contained in the nucleus, the entry of the particle is governed by simple laws. In the case of charged particles, their penetration into the nucleus is determined by Gamow's repulsive Coulomb potentials; as to neutrons, the optical models developed by Weisskopf and co-workers describe the nucleus as having appropriate wells of attractive potential (Fig. 4).

After the incident particles have penetrated the surface of the nucleus, either of two types of reaction may occur.

One is the direct reaction, in which the incident particles collide with a surface particle of the nucleus. In the brief time of about 10^{-22} seconds either the particle struck or the incident particle may be emitted as a result of the impact.

The direct reactions have been known for a decade or more, yet their properties, for instance their collision cross-sections at various energies and with various nuclei, remain largely undetermined and there is not even an overall classification of these reactions.

In the majority of cases, however, the reaction is not direct; the incident particle becomes completely embedded in the nucleus, within which its energy is dissipated in the form of heat.

At this point it is legitimate to introduce certain concepts of thermodynamics such as nuclear temperature, entropy, etc. After a time which is, on the nuclear scale, relatively long (10^{-18} to 10^{-12} seconds) the nucleus "evaporates" one or more nucleons or an alpha particle and cools down to its fundamental state.

This immediate particle emission, or "evaporation", is studied on the statistical model, which uses the traditional thermodynamics methods; it can be used to calculate the probabilities of emission of the different particles, their energy distribution and their angular distribution (Fig. 5).

Fission

Although our acquaintance with fission phenomena is of so many years' standing, there are still considerable gaps in our experimental knowledge and a complete theoretical model describing these processes remains to be devised.

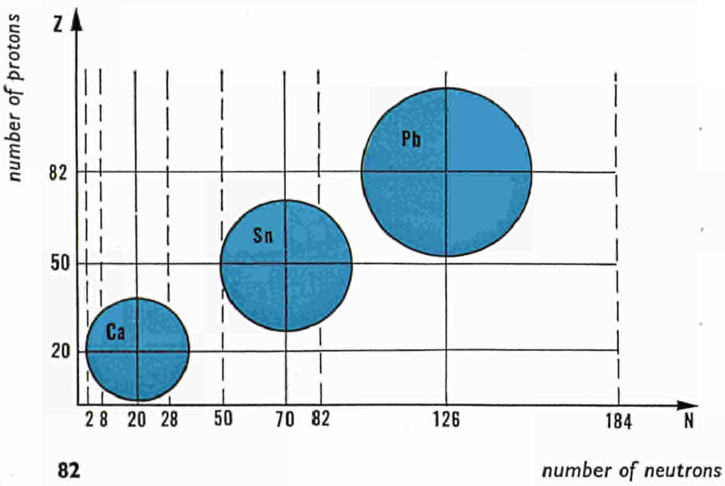
Even now a set of the basic properties governing the fission process is still explained by Bohr's original theory, which assumes the fissile nucleus to have the properties of a liquid drop of nuclear matter and studies its deformations and breakup into two fragments. Bohr showed in particular that, before splitting, the nucleus assumes peculiarly elongated forms, known as "saddle states". These forms represent an unstable condition beyond which the nucleus divides into two parts (Fig. 6). So far, however, the liquid drop nuclear models have not shown the way to a detailed description of the various modes of fragmentation of the fissile nucleus – mass of the fragments, their kinetic energy, and the energy of excitation and subsequent evaporation of the neutrons.

Towards a systematic picture

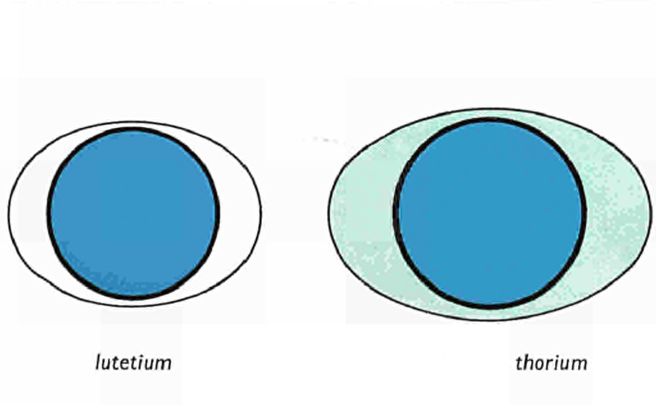
As we have seen, the study of these enthralling problems aims at building up a logical overall picture of the nuclear properties, and there are still many gaps to be filled in. We should note, however, that every subject examined by nuclear physicists is also of immediate practical interest, in that it illustrates a technique of manipulating nuclei. Every study of nuclear reactions or nuclear radiations emitted by nuclei goes to swell the great atlas of nuclear data being compiled by physicists. This collection is the source of the nuclear data used in the various applications of nuclear energy, radiations and radioisotopes.

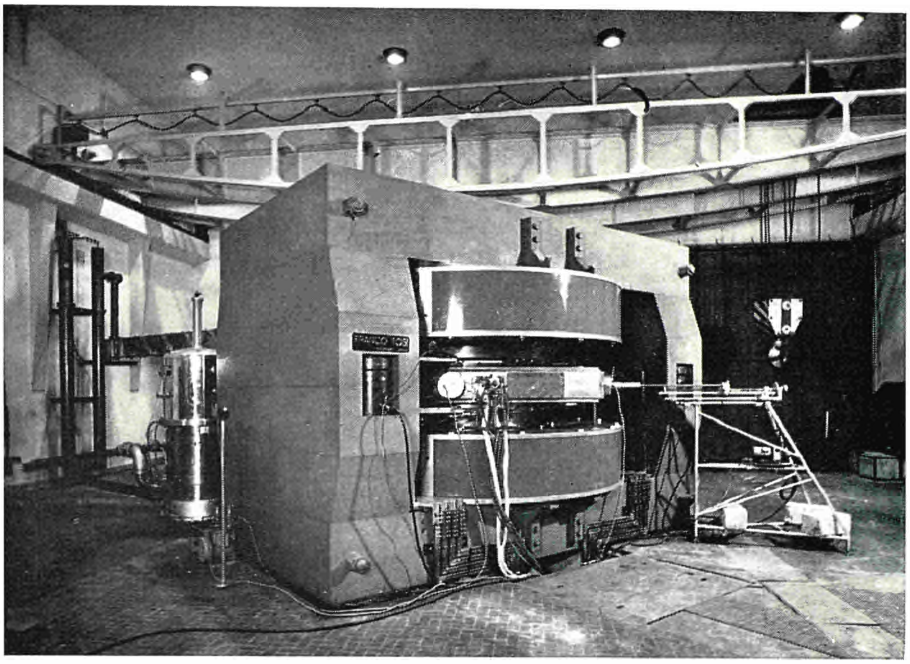
Even from this angle, however, our knowledge is far from satisfactory. Although in the field of slow neutrons, for instance, everything measurable has probably already been measured, when we turn to the reactions induced by fast neutrons and other particles the unexplored zones are far more extensive than the charted areas; for, by reason of the multiplicity of utilisable particles, their energies, and the many nuclides, the number of nuclear reactions possible is immense. Furthermore, it must be remembered that the study of emitted particles involves measurements of energy, angular distribution, angular correlations, and gamma ray analysis.

Fig. 2: Some nuclei have a spherical kernel structure. These are the "magic" nuclei, i.e. those with 2, 8, 20, 28, 50, 82 or 126 protons or neutrons.



In the intermediate nuclei the spherical magic kernel is surrounded by a cloud of outer nucleons which generally assumes an ellipsoidal shape.





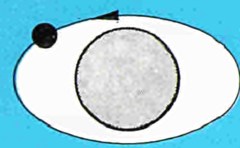
45 MeV cyclotron constructed by G. Tagliaferri, C. Succi and co-workers at the University of Milan·

Obviously at this point the classification of all possible reactions and their analysis is so huge a task that the enormous labour of collection and sifting of such data will go on for years to come. This mass of work ought to be tackled by special centres set up on the lines of the *Bureau of Standards*, which would carry out a systematic and detailed analysis of each reaction. But the continual evolution of techniques and analysis methods, the growing interest shown by engineers in information liable to further the progress of reactor technology, and above all the desire of physicists to pin-point as yet unexplored details through these individual reactions or to gain a brief insight into the properties of nuclear structures, are such that this broadening of our knowledge, however disorganised and repetitious it may often appear, is nevertheless a vigorous and exciting process, whereas standardisation and classification are a much slower affair.
It is often important to the nuclear engineer to be able to predict the properties of nuclear reactions even where no direct measurement data are available. In such cases he has to utilise the basic concepts and, in particular, the models, developed by physicists, and in this field close collaboration between engineer and physicist is particularly vital.

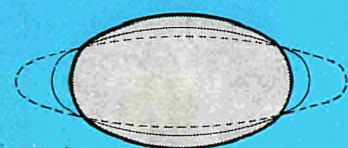
Measuring techniques

Another valuable contribution by nuclear physics to technological advance is the parallel development of nuclear measuring techniques.
The search for new ways of studying nuclei has in late years given rise to new methods of particle detection, to more accurate analysis of their properties, and to more powerful devices for generating particle beams with determined properties.
Beside the old Cockcroft-Walton generator now stand the tandem Van de Graaff, cyclotrons and linear accelerators in a steadily evolving line.
In the field of detectors we have added to the old Geiger-Müller counters and ionisation chambers crystal scintillators and the silicon and germanium detectors which

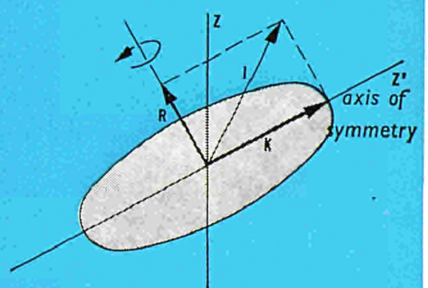
Fig. 3: In the spherical nuclei, in the first excited levels, one or several nucleons leave their orbits and rotate in excited orbits.



In the ellipsoidal nuclei, however, the first energy levels correspond to overall motions of the cloud of outer nucleons: vibrations,



or rotations.



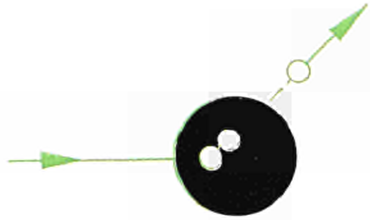
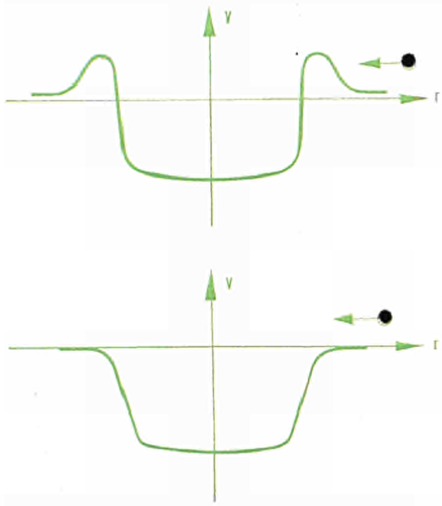


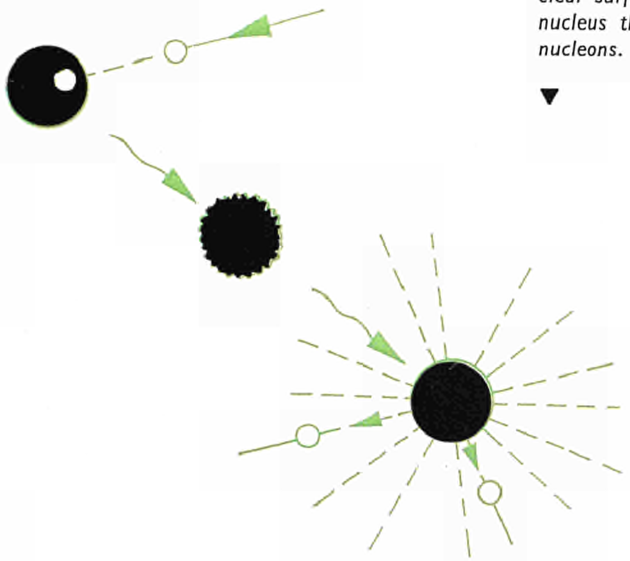
Fig. 5: In direct reactions a collision occurs between the incident particle and one of the nucleons of the nucleus.

◀

Fig. 4: The interaction between a particle and a nucleus can be described by means of a nuclear potential: in the case of a charged particle (proton or α particle) the potential consists of a repulsive component and a well of attractive potential due to the nuclear forces.



In the case of neutrons only the attractive well is present.



In "evaporative" reactions the whole nuclear surface is heated and the excited nucleus then "evaporates" one or more nucleons.

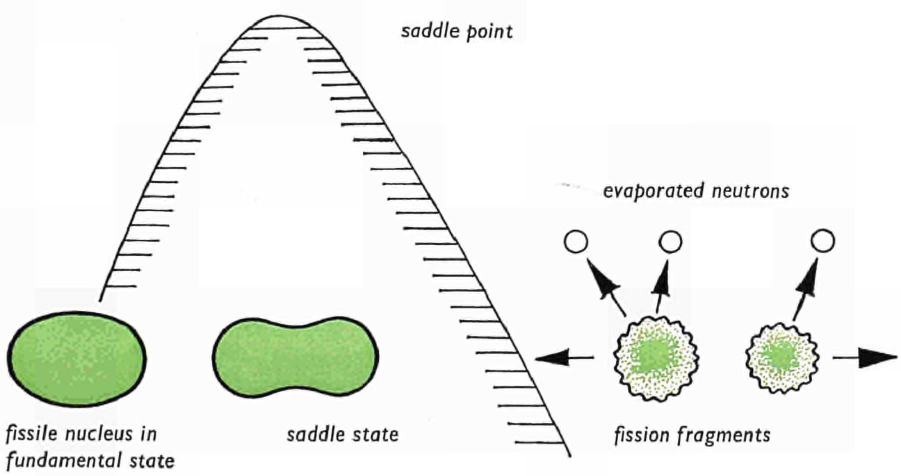
▼

today enable us to determine the energy of ionising particles to within a few ppm and with almost 100% efficiency, as well as time-of-flight spectrometers for fast neutron measurements, which are capable of determining time intervals of the order of 1/10,000,000,000 sec.

All these techniques, devised mainly in the nuclear research laboratories, today form part of the basic equipment of nuclear measurement centres, radiochemical centres, reactor control rooms, nuclear materials testing laboratories, health physics laboratories and, generally speaking, wherever radiations or radioisotopes are used.

Another function of the nuclear physics laboratories is to train in the use of these techniques physicists who will be able to go and put their knowledge into practice in the applied research laboratories. In general, the two-way exchange which takes place between the groups pursuing fundamental research and those engaged in nuclear engineering continues to be most valuable.

Fig. 6: Fission states: in its fundamental state the uranium nucleus has the usual ellipsoidal shape; when excited by a neutron it assumes the "saddle state" form and then splits into two hot fragments. The curve shows the evolution of the total energy of the nucleus for increasing deformations.



Nuclear energy insurance

HANS-DIETER MOSTHAF, *Directorate for Economy, Euratom*

There are still people who imagine nuclear energy to be a physicists' preserve. But in order to progress from atom-splitting to nuclear power plants, physicists had to enlist the help of technical specialists of all kinds and men of many other professions, such as businessmen and lawyers. One example of the need for this co-operation is nuclear risk insurance. If nuclear power plants are to be built, there must be a means of insuring the risks which they entail.

In the early stages of nuclear energy production, ten years ago, insurance companies were not at all prepared to provide cover against nuclear hazards, yet this cover was vital. The authors of the Euratom Treaty therefore saw one of the tasks of the European Atomic Energy Community as being "to facilitate the conclusion of insurance contracts" (Article 98).[1]

Why is this still so difficult? Have we not for over a century had in Europe a flourishing insurance business, able and willing for its own profit motives to insure risks?

Unfortunately this does not apply to nuclear insurance.

The first obstacle was a psychological one: we all made our first acquaintance with nuclear energy through the atom-bomb. It is not surprising that insurers, like the rest of us, wanted to steer clear of nuclear energy. Of course, nowadays we all know that nuclear energy in the bomb and nuclear energy in the power plant are two quite different kettles of fish, but a certain diffidence in the face of this new hazard nonetheless persists.

In addition to this psychological factor there are solid business reasons for this attitude: we know that a nuclear power plant cannot explode like a bomb, but has anyone yet seen what does happen in the event of a major accident in peaceful nuclear energy production? The answer is no.

The unknown nuclear risk

How are the insurers to assess this unknown nuclear risk? Nuclear plants are built in such a way that no nuclear damage can occur—at least that's what the engineers say. But this is an elementary principle of aircraft construction, dam building and railway engineering. The probability of a major nuclear accident is doubtless very small, but it is not zero, otherwise no one would be trying to insure against it.

It might be thought that the insurers ought to welcome this new business, which brings in premiums and barring accidents costs them nothing. But the insurer's reply is that he has to be prepared for large-scale damage any day. If this should occur, where does he get the money to meet the claims? In traditional branches of insurance he draws on the premiums contributed by the many other insurants in the same field for whom it was no-claim year. The business risk then consists merely in the possibility of the total damage being a fraction of the per cent better or worse than the predictions based on the previous year's figures. If an insurer has to make out a million third-party car insurance policies he can be sure that the compensation-rate to his clients will jibe roughly with the statistics; but this is by no means the case if he has only ten risks to insure. Bad luck might then have it that in spite of (let us say) a 1% compensation-probability on the ten risks, he might have to pay five times that amount. In order to hedge against this eventuality, when the number of insurants is small he will have recourse to reinsurance. Insurance companies are linked together within a worldwide reinsurance network, which guarantees the permanent spreading of risks.

A speculative business?

To return to nuclear insurance; at the moment there are not more than one hundred nuclear plants in the whole world, including nuclear power plants, research centres with their reactors and laboratories, plants for the processing of irradiated nuclear fuels, storage facilities and so on. There are thus at most one hundred potential nuclear insurance risks. We say *potential*, because many of these risks are not insured—e.g., most research centres and also many power plants under public ownership—since the owners feel capable of bearing the consequences of any damage themselves.

It is clear that with so few plants it is not possible to spread the risk. The situation would not be so difficult if one could rely upon there being a large number of instances of small-scale damage. But the opposite is true: the damage probability is extremely low, but the possibility of very large damage is still not completely ruled out. An insurer—even if he takes the lion's share of ten nuclear risks out of the small number on the market—can still not achieve a judicious statistical spread of the risk.

As we have seen above, this would not in itself be too serious, in view of reinsurance. But it can easily be seen that this again is not possible here, as there are too few nuclear risks in the whole world for it to be possible to achieve an overall statistical spread by reinsurance.

1. The Euratom Commission has held colloquia with the nuclear insurers and insurants to discuss the major problems. The first was held in Wiesbaden in 1961, the second in Florence in 1962, the third in Aix-en-Provence in 1964 and the fourth in Berlin in 1965. The proceedings of the last three colloquia have been published by the Euratom Commission under numbers EUR 486, EUR 2464 and EUR 2642.

Nuclear insurance is thus a veritable speculation for the insurance companies; and they do not consider such speculative risks to be within their province.

It was therefore impossible at first to find any insurance cover. But wherever nuclear plants are to be built and operated by private owners it is a matter of urgency to provide insurance coverage—indeed this is a precondition for the industry's development. If private insurance had declined to meet the need, to cover this risk the state would certainly have found a way, either through government guarantees or by some other means such as a public and fiscal arrangement—as has in part already happened. But the insurance business felt it must play its rôle within the national economy. It would be safe to assume that insurers would be very reluctant to see the state muscle in on their territory and take over a field which they themselves had appeared to spurn. This might lead to state intervention in other insurance fields too. Furthermore, the insurers perceived that nuclear business would be bound to boom in the course of time.

These are all commercial motivations. We will not conceal, however, that insurance circles also felt a general responsibility not to shirk this national economic task, and to find a way of meeting the demands made on them.

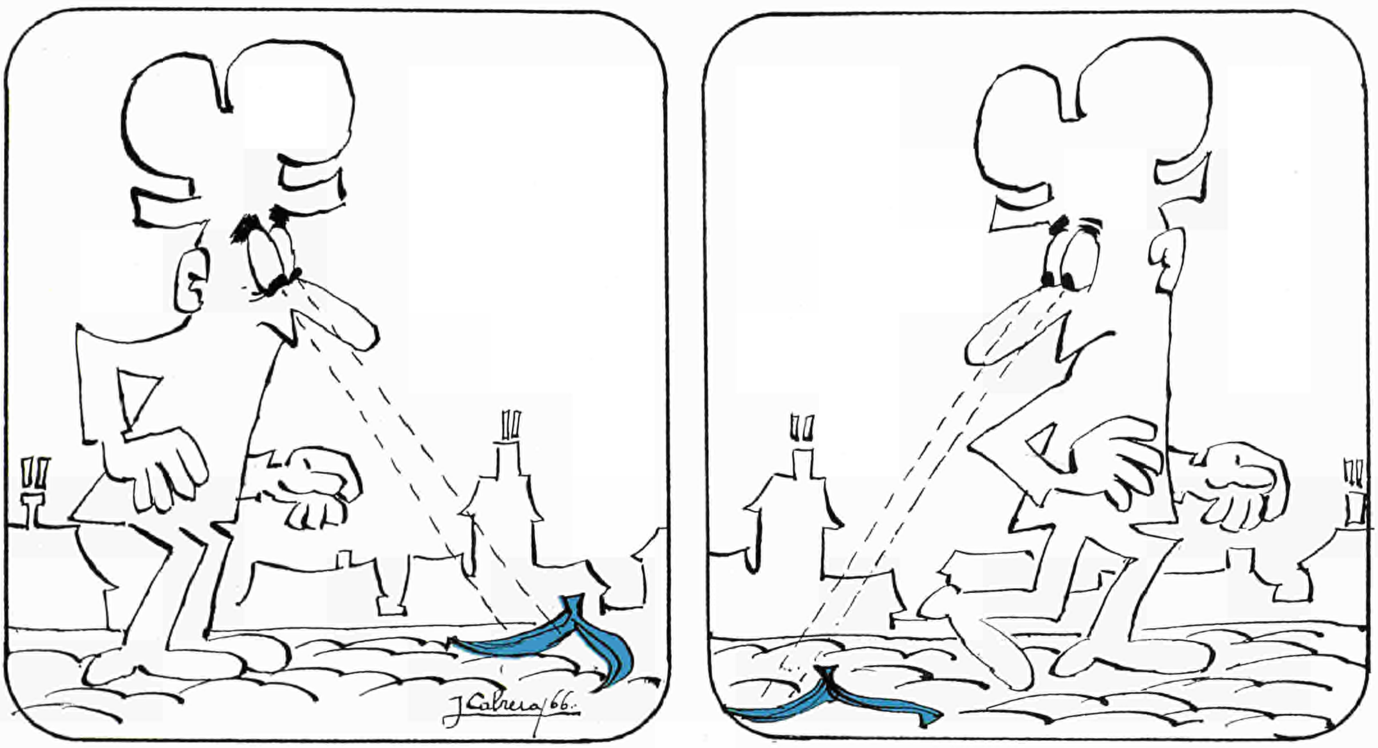
Why insurance pools?

The insurance business has therefore stated its readiness to cover nuclear risks. But what could it do to circumvent the dangers inherent in its inability to spread the hazard? The insurers decided that if they declared themselves ready to take on nuclear risks and thereby embark upon speculative enterprises, they could do so only up to very low ceilings. Some big insurance companies were thus ready to chip in to the tune of half-a-million units of account[2], for example, others with 50,000 or as little as 10,000 u.a. But the nuclear power plants being built today are worth 60 to 150 million u.a. If the material value of such a plant is to be insured, the cover which an individual insurance company is willing to provide will only be a very small fraction of the total.

In order to remedy this situation, the insurers joined forces to form pools, as had already been done elsewhere, e.g. in air-travel insurance. This happened first in the USA and then also in Europe (in all Community countries except Luxembourg). All insurance companies in the country in question which wanted to get in on nuclear insurance joined their national pool and quoted the cover which they were willing to contribute for each individual risk. But even the total cover which a national pool was able to build up from the contributions of its members was far from adequate to provide for meeting the potential claims. In so far as the capacity of the pool in question is inadequate, the pools of other countries join in as reinsurers. Even then it is not certain that in every instance the sum will be sufficient fully to cover the value of the plant.

A great number of obstacles remain. Let us take for example the lack of competition. When all the insurers in the world have to join together in covering a risk, all competi-

2. 1 unit of account = 1 US dollar.



tion is ruled out.[3] The insurers have agreed that direct insurance coverage be limited strictly to the pool of the country in which the insurant plant is situated, the other pools being associated solely as reinsurers with a risk in a country other than their own. In fact the total exclusion of all competition is brought out particularly clearly by this system, under which all the nuclear insurers have to share in every big risk in order to accumulate sufficient cover.
It is clear that this kind of market does not make for flexibility. We may reflect that the pools, consisting in many countries of well over a hundred insurance companies—often with small or even trifling contributions—can be very ponderous organisations, whose decision-taking machinery is liable to be far more sluggish than that of a single insurance company. An escape from this take-it-or-leave-it situation will be possible only when the insurance companies make larger capacities available for nuclear insurance. Despite the undeniable risk which expansion of capacities entail for the insurer in view of the far too limited number of policies, a not inconsiderable increase has in fact occurred in the course of the years. This is much to be commended. But it is quite insufficient even to make competition possible among the pools, let alone eliminate the need for such a system.

Increase capacities!

In the course of its close collaboration with the nuclear insurers Euratom has repeatedly expressed the hope that insurers would extend their capability to the utmost possible limit. It based this hope upon the fact that the various insurance companies exhibit very different degrees of boldness in regard to the nuclear field, that companies in comparable situations make very varying sums available, and that for example the British insurance market is much more enterprising than the continental, so that on occasion the British pool assumes up to three-quarters of the risk for large nuclear plants.

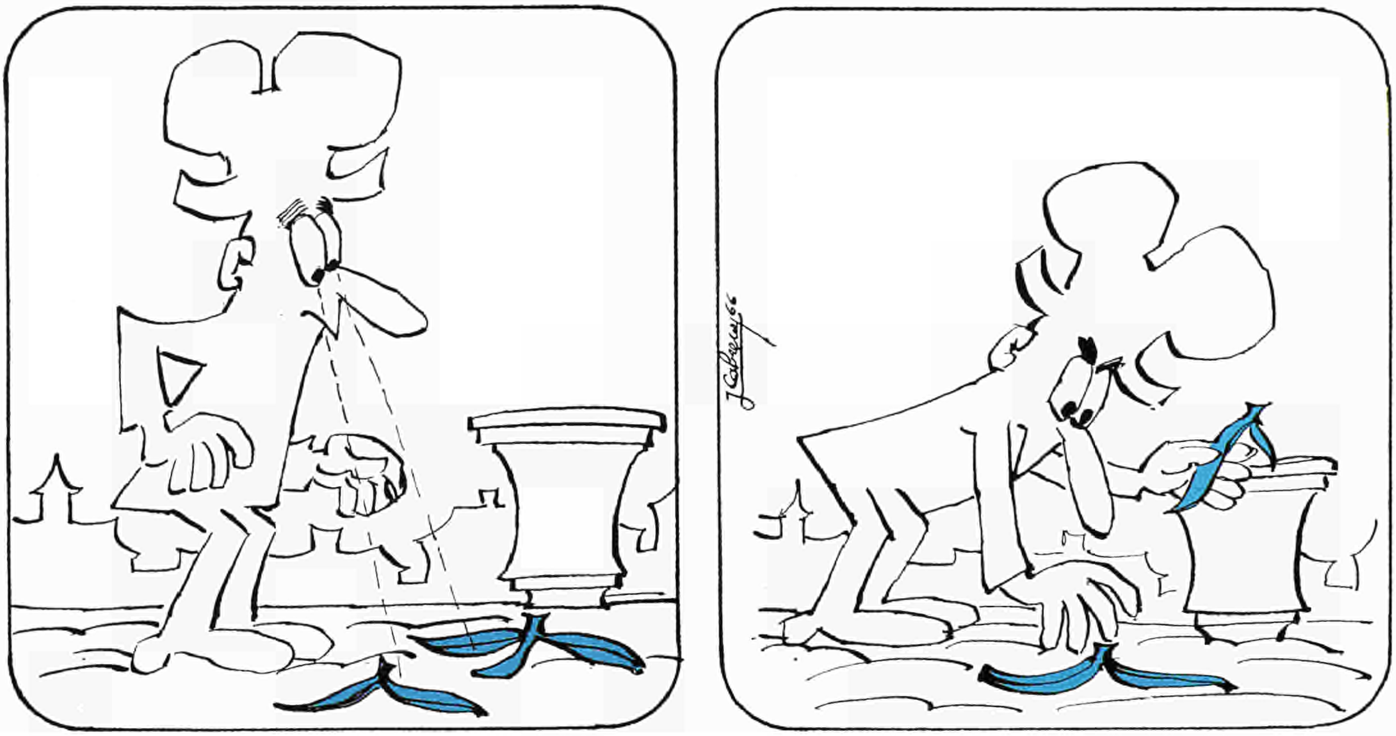
Insure all plants

Another Euratom initiative is aimed at the insurants, who are urged wherever possible to take out insurance for their plants. The uninsured plants are mainly those owned by the state, since the public authorities are often confident of their ability to cover the risk themselves. The majority of nuclear plants now in existence still serve research purposes and have no commercial value. But the new plants will mainly be designed to generate electricity. It is to be hoped that the majority of these power plants and other commercial plants—including those which are state property—will be insured.

Third party damage

Up to now we have confined our remarks to insurance against losses restricted to the plant. But another branch of nuclear insurance is equally important—civil liability insurance, i.e. insurance against claims

3. In order not to have to surrender unconditionally to pressure from a monopolistic nuclear insurance business, whether as regards insurance conditions or premiums, the Dutch Atomic Liability Law of 1965 envisages the possibility of the state covering for risks in exchange for premiums, in the same way as an ordinary insurer, and thus competing on the insurance market and insuring private undertakings. Until now, however, this possibility has not been translated into practice.



advanced by third parties against the plant operator in respect of damage caused by the plant. Here again the vexatious capacity problem arises. Commercially these two aspects cannot be considered in isolation. In the event of a serious accident with third-party damage which had to be met from civil liability insurance, it is fairly safe to assume that the plant itself would also be damaged, and that payments would also have to be made on plant insurance policies. The insurers' risks would thus snowball. The insurers have therefore declared themselves unwilling to cover civil liability risk up to the maximum credible amount of damage, but only up to a certain ceiling.

The new nuclear civil liability law

A brief reference must be made at this point to the new European Nuclear Liability Conventions. With Euratom's collaboration two European Nuclear Liability Conventions have been elaborated, containing a new and uniform set of provisions. These are the Paris Convention on Third-party Liability in the Field of Nuclear Energy, of 29 July 1960, (Paris Convention), and the Brussels Supplementary Convention to the Paris Convention on Liability in the Field of Nuclear Energy, of 31 January 1963 (Brussels Convention), both in the version of 28 January 1964.[4]

Here are briefly the principles of the Conventions:

— They introduce the so-called *absolute liability* principle, under which the installation operator is liable irrespective of fault. Compensation is therefore guaranteed in all cases.

— The Conventions envisage a so-called *channelled liability*, by virtue of which *the installation operator—and only the operator—* is liable for nuclear incidents connected with his installation, even when a third party is to blame.

— The Conventions also envisage that the installation operator shall be required to provide a security or a financial guarantee ensuring that the party liable for damages can meet his obligations in all cases.

4. cf. Dr. Reinhart Bauer's article "Euratom and the Questions of Liability and Insurance in Nuclear Energy" in No. 3/1962 of *Euratom Bulletin*.

— They also provide that this liability regulation shall be valid in all the signatory states—that is in almost all European states west of the Iron Curtain.[5] This is very important for the nuclear industry and for insurers, since nuclear damage can extend over wide areas and transcend state boundaries. This European liability regulation will greatly simplify insurance and licensing procedures. Furthermore a uniform regulation is important for international transport. It also facilitates reinsurance.

Nuclear damage and state intervention

All the above principles are important for nuclear insurance; the provisions of the Paris Convention on the limitation of liability, however, are really vital. The Convention limits the installation operator's lia-

5. On 28 October 1965 the Euratom Commission issued a recommendation for the alignment of the implementing legislation of the Community Member States on these Conventions. In the spring of 1966 the Conventions are not yet in force, because they have not yet been ratified by a sufficient number of Member States. The Euratom Commission is pressing for speedy ratification.

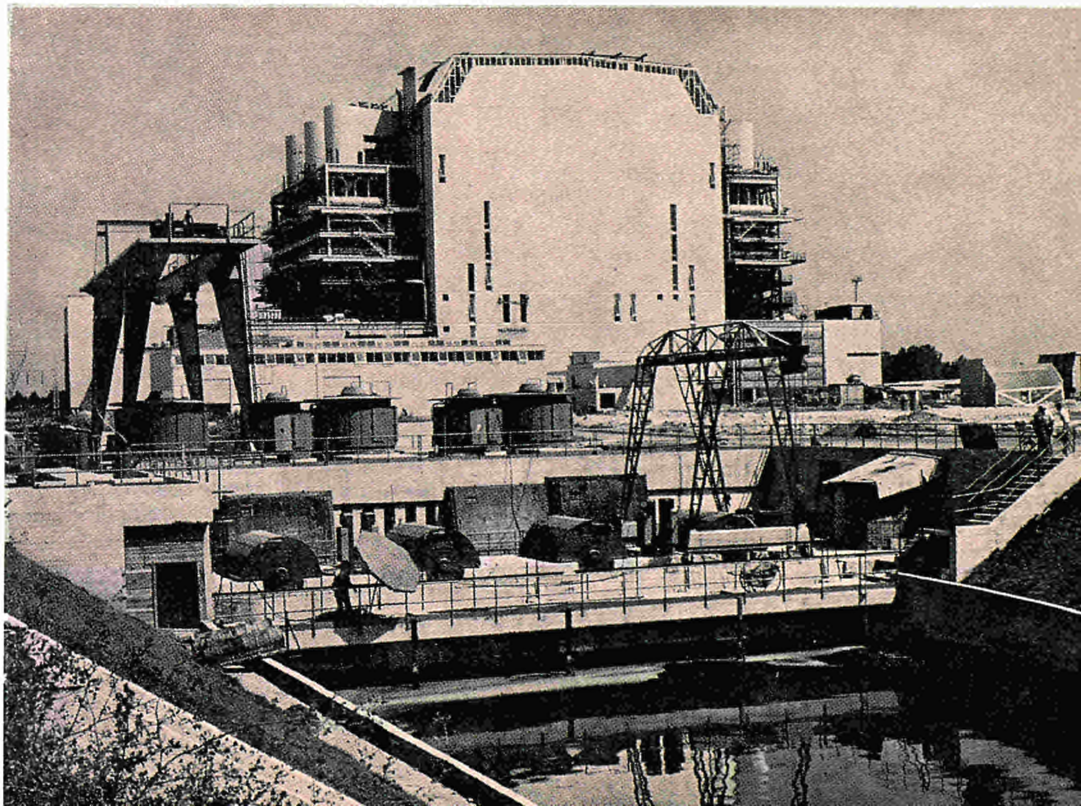
The high flux research reactor at Petten (Netherlands)

bility to 15 million u.a. The signatory states can however raise the liability ceiling in line with the possibilities offered by the insurance business, or reduce it to 5 million u.a. This restriction of liability is designed mainly to meet the wish of the insurers, who were unwilling to take on a major third party risk in addition to the property risk.

What solution have the Community countries chosen? Belgium 10 million u.a. (draft law), France 10 million u.a., Italy 5 million u.a., Holland 15 million u.a. and Germany an amount to be fixed for each plant individually according to particular criteria. In the USA, incidentally, the previous liability ceiling of 60 million dollars accepted by the insurance companies has now been raised to 90 million.

This restriction, which, as indicated, meets the insurers' wishes and also the economic interest of the nuclear industry, whose premium obligations are thereby obviously reduced, is not without its problems. Should third party damage occur which exceeds these liability limits, the victim can clearly not be left without compensation. But the Paris Convention made no provision for compensation exceeding the basic limit of 15 million u.a.

The Euratom Commission therefore took the initiative in drafting the Brussels Supplementary Convention, which ups the liability ceiling. Almost all the signatory states of the Paris Convention—except Portugal, Turkey and Greece—have subscribed to it. Under this Convention the state in which the installation is located pays compensation up to 70 million u.a. in the event of damages exceeding the so-called *first instalment* normally covered by the insurance companies. Should the damage be still greater, then all the signatory states combine to pay compensation between 70 and 120 million u.a. (If contrary to expectation even greater damages are entailed, the compensation will be settled ad hoc). The states thus bear the risk of major damage, since the insurance business has declared its inability to do so.



The 200 MWe nuclear power plant at Latina (Italy)

Many experts consider damage on such a scale as an extremely remote contingency. But whether the possibility can be completely ruled out or whether merely an improbability is involved, we can be sure that in most cases the third party damages will lie within the limits of the first instalment, i.e. within the purview of private insurance. But should damages to the extent of 120 million u.a. ever occur, the insurance business would in the extreme case cover only 4%, and the state the remaining 96%. Anyone who supports the principle of a liberal economy based on private initiative must regret this state intervention. It is to be hoped—and Euratom expressed this hope at the Berlin Colloquium—that European nuclear insurance will emulate its American counterpart, further extend its capacity for third party liability, and thus reduce and perhaps eventually eliminate the part which the state has to play.

Since this amplified capacity can be used not only to widen the liability borne by insurance, but also to ensure that, at a constant level of demand, the nuclear insurance capacity on offer rises above the requirement per risk and thus creates the basis for a competitive market, we believe that it is expedient to apply it first of all to stimulate competition and only later to proceed to raise the nuclear liability ceiling. On the other hand it seems advisable for the Member States to bring into line the ceiling of the first instalment, either at 10 million u.a. or at 15 million u.a. The differences in first-instalment liability lead to a number of difficulties, particularly as regards international transport.

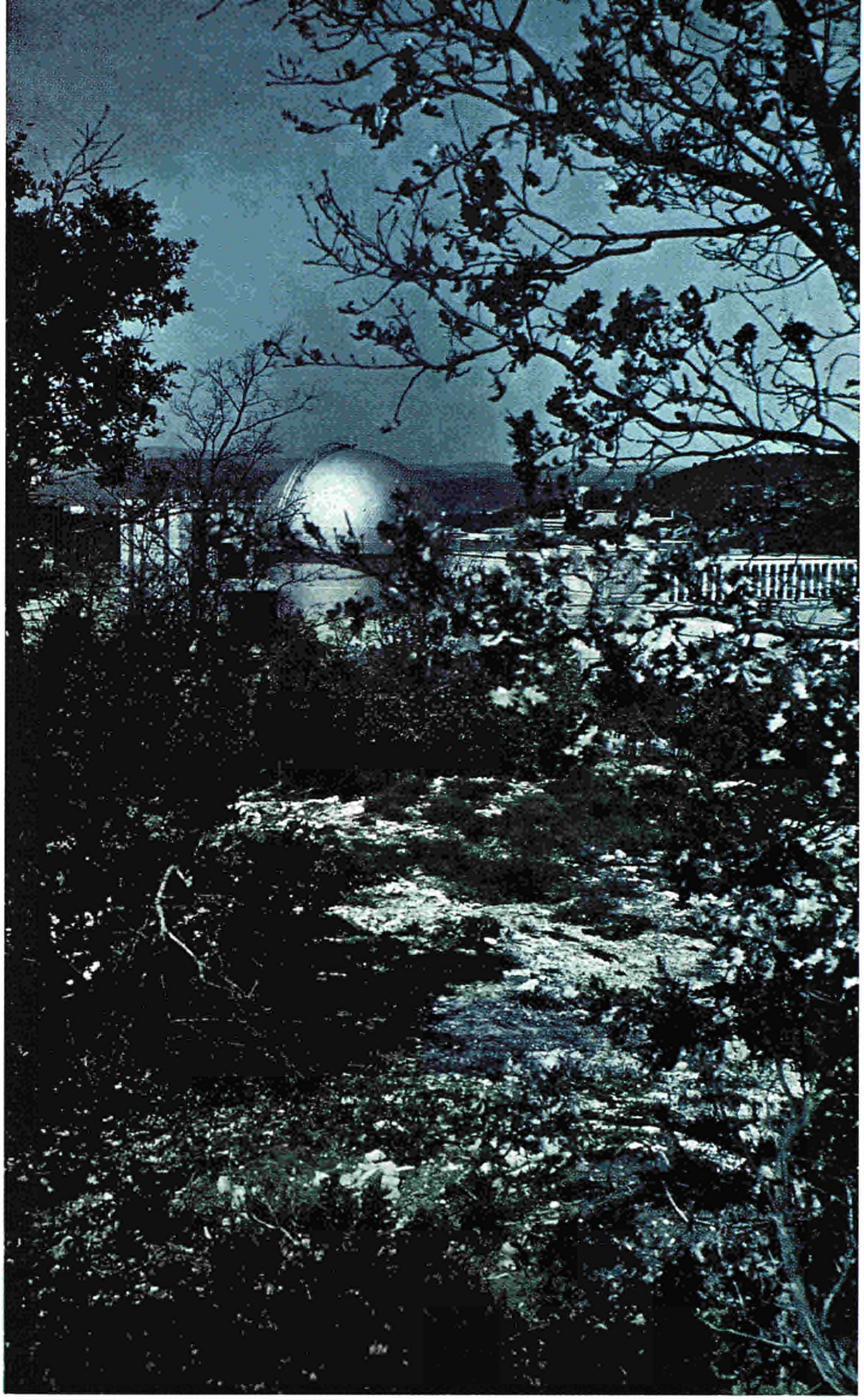
If insurance does not cope . . .

Another complicated problem is raised by the exceptions and limitations of insurance protection. Every insurance contract has them. Now nuclear third party insurance is not an ordinary voluntary insurance. It bears a close resemblance to a compulsory insurance, such as we are familiar with in most European countries, e.g. for vehicle third party liability.

But it differs from a compulsory insurance in that the Paris Convention admits other financial guarantees in addition to insurance, e.g. bankers' guarantees or the deposit of securities. A further difference lies in the fact that the signatory states of the Paris Convention not only arrange cover but provide it themselves. When the signatory states license an installation, they must vouch for the existence of an adequate guarantee. If they license an installation, therefore, and there is no insurance at all or inadequate insurance, with no other financial guarantee, the licensing state must itself stand surety. If a nuclear civil liability is not insured, the states assume responsibility.

This is of particular significance because the insurance does not—as is otherwise customary in third party insurance—cover each new case of damage afresh up to the sum insured. The nuclear insurers provide merely a "write-off policy", i.e. they insure only up to a fixed maximum sum per installation or per transport. Once this sum is spent by one or more previous incidents, the insurance is no longer valid. In such case the state then becomes liable.[6] The same applies if the insurance fails to cover particular cases owing to exclusion clauses in the insurance contract. The knowledge that should private insurance not be operative, the state will guarantee compensation, has led to a tendency on the part of some insurants to accept a policy containing many exclusion clauses and limitations, meaning of course lighter premiums, thus leaving a large part of the guarantee to the state, which supplies it cost-free. This is clearly undesirable to the state, both from the standpoint of government finance and on general economic grounds, and the states can influence the formulation of policies in that they must authorise them. But there are limits to this influence, since of course in each state only one insurance pool will offer a policy. The states have, however, another lever at their disposal. While the Paris Convention indeed prescribes that the state must guarantee any installation which it licenses, there is nothing to prevent the state claiming on the installation operator subsequently. Legislation in many countries makes provision for such recourse, although

6. The licensing authorities will however require that the sum insured be made up again to the full amount after a payment of compensation, and in the event of non-compliance will order the installation to close down. A further accident could clearly occur before it was possible to replenish the sum insured by supplementary or new insurances.



View of the experimental fast neutron reactor RAPSODIE *(Cadarache, France)*

this is usually restricted to accidents attributable to the operator.

Euratom framework policy

In collaboration with the nuclear insurers and the Industrial Insurants' (*UNICE*) and Power Producers' (*UNIPEDE* Committee for the European Community) Associations, the Euratom Commission has drafted a framework policy for third party nuclear liability insurance which lays down uniform principles and rules and is intended to serve as a counterpart to the uniform liability and coverage rules of the European Liability Conventions. Such uniform principles are required if liability is to be regulated at European level. The joint elaboration of such a policy by insurers and insurants with Euratom's help was particularly desirable, since in the absence of competition the insurance terms cannot be determined by the free play of supply and demand. The Euratom Commission therefore warmly welcomed the readiness on the part of both insurants and insurers to help in the joint elaboration of the framework policy which, now completed for fixed plants, is to be supplemented by a similar text for nuclear transport insurance. This will however raise a not inconsiderable number of still unsolved technical problems stemming from the complexity of the provisions of the Paris Convention, the traditional rules and practices of marine insurance, the international liability regulations for air, sea and road transport which overlap with the Paris Convention and the fact that transports often take place outside the geographical limits of the Paris Convention, with the result that other national and international insurance liability regulations must also be taken into account.

Risk assessment

An issue which gives rise to lively discussion between insurers and insurants is the assessment of individual hazards. The various plants and transports must of course be assessed on their merits according to their particular degree of danger. The Euratom Commission has brought up this point in the various colloquia held with insurers and insurants. At the last Conference, organised in Berlin in the summer of 1965, it was resolved that Euratom should systematically examine risk assessment in this new field in conjunction with industry, electricity producers, the technical inspection authorities and the insurers.

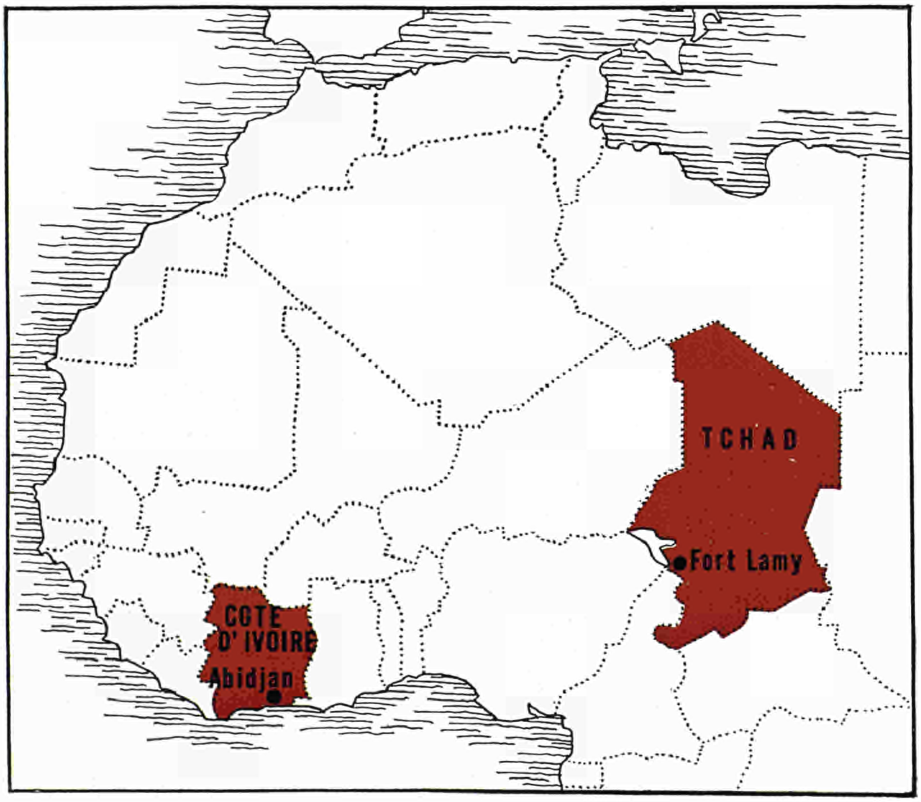
We may assume that within a few years—whether ten, twenty or thirty—the nuclear business will be just another branch of insurance, with no more and no less problems than any other field. But we already need this insurance now while it still has to cope with exceptional conditions. If nuclear insurance is to become a usable tool for nuclear industry, the insurers and the whole European economy, there must be sympathetic and prudent co-operation between all business circles, as well as between them and the European and national authorities. Euratom wishes to discharge its duty of promoting nuclear energy by acting as "honest broker" between the nuclear industry and the insurance business.

Ivory Coast and Chad—Schemes for preservation of fish and meat by irradiation

The director of the Euratom/*ITAL* Association and a representative of Euratom's biology departments paid a visit to the Ivory Coast and Chad during May on behalf of the European Development Fund for Overseas Countries and Territories, which is a Common Market body.

The purpose of the visit was to obtain additional data for the preparation of two projects covering the utilisation of nuclear techniques in the African countries which are associate members of the European Community (see *Euratom Bulletin*, Vol. V, 1966, No. 1). These two projects concern the preservation of fish and meat by irradiation and make a direct contribution to solving one of Africa's major problems, namely, that of the lack of protein in the diet.

The first project deals with the preservation of fish in the Ivory Coast. About 20,000 tons of sardines are landed annually off Abidjan, the bulk being eaten in the locality. As things stand at present, only a small amount is sent elsewhere. The problem is how to transport the fish further into the interior of the country while ensuring that it is still fit for human consumption.



One of the most promising methods of preserving it is by a combination of irradiation and refrigeration (see page 73 of this issue). During the first stage of the project, studies will be performed in the laboratories of the Euratom/*ITAL* Association in the Netherlands on a series of techniques combining the use of irradiation and different types of refrigeration, to see which offers the most economical method of transporting fish to the interior of the country without its nutritive value being affected.

In the course of a second "pilot" stage in the Ivory Coast, the methods will be tested in local conditions and in local distribution networks. Finally, the third phase will entail the installation of an irradiation unit capable of handling at least 10,000 tons of sardines a year.

The cost of the first stage will run to about 15,000 dollars, this sum being used to cover the cost of transporting samples of fish from Abidjan to the Netherlands. The pilot stage is estimated to cost 100,000 dollars, while the cost of the final installation will amount to about 600,000 dollars.

The second project concerns the use of irradiation for preserving meat in Chad. It was originally planned to combine economic and sanitary motives in wiping out tenia larvae in butcher's meat, but it emerged that irradiation was not warranted on either of these two grounds above.

Meat preservation, on the other hand, is an economic problem of the greatest importance to Chad. Livestock is raised in Chad not only for consumption on the home market, but also for export to other African countries, mainly Congo-Brazzaville and Nigeria. The animals are either slaughtered in Chad and immediately transported by air or else are driven to their destination on foot, which leads to loss of weight. Neither of these is a very economical method, and it would be far better to set up, instead, a distribution system based on the preservation of meat on an industrial scale. A situation would thus be created whereby the distribution networks could be extended.

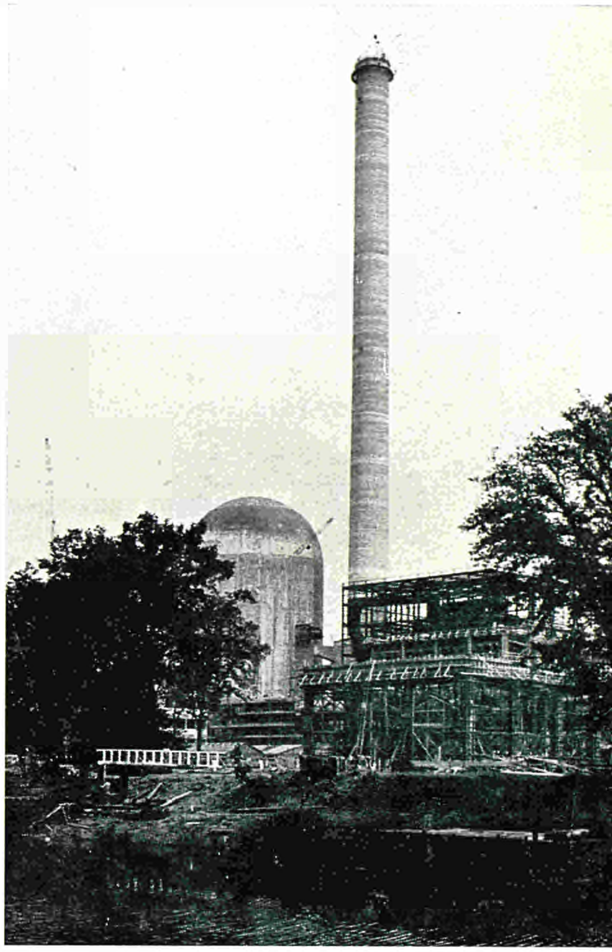
Like the first, this project is divided up into three stages. Firstly, there is an exploratory phase, which would be carried out in the Netherlands and would involve studies of the various possible combinations of irradiation and refrigeration with a view to developing an economic method of preserving meat and, at the same time, of killing off any tenia larvae in it. This would be followed by a series of small-scale trials in local conditions. Finally, an irradiation installation would be set up at Fort Lamy. The cost of this project is estimated at about 20,000 dollars for the first phase, 100,000 for the second and 600,000 for the third.

Since the necessary data are now on file, the European Development Fund is to be asked to take a decision with regard to the financing of the first two phases of each of these projects.

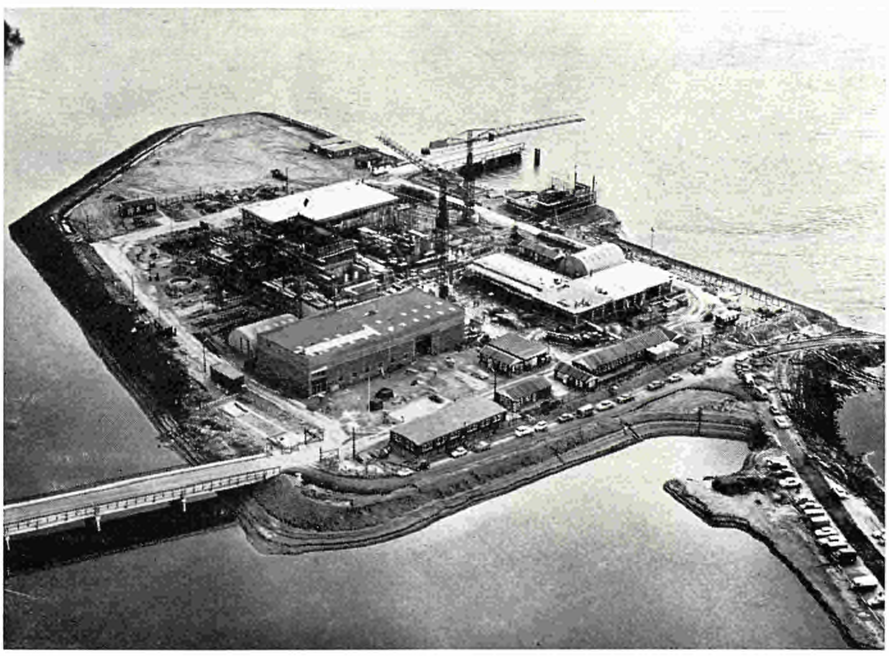
Fuel for Lingen, Dodewaard and Obrigheim reactors

In May 1966 the Euratom Supply Agency signed two contracts for the supply of enriched uranium fuel to the *KWL (Kernkraftwerk Lingen GmbH)* 250 MWe boiling-water power reactor at Lingen, Lower Saxony, Federal Republic of Germany. The first, under the US/Euratom Agreement of Co-operation, was with the *USAEC* for the supply of enriched uranium containing 970 kg of uranium-235. The second, between the constructors of the reactor, the *Allgemeine Elektricitäts-Gesellschaft (AEG)* and the Supply Agency, covers the transfer to the German firm of the right to use and consume the fuel supplied under the first contract.

Similar contracts were signed, in June 1966, covering the supply of enriched uranium containing 290 kg of uranium-235 to the *GKN (Gemeenschappelijke Kernenergiecentrale Nederland)* for its 54 MWe boiling-water power reactor in Dodewaard, and, in July 1966, covering the supply of 1.160 kg of contained uranium-235 to the *KWO (Kernkraftwerk Obrigheim GmbH)* for its 300 MWe boiling-water power reactor.



▲ *The Lingen nuclear power plant (Federal Republic of Germany) under construction off the Dortmund-Ems-Canal*



◀ *General view of the Dodewaard nuclear power plant (Netherlands)*

Comprehensive study on pressurised-water reactors

Under a contract drawn up with Euratom in July 1966, the *Ente Nazionale per l'Energia Elettrica (ENEL)* is to carry out a major research programme on pressurised-water reactors with the aid of its 257 MWe power reactor at Trino Vercellese.
The general aim of the research programme is to increase and disseminate technical data concerning pressurised-water installations and more particularly "soluble poison control" or "chemical shim", to which these reactors are especially well suited.
The pressurised primary circuit operates in closed cycle, so that it is possible to inject a neutron-absorbing substance into it, e.g., boron in the form of boric acid, and to adjust its concentration without difficulty. It is thus possible to dispense with some of the classical control rods, namely those which are gradually withdrawn from the core as the fuel is used up and the reactivity decreases.
The programme will deal with twelve different technical problems.
Information is to be obtained, for instance, on possible tendencies on the part of boron compounds to become concentrated and precipitate on the surfaces of the core under surface boiling conditions, thus altering the reactivity; steps will be taken to ensure that the presence of boric acid does not accelerate corrosion of the materials, etc.
Euratom is at present in the process of negotiating a contract with *FIAT* under which this company would carry out the various analyses as well as the interpretation of the data obtained.
The *Société d'énergie nucléaire franco-belge des Ardennes (SENA)*, is likewise expected to collaborate on this programme under its contract of participation with Euratom. The power reactor built for this company at Chooz in the Ardennes (which is just about to receive its first core charge) is in fact of the same type as the Trino Vercellese plant. *SENA* will therefore be able to make direct use of the study results.
The research will take three and a half years and a budget of about 1,400,000 dollars has been earmarked for it.

A prototype isotope generator

The *Société d'exploitation des matériels Hispano-Suiza* of Bois-Colombes, France, has been asked by Euratom to design and build a prototype of a thermoelectric radioisotope generator. This will be the first device of its kind to be developed by a private company in the Community.
In these devices, the energy emitted by a radioisotope in the form of radiation is transformed into heat and then into electricity by thermoelectric conversion. Their main appeal lies in the fact that they are sturdy, independent sources of electric energy which can be used for special purposes where normal generators cannot be employed. For instance, radioisotope generators can be used to supply current to radio emitters fitted in underwater pipelines to enable them to be located. They can also be employed on buoys, automatic weather stations, etc.
The prototype to be built by the *Société d'exploitation des matériels Hispano-Suiza* will have an output of about 0.2 watts and will be equipped with bismuth telluride thermocouples and strontium-90 titanate heating elements of about 1,000 curies.

When the project is completed, the generator will be handed over to Euratom and will be used for demonstration purposes in the various Community countries.

Collaboration in the field of direct conversion

A contract for co-operation in the field of direct conversion has been concluded between the Euratom Commission and the *B.B.C.* Company of Mannheim, which carries out work on direct conversion with financial backing from the German Federal Ministry for Scientific Research.
The agreement covers, in particular, the design and construction of thermionic generators, their use in conjunction with reactors and radioisotopes and the problems relating to the transfer of heat to such generators and methods of cooling them.
Under the agreement the partners are to co-ordinate their work, exchange knowhow and assist each other with regard to both personnel and equipment.
Each partner assumes responsibility for the costs incurred by its own activities. As regards the knowhow stemming from the research to be carried out under the contract, each partner may use the experience acquired by the other and is entitled to a cost-free licence to exploit the patents filed by the other, as well as being allowed to grant sub-licences under certain conditions.
This type of co-operation may be extended, on terms which still have to be negotiated, to any Community concern which is in a position to make a significant contribution to the development of direct conversion techniques.
Interested parties are requested to contact Euratom, Directorate General for Research and Training, 51 rue Belliard, Brussels 4, Belgium.

Uranium propecting in the Community

In 1963 the Euratom Commission published a report by the Supply Agency's Consultative Committee entitled "The problem of long-term resources and supply of uranium" in which the question of uranium supplies to the Community was reviewed in the light of total Western world resources.

From the conclusions which emerged from this report, it is apparent that the Community will become a major consumer in the uranium market and, furthermore, will find itself dependent on other countries for its future supplies.

On these grounds it seemed advisable, before going into the development of external sources—which is already proving necessary—to draw the attention of interested parties to the possibility of discovering uranium deposits within the territories of the six member states.

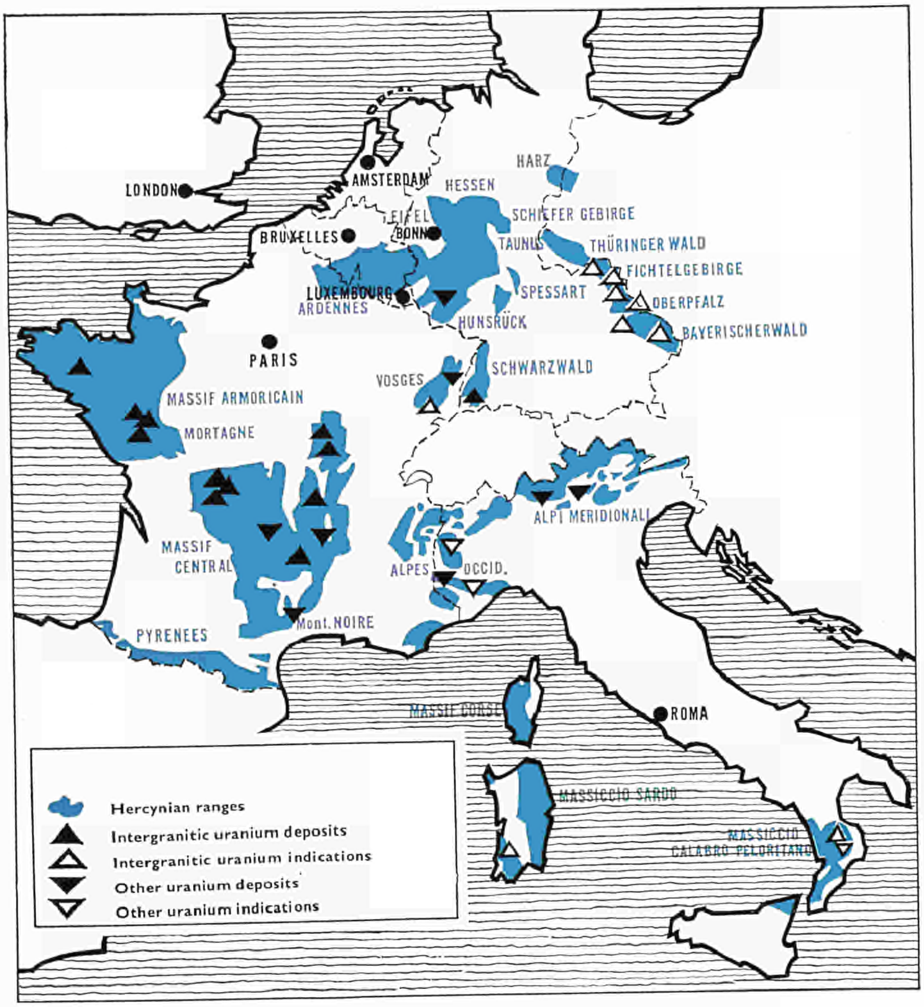
With this object in view the Euratom Commission, as empowered by Article 53 of the Treaty, issued a directive to the Supply Agency to instruct its Consultative Committee to draw up a report, with the help of geologists of the member countries, on uranium prospecting in the Community.

Their report, which was published recently, shows that the surveys performed up to 1964 detected resources that can be developed at a price of not more than $ 8 per lb U_3O_8, amounting to some 31,000 metric tons of uranium metal.

The geologists believe, moreover, that an exploration programme carried out in three of the Community countries, France, Germany and Italy, should reveal further uranium deposits workable at comparable prices.

It is hard to predict the exact tonnage of these suspected resources; but the geologists think they might be as much as 20,000 tons in France, 10,000 tons in Germany and 10,000 tons in Italy, which, in their view, would make a greater prospecting effort worthwhile.

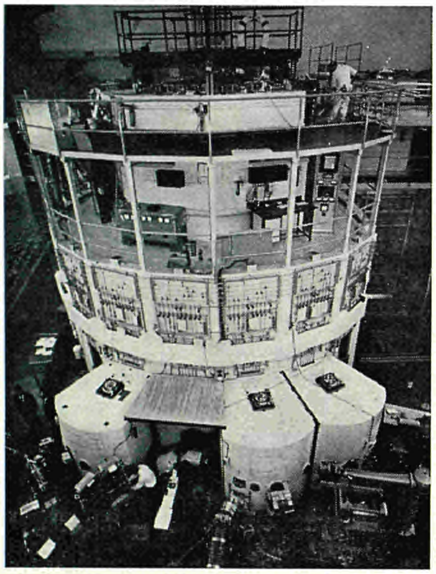
The authors of the report hope that closer relations will be set up among the experts of the various Community countries; in addition, they particularly recommend that the six countries collaborate to organise more frequent exchanges of experts, so that the work may go forward with maximum efficiency.



Map of uranium deposits and main mineral indications in the European Community

EURATOM NEWS

Petten HFR reactor uprated



The power of the *High Flux Reactor (HFR)* at Euratom's Petten research establishment has been uprated from 20 to 30 megawatts. Thanks to the higher neutron flux and higher irradiation capacity which this entails, it will be better able to meet the Community's growing irradiation requirements. This result was obtained without introducing many significant modifications: the number of fuel elements in the core has been slightly raised and hydraulics and neutronics studies carried out at the establishment have made it possible to redesign the core so as to increase their individual rating.

The High Flux Reactor in Petten (Netherlands)

Radioisotopes for detecting wear in Diesel engines

Diesel engines are subject to a particular kind of wear which especially affects their water-jackets. The trouble can be traced back to a "cavitation" phenomenon, caused by vibration, but it is still fairly mysterious. Apparently bubbles form in the circulating liquid and, when they collapse in the neighbourhood of the water-jacket walls, do so with enough violence to remove particles of the wall material.

This problem is serious in the case of large Diesel engines, such as those used in ships or for electricity generation, which have to be designed for many years of almost constant use. Attempts have been made to get round it by applying additives but no fundamental cure seems to have been found yet.

Among the several attempts already made to arrive at a deeper understanding of the phenomenon is a programme recently launched by *FIAT* of Turin under Euratom contract. A measuring apparatus, relying largely on the use of radioisotopes, is being developed to assess the role of various parameters: amplitude and frequency of vibration, temperature and pressure of the fluid, the effect of deaeration, etc.

The main objective of this Euratom research contract is to devise an apparatus which, if not transportable, will at least be easy to reproduce. Thus other Diesel engine manufacturers or other firms with similar wear problems due to cavitation will be able to use this apparatus.

Euratom Economic Handbook

The Euratom Commission will shortly publish an "Economic Handbook" proposing a standard method of calculating nuclear power generating costs.

Almost since the very beginning of nuclear power generating history the need for standardisation in this field has been felt; even today enquirers find it difficult to make accurate cost comparisons between power reactors of different types, such is the variety of the methods used when making estimates.

The first step towards a uniform method for the European Community was taken in October 1963 at a symposium held by Euratom in Venice. For the first time a basic scheme was discussed with representatives of all interested parties. Shortly afterwards the Commission signed a contract with the French *Commissariat à l'énergie atomique*, the French firm *Indatom*, the German firm *Siemens-Schuckert-Werke AG* and the Italian firm *SORIN*, who were instructed, on the basis of the scheme discussed in Venice, to carry out the studies required for the compilation of the "Euratom Economic Handbook".

In the meantime, Euratom received the actual operating data of the first power reactors in which it has a financial stake. On the basis of these data the *Comitato Nazionale per l'Energia Nucleare* evolved, under contract to Euratom, a method of calculating the fuel cycle cost.

The "Economic Handbook" relies heavily on the results of all these studies. It should be stressed that it is not its purpose to establish criteria for assessing the relative merits of different electricity-producing plants, whether nuclear or conventional. It merely presents a method of calculating a power generating cost which it is hoped will meet with general acceptance.

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The CIRENE design: uranium metal or oxide?

The *CIRENE* programme, it will be recalled, was launched with a view to developing a family of natural-uranium-fuelled reactors with heavy-water moderator and boiling light-water coolant (cf. *Euratom Bulletin* Vol. IV, 1965, No. 2, pp. 54-60), under a contract of association concluded between Euratom and the *Italian Atomic Energy Commission (CNEN)*. The major part of the work was performed by the *Centro Informazioni Studi Esperienze (CISE)* in Milan.
From the outset of the conceptual design studies, attention had been given to both Zircaloy-2-clad uranium oxide rod bundles and uranium metal tube clusters with internal cooling. A comparative study of the two reactor versions (each of 500 MWe) which these fuel types would entail shows no clear advantage of either one over the other.
Admittedly the uranium metal version offers the greater reliability from the reactor control and safety angle.
On the other hand, in view of the data so far acquired on the irradiation stability of uranium metal, it appears unlikely that it can be employed at the high burnup levels feasible with a heavy water moderator. Another drawback is that, according to uranium-metal/heavy-water compatibility studies carried out, a cladding failure would give rise to serious difficulties. These two stumbling-blocks are not insuperable, but a considerable research effort would be required in order to overcome them.
Uranium metal was therefore finally abandoned and the oxide formula adopted. A point in its favour is that any enrichment decided upon would be of greater advantage to the oxide, which is not affected by the burnup limitations inherent in the metal.

Also, the oxide clearly appears to be more suitable for use with superheat channels. Now that the choice has been made, *CIRENE* has come to be a closer relation of the Canadian *CANDU-BLW* and the British *SGHWR* systems.

Scientific and technical documentation takes a step forward

The Centre for Information and Documentation *(CID)* of the European Atomic Energy Community has just placed a machine documentation service at the disposal of Joint Research Centre staff-members and Euratom contractors covering the entire field of the peaceful applications of nuclear energy.
At the *CID*, a team of engineers and scientists from the six countries will henceforward be able to reply at short notice to technical questions addressed to it by sending complete bibliographies and abstracts; these replies are obtained by tapping the magnetic memories of a powerful computer in which are at present stored references on nearly 500,000 publications, to which about 120,000 new publications will be added in an average year.
Parallel to this "question-reply" service, it is intended to send regularly to interested subscribers a selective bibliography accurately and exclusively covering their field of activity. They will thus avoid the loss of time occasioned by consulting numerous documents which prove after perusal to be unsuited to their needs, and will be sure of having at any given moment a complete overall picture of the latest developments in their particular field.
The *CID* intends shortly to make these services available to all scientists and engineers in the Community countries.
This achievement has been made possible by an alliance between man and machine, for while the machine can perform numerous routine operations quicker and better than man, in the last resort it is man's intellectual capabilities which enable him to programme and feed the machine.
Once again it is noteworthy that a project which has no rival in the world in the nuclear field has been brought to fruition by a Community effort.

Five-year index to Transatom Bulletin

Since the beginning of 1961, *Transatom Bulletin*, which is published by Euratom, has been facilitating the West's access to the nuclear literature of the East by announcing systematically Eastern nuclear documents (e.g. in Russian, Polish, Japanese, etc.) which exist translated into a Western language.

Transatom Bulletin has decided to publish a cumulative five-year index covering the years 1961-1965, which should be available shortly. The price of this volume, in which there will be about 120,000 entries, will be approximately 10 dollars. It can be ordered from: Transatom Bulletin, C.I.D., 51, rue Belliard, Brussels 4 (Belgium).

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