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Inside the AVR pebble-bed reactor in Jülich: a heat-exchanger.

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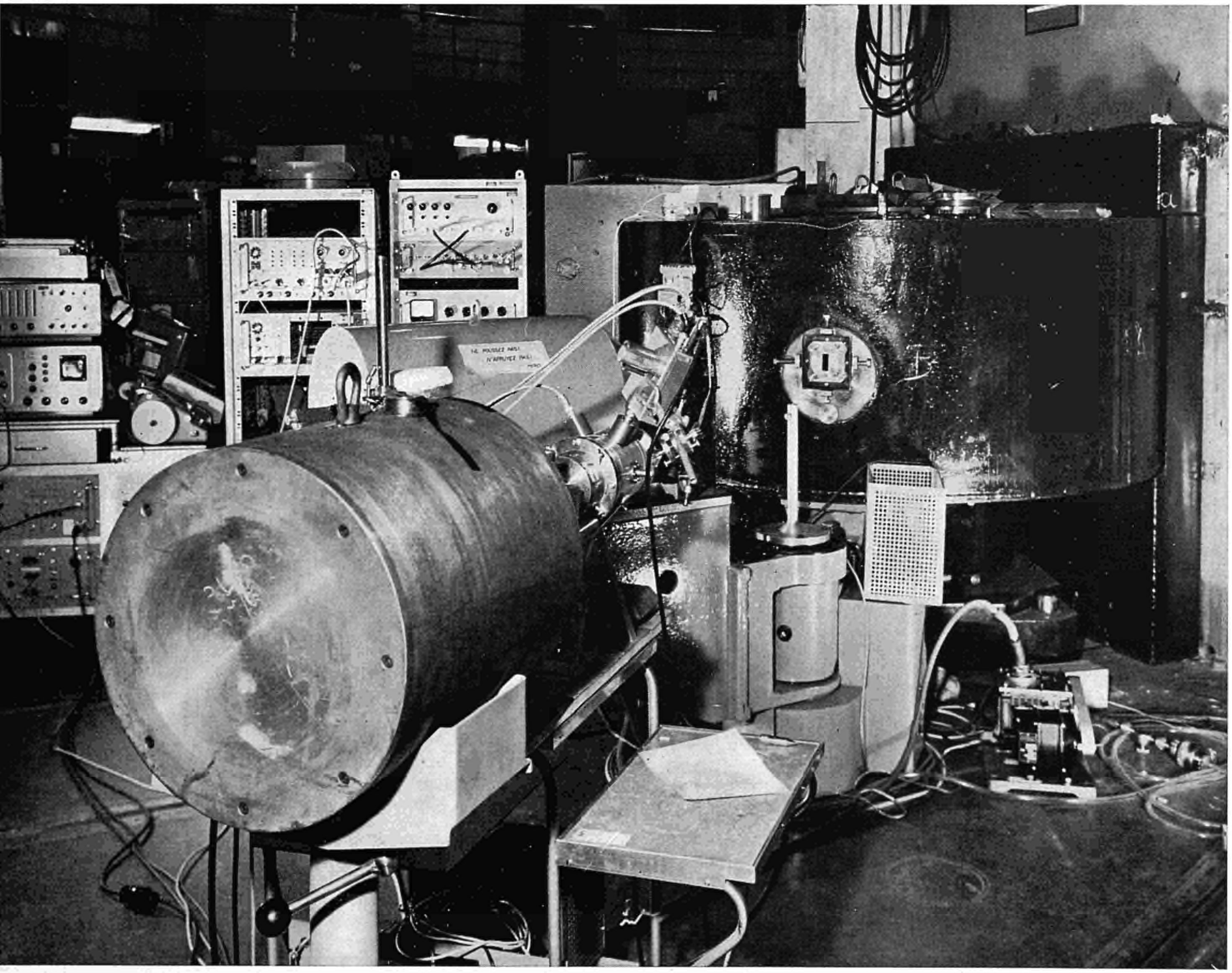
The Community's mission is to create the conditions necessary for the speedy establishment and growth of nuclear industries in the Member States and thereby contribute to the raising of living standards and the development of exchanges with other countries (Article 1 of the Treaty instituting the European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

The Euratom Information and Documentation Centre recently prepared statistics on the origin of the "nuclear" documents covered by its automatic documentation system.
It emerged that 38% of the items in its collection originated in the United States. Next come the East European countries, including the USSR, with 21%, the Community countries with 18%, the United Kingdom with 8% and Japan with 5%.
These figures show that more than a quarter of the documents in the collection come from Eastern Europe and Japan, i.e. from countries using languages which most Westerners regard as "difficult". The size of this proportion is further proof that Western research scientists can no longer afford to be ignorant of the results achieved by their opposite numbers working in those countries.
At the same time, however, we may well wonder if the collection is really complete, and whether the figure for Eastern Europe and Japan ought not to be yet higher.
It is well known that even to get hold of everything published on a given subject in one's own country is no easy task; what sort of access can we expect, then, to nuclear literature in those linguistically far-off lands? Clearly, this is a problem that needs tackling, and "Eastatom" has been set up, in the Jülich Nuclear Research Centre, for that express purpose.

Neutron techniques in



condensed state physics

VICTOR RAIEVSKI, *Head of Reactor Physics Department, Ispra, Establishment of Euratom's Joint Research Centre*

NEUTRON PHYSICS is certainly less familiar to the non-specialist scientific public than high-energy physics. The latter at once evokes the large accelerators which are needed to produce high-energy particles, and which have likewise stimulated the growth of this branch of physics by reason of the huge investments involved and the resultant concentration of efforts. The *CERN* 30 Gev synchrotron, for instance, cost 22 million dollars.

Though still unperceived by the general public, a similar growth is taking place in the sphere of neutron physics, and unquestionably the sheer magnitude of the funds and investments entailed in this branch of physics will help to lift it out of the experts' corner and on to the front page with its companion, high-energy physics.

Take, for instance, the cost, in dollars, of building intense neutron sources—15 million for the nuclear reactors that recently came into operation in the United States, 30 million for the new American and European projects, 150 million for the Canadian project. Even more important than this spectacular aspect, the constructing of these huge machines will lead to a concentration of effort within specialised installations, and to programme co-ordination on an international scale, which has already started.

Condensed state physics:

Knowledge of the properties of matter in the condensed state, i.e. of solids and liquids, is of practical value. Condensed state physics, by enabling us to understand the reasons for these properties and revealing new ones, opens the way to major developments in all branches of technology.

Certain of these applications, such as the still quite recent discovery of the properties of semiconductors and their use in electronics, are among the most widely-known though not the most important; others such as lasers, masers, Josephson junctions, or the Gunn effect, are beginning to reach public notice. The last-named is a very good example of systematic research on properties with a view to their practical application. The object was to produce a crystal with negative electric resistance which could be used as an oscillator to generate high-frequency electromagnetic waves. The physicists found the answer through their work on the phenomenon of variation in the apparent mass of the electrons in a crystal subjected to stress.

It should not be forgotten, moreover, that our knowledge of materials is founded on condensed state physics.

In order to understand the properties of matter in the condensed state, it is essential to know its structure and the nature of the forces of interaction that are exerted between the atoms.

research on the structure ...

The structure may be crystalline, meaning that an assembly of atoms representing a unit cell is reproduced regularly lattice-wise, rather like a wallpaper pattern. One then has to determine the lattice's symmetry properties and the arrangement of the atoms in the assembly forming the unit cell. There is still a great deal of research to be done in this field to determine the structure even of such everyday substances as water.

... and the dynamics of matter ...

Essentially, solids cohere through electrostatic forces, with a slight contribution from magnetic forces. In general these forces are not uniformly exerted but are predominant in certain directions. One of the aims of condensed state physics is to discover the intensity and direction of these interacting forces.

If a nucleus is shifted out of its equilibrium position, it moves back to it with an oscillating motion which is characteristic of these binding forces. In fact, a disturbance of this sort will trigger off collective atom movements that propagate through the crystal at nearly the speed of sound, much like a wave.

This phenomenon can be described as a propagating disturbance, to which an energy and a momentum and therefore a mass can be assigned. There is nothing to prevent us from regarding it as a special kind of particle. Physicists have named it the "phonon". For solid state physics also has its "strange" particles, and the phonon is only one of several, such as the "magnon" and the "exciton".

... by means of neutrons

The structure of matter can be determined by observing the diffraction of waves of a length comparable to that of the distance between the atoms of the crystal, generally of the order of one angström (1 Å = 10^{-8} cm). X-rays of about 50 kev (kilo-electron-volts) have the same order of wavelength and are generally used in diffraction experiments.

Figure 1: *The photograph shows a particular type of crystal monochromator. This is the instrument installed at the Solid State Physics Department (M. Meriel),* CEN, *Saclay, France.*

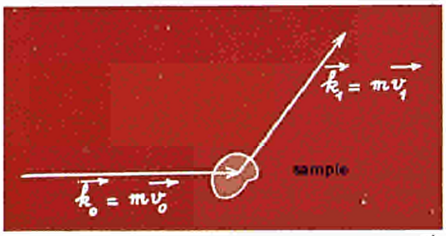


Figure 2: *An incident neutron of velocity* $\vec{v}_0$ *is scattered by the sample; its post-scattering velocity is* $\vec{v}_1$.

Whereas X-rays are scattered by electrons, neutrons are scattered by nuclei, and it happens that the wavelength needed for diffraction experiments corresponds to neutrons with an energy of the order of 25 mev (millielectronvolts), which are produced in abundance in nuclear reactors. The principle of structure determination by X-ray or neutron diffraction is as follows. A parallel beam of radiations strikes the crystal. Each atom of the crystal scatters the beam in all directions, and the resultant scattered radiation is measured at a distance with a counter. If the atoms are evenly distributed, the waves interfere and form images of the radiation source in certain preferential directions known as "Bragg directions". These directions furnish a means of determining the nature of the lattice, and from the intensity diffracted in these directions one can determine the arrangement of the atoms inside each unit cell making up the lattice. The scattering is elastic, i.e. the direction of the radiation is changed but not its energy; it is coherent, for the waves interfere to give rise to Bragg peaks.

Neutron diffraction is particularly important to the study of structures containing light nuclei, to magnetic structures, and to the study of the dynamics of matter. The importance of neutrons in research on dynamics must be emphasised. Owing to its mass, at equal momentum the neutron's energy is about a hundred thousand times weaker than that of the X quantum. The energy transferred to the crystal in a collision is of the same order of magnitude as the neutron's incident energy. Hence the variation in the neutron's momentum and energy can be exactly measured; in the case of the X-ray the energy variation is about a hundred millionth and can only be measured in certain very special cases by using the Mössbauer effect.

The techniques used in neutron physics . . .

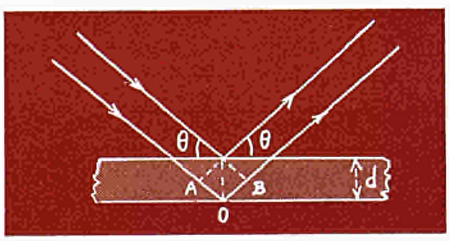
The measuring principle is extremely simple. Neutrons of energy E_0 and momentum $\vec{k}_0 = m\,\vec{v}_0$ are selected. One measures their energy E_1 and momentum $\vec{k}_1 = m\,\vec{v}_1$ after scattering by the sample of matter under study. By reason of the law of conservation of energy and momentum, the differences $E_0 - E_1$ and $\vec{k}_0 - \vec{k}_1$ show the energy and momentum transferred to the sample (Fig. 2). One also measures the fraction of incident neutrons which, after scattering, have the characteristics $(E_1\,\vec{k}_1)$. These quantities provide all the data needed to determine the structure and dynamics of the substance.

The technique consists in selecting neutrons with the desired energy and momentum.

The neutrons produced by fission in reactor fuel-elements are slowed down in a moderator, and their velocity distribution is close to that of molecules of a gas of the same mass at the moderator temperature. The intensity of these neutrons in the moderator is characterised by the flux, i.e. the number of neutrons crossing one square centimetre per second in the moderator.

In the reactors used for this sort of research, the flux is from 10^{12} to 10^{15} n/cm^2.sec[1]. The beams are formed by neutrons that cross the outer surface of the moderator and escape along channels through the reactor shielding. They emerge via an angular aperture bounded by collimators—thin steel plates positioned inside the channels and parallel with their axis. It is a simple task to select the direction of momentum by this process, but not so easy to select the energies. This can be done in two ways:

Figure 3: *Bragg scattering: the waves scattered in direction θ will interfere if the optical path AOB is a whole multiple of the wavelength λ. The Bragg condition for reflection of the first order is AOB = 2d sin θ = λ.*



. . . selection by Bragg diffraction . . .

We have already seen that a neutron beam, on striking a crystal, is scattered in certain preferential directions, called Bragg directions. The neutrons scattered in those directions have a certain definite energy. If d is the distance between a series of lattice planes and θ the angle of incidence of the neutron beam, the Bragg selection depending on angle θ for neutrons of wavelength λ is given by the relation

$$\lambda = 2\,d \sin\theta$$

This is the equivalent of the familiar equation for optical lattices and corresponds to the same phenomenon; neutrons of wavelength λ will be scattered[2] in the direction θ if the difference of phase of the scattered waves is a multiple of 2π in that direction. Placing the sample studied or the detector in the direction θ amounts to selecting, out of the neutrons of all energies impinging on the crystal, the ones whose wavelength satisfies the Bragg equation. (fig 3). At this point it will help if we explain the relation between the energy-selection and the direction-selection of the single crystal diffracted beam.

If we consider a neutron beam of angular aperture dθ with a spectrum of energies, impinging on a crystal along a direction θ, all the neutrons inside the angle dθ whose wavelength satisfies the Bragg equation

---

1. The neutron flux (neutrons of any energy and any direction) is written φ. If the energy and velocity are to be specified, one writes φ (E, Ω). φ is the integral of φ(E, Ω) over all values of energy and velocity.
2. It does not matter if we speak of neutrons of energy E, or of velocity v, or of wavelength λ: these quantities are interrelated by the equations:

$$E = \frac{1}{2}\,m\,v^2;\ \lambda = \frac{h}{mv}\,.$$

will be diffracted. Thus one gets a diffracted beam of aperture $d\theta$, and the wavelengths of these neutrons will be within a range $d\lambda$. The energy selection $dE/E = 2d\lambda/\lambda$ will depend on the angle selection $d\theta$. To find this dependence, we have only to differentiate the Bragg equation, which gives:

$$\frac{d\lambda}{\lambda} = \frac{d\theta}{tg\theta}$$

Large diffraction angles facilitate selection. But the physicist is not concerned only with selection; another important characteristic is intensity, i.e. the number of neutrons received per unit of time. Efficient selection results in loss of intensity, and for each separate experiment a compromise has to be sought between these two conditions.

The device used to select neutrons of a given energy by Bragg diffraction is called a crystal monochromator (Figs. 1 and 4).

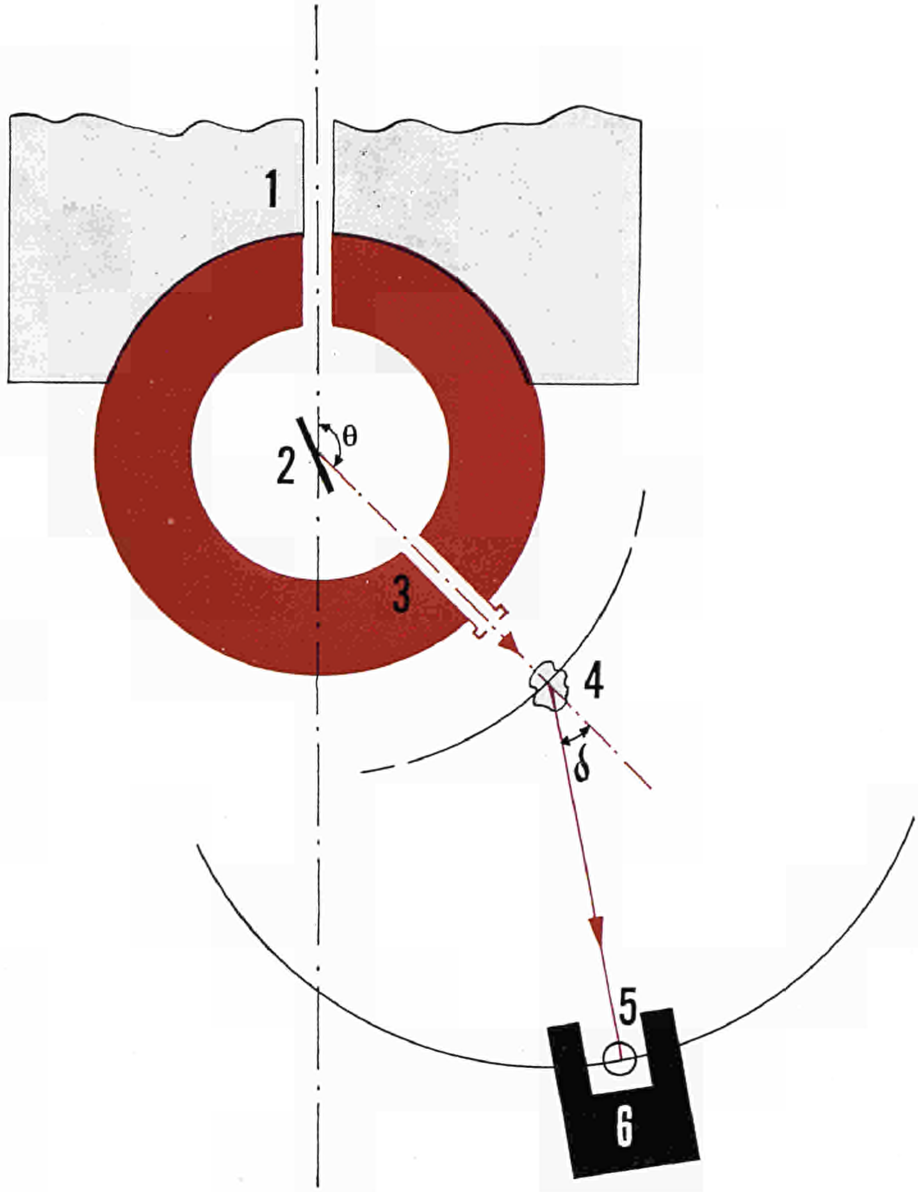


Figure 4: *The neutrons leaving the reactor traverse collimator 1, are diffracted by crystal 2 (e.g. copper) at an angle θ selected by collimator 3 and strike the sample 4. The detector 5, inside a shield 6, can be used for analysing the intensity of the neutrons scattered by the sample as a function of the angle δ. In modern crystal spectrometers a programme is employed for automatic analysis.*

. . . and selection by time-of-flight

In this method, the neutron beam emerging from a reactor channel is chopped into very short lengths, generally of a few microseconds (μs), by a rotating shutter (Fig. 5). This consists of a diametrical slit in an absorbent disc spinning very fast opposite the beam collimator. The beam can only pass through during the very short time that the collimator and the slit are in line (twice per revolution); each time, neutrons of all energies in that batch fly forward. The faster outstrip the slower ones, and the batch strings out as it advances. In the beam path, at a certain distance (the flight base) from the disc, a counter is placed; synchronised with the disc, it opens for a very brief time, usually equal to the disc aperture time, and with an adjustable time-lag after the start of the batch. It will readily be seen that with the right time-lag the counter will record the neutrons of the energy desired.

The ratio dt/l is a measure of the selectivity of a given installation, where dt is the pulse duration and l is the flight base. It has become customary to express this selectivity in microseconds per metre (μs/m).

The pulse repetition rate is a factor that has to be allowed for. It must not be so fast that the fastest neutrons in one batch can catch up the slowest in the batch ahead. By using suitable filters, one can limit the energy range of neutrons allowed into the beam and slightly increase the frequency of repetition.

If f is the pulse repetition frequency, it can be shown that the selectivity is simply a function of the product $f.dt$, that is, of the time during which neutrons are admitted into the beam. Clearly, therefore, good selectivity depends on a short admission time. As with the crystal monochromator, the price of selectivity is a loss of intensity.

This device is known as the time-of-flight monochromator, or "chopper" (Fig. 6).

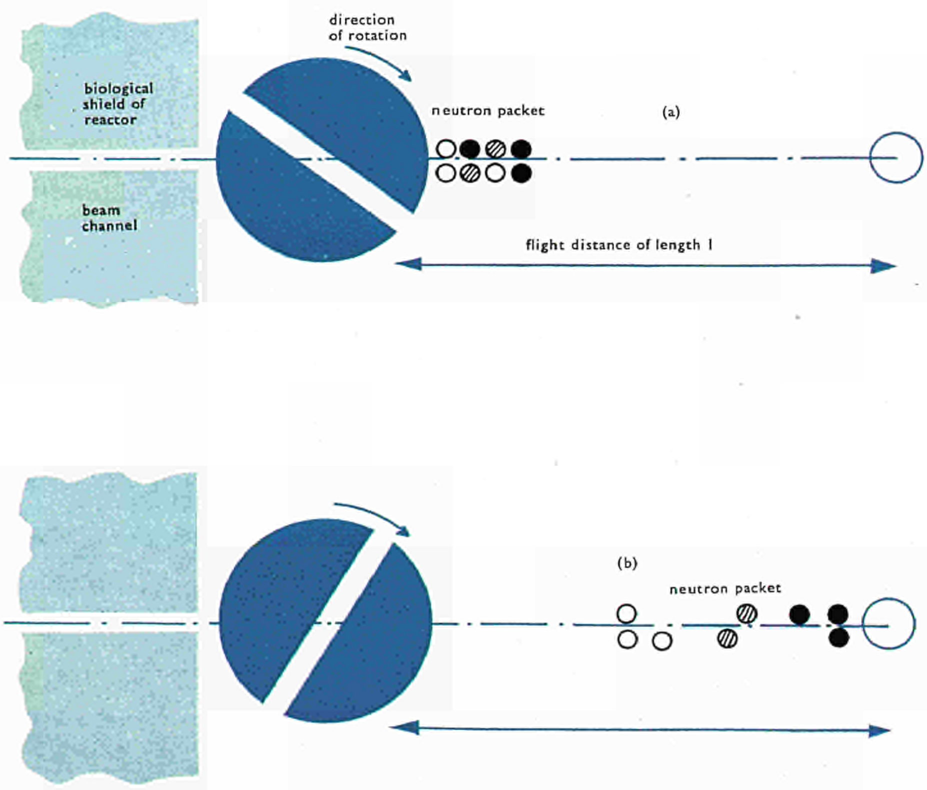
At first sight it appears that the chopper rejects more neutrons than the crystal monochromator does; a quick analysis shows that this is not so.

The chopper is linked with a multichannel selector which distributes the neutrons received by the detector over a set of counters according to their time-lag (Fig. 7). Each counter registers only neutrons of a given energy, but all the neutrons in the batch are utilised.

Given equal selectivity, both systems reject the same number of neutrons, but they do so in different ways.

The devices used in neutron experiments often include combinations of various types

Figure 5: *Principle of the chopper. In (a) the neutron batch has just been formed; black dots represent the fast, white the slow, and grey the medium-velocity neutrons in the batch. Diagram (b) shows the batch an instant later.*



of monochromator, and it soon becomes extremely difficult to analyse the respective merits of the different combinations; in these circumstances it is not surprising that even the experts find it hard to decide which are best. Two international meetings were held in 1966 to study this problem and the question of neutron sources, the first at Dubna (USSR), organised under the auspices of the *International Atomic Energy Agency* in July, and the second at Santa Fe (USA), organised by the *European Nuclear Energy Agency*. They undoubtedly gave a great impetus to ideas on this subject.

Intense neutron sources:

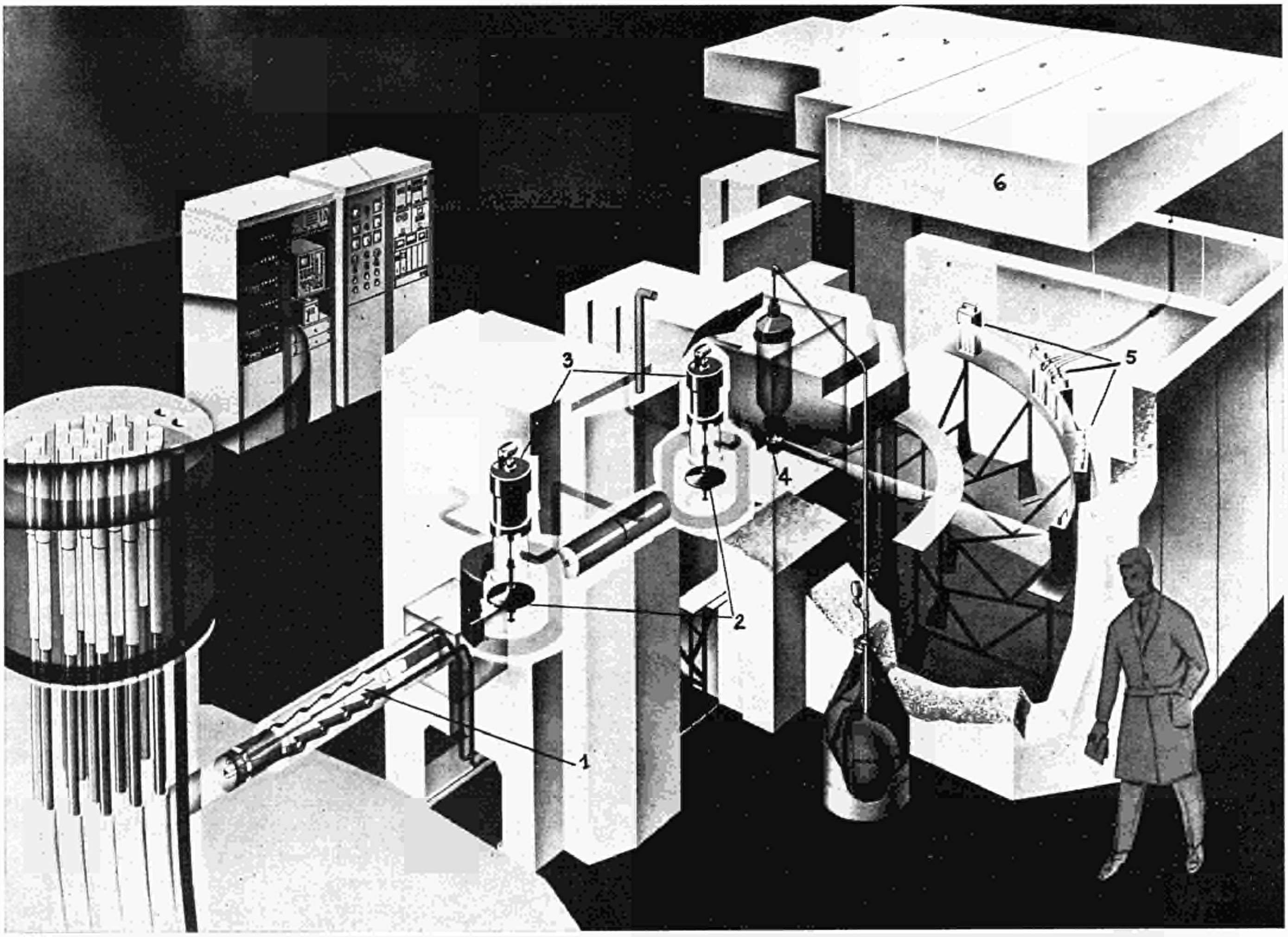
Neutrons are produced in nuclear reactions; the reactions used by intense neutron sources are either fission or reactions with charged particles. One important characteristic is the heat released per neutron produced. As this heat has to be carried off, it governs the size of the source-cooling device. Table I gives some of the values for the nuclear reactions generally used.

Table I:

Reactions	Heat generated, in Mev/available neutron
(e, n) 50 Mev electrons	600
fission, U 235	160
fast fission, Pu 239	100
spallation, Bi (p, xn) 1,000 Mev	30

The first of these is the reaction used in linac-type electron accelerators, where the high-energy electrons produced by the accelerator are slowed down in a heavy uranium or plutonium target and generate *Bremsstrahlung*, an intense gamma radiation due to braking, which produce neutrons by photoreaction on the target nuclei. The table shows that this device releases the greatest heat in the target. The linac, used in pulses, is a particularly useful instrument in nuclear spectroscopy, where the advantage of the very short pulse duration outweighs the drawback of low intensity.
The spallation reaction is the boiling up of the nuclei produced by the impact of high-energy protons. During this boiling a large number of neutrons are emitted. This is the most profitable reaction because of the small amount of heat released in the target, but it requires an accelerator capable of

Figure 6: *Velocity-selecting neutron monochromator (chopper). The neutron beam leaving the reactor traverses collimator 1 and then the slits in two rotors. The monoenergetic neutrons strike the sample 4 and are analysed by the time-of-flight technique with the detectors 5. The shielding 6 ensures that the experimental installation is biologically safe. This dual-rotor device permits energy selection before and after scattering (in cases of inelastic scattering).*



giving protons an energy of some 1,000 Mev. This device has been proposed by the Canadians as an intense neutron source for a vast research programme ranging from condensed state physics to high-energy physics. No device of this kind is being used for condensed state physics at the present time, however.
Fission reactions are used in nuclear reactors, which are the major class of intense neutron sources for condensed state physics. The nuclear reactors used for these experiments are usually in continuous operation, a system which is not suitable for the time-of-flight method. For a chopper with an admission time of 1%, for example, a continuous reactor produces 99% of dead-loss neutrons, and this useless output engenders heat which has to be carried off.
If the reactor could deliver these neutrons in pulses and in time with the chopper, with the same average power it would provide a neutron beam 100 times more intense. In that case, the reactor itself being a pulsed source, the chopper can be removed or replaced by a simpler device serving only to cut off the pulse tail which is always present in a pulsed reactor. Owing to the very short duration and high repetition rate of the pulse, the fast neutron reactor is the most suitable for this purpose. This relatively recent concept is being developed rapidly.

. . . the stationary reactor . . .

Apart from the *IBR* reactor at Dubna (USSR), all the reactors used today for condensed state physics are of the continuous type. The first was the *CP1* reactor at the Argonne Centre (USA), which went into service in 1942. The *CP1* neutron flux was 10^{13}n.cm^2.sec. Since then, several generations of reactors have followed, and the flux has increased roughly tenfold every ten years. The latest generation, producing

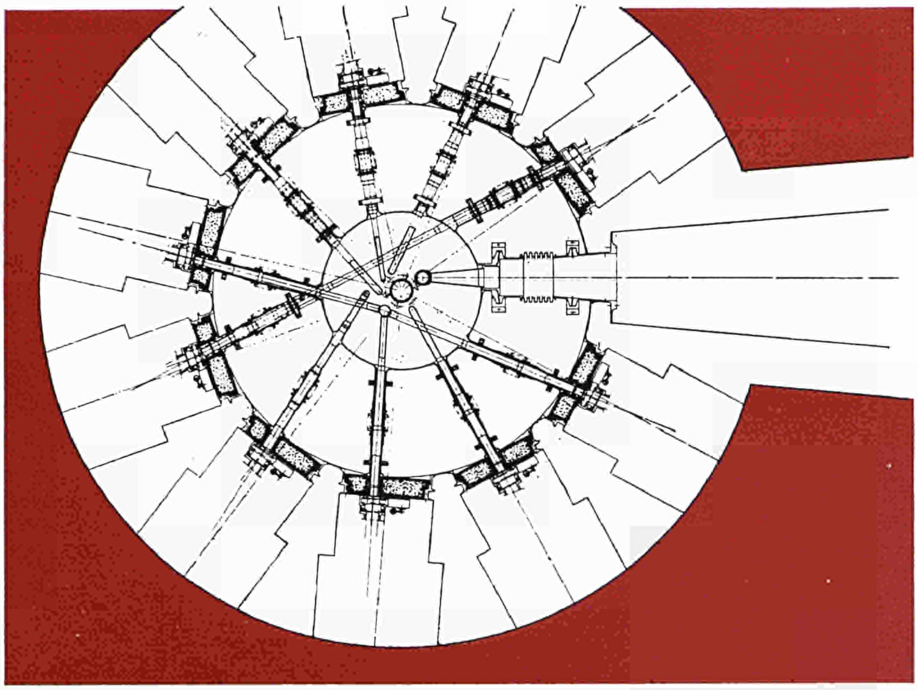
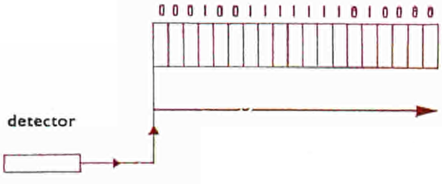


Figure 8: *Horizontal cross-section of the Grenoble* GFHFR, *showing the core, moderator and horizontal channels for beam extraction. (Extract from the paper by Messrs. K. H. Beckurts and R. Dautray: "Project Studies for the Franco-German High Flux Reactor", AEC-ENEA Seminar on Intense Neutron Sources—Santa Fe, USA, September 19-23, 1966).*

fluxes of the order of 10^{15}n.cm².*/*sec, are known as *HFR* (High Flux Reactors); it is not a very well-chosen name, but we will bow to this recent custom and keep this generic term.

The *HFR* reactors have many characteristics in common. They consist of a ring-shaped core made up of fuel elements in the form of highly enriched uranium plates, clad in aluminium and cooled by a stream of heavy or light water. The core is very under-moderated. Moderation takes place mainly in an external reflector of heavy water, where the moderated neutron flux attains its highest value and where the ends of the

Figure 7: *Principle of the multichannel selector. The detector pulses are selected according to their time gap* t *since the moment the neutron batch was formed. An individual distribution for one batch is represented here. Modern selectors have over 1,000 channels.*



neutron beam outlet channels emerge.

The power density is considerable, 1-2 MW/l on average, rising to 5 MW/l in certain parts of the core. The heat flux on the fuel element surfaces reaches 400-700 W/cm², and in order to extract it the cooling water has to circulate at speeds of 10-15 m/sec. Obviously cooling conditions of this sort are not far from the technological limit, and, short of singularly expensive contrivances, it is agreed that the highest economically feasible increase over present flux values is of the order of 2-3.

There are three reactors of this type in operation today—*SM2* (New Melekes, USSR, 1961), *HFIR* (Oak Ridge, USA, 1965), *HFBR* (Brookhaven, USA, 1965), and three others at the design stage—*AARR* (Argonne, USA), *UKHFBR* (UK), and *GFHFR* (Grenoble, France). The *HFBR* is typical of this reactor generation. It produces a flux of 0.6 . 10^{15}n. cm².sec for a power of 40 MW (Fig. 8). The French have introduced the concept of "efficiency", expressed in flux per unit power. The *HFBR* has an efficiency of 1.5.10^{13}. n.cm².sec.MW.

The joint Franco-German *GFHFR* project is fairly similar in design to the *HFBR*, but its improved core design raises the power to 55 MW and the efficiency to 1.8.10^{13}. Thus it will have twice as high a flux as the *HFBR*. The particular interest of this project, however, lies not in the doubled flux but in its cold source. This is a volume of liquid hydrogen positioned inside the reactor, which serves to moderate the neutrons at a temperature far lower than that of the reflector, thus affording a ten times greater flux of the very long wavelength neutrons which are especially important in these researches.

. . . and the pulsed reactor

The only currently operating pulsed reactor used for condensed state physics is the *IBR* reactor at the Dubna Centre (USSR), which started up in 1960. The *IBR* demonstrated that it is feasible to operate a reactor in pulsed conditions without encountering special difficulties in the way of structure behaviour or power regulation. Current projects envisage considerably higher powers, of the order of 1 MW or more.

The pulsed reactor comprises a highly enriched uranium or plutonium core, made up of stainless steel clad fuel elements and cooled by a sodium or eutectic potassium-sodium stream. The core volume is very small, 5-10 litres. It is surrounded by a metal reflector containing the control and safety rods and the hydrogen moderators in which the neutrons are slowed down (Fig. 9). The channels run through the biological shield and the metal reflector, ending against or inside the hydrogen moderator from which issue the neutron beams used in the experiments.

The power pulse is produced by a sharp periodic reactivity rise caused by the rapid rotation of a large-diameter wheel which carries either a sample of fissile material or a reflector sample. In the former case, the sample enters the core through a slot; this is the solution adopted in *IBR*, and it limits its power. In the latter case, the solution adopted for high-power devices, the trajectory is tangent to the core.

The *SORA* project designed by Euratom is characteristic of high power pulsed reactors. The core volume is 6 liters, the average power 1 MW. The power density, 0.15 MW/l, is low compared with that of the *HFR* and even the fast power-generating reactors (0.5-1 MW/l). In this respect the project may be considered very cautious, and there are other projects or designs (Brookhaven, USA - Harwell, UK) at a less advanced stage than *SORA* but with power density values ten times as high (Fig. 10).

The reactivity pulse is obtained by rotating a beryllium reflector fitted on a wheel 190 cm in diameter at a speed of 50 rps. The power pulse has a duration of 50 µs and a maximum amplitude of 300 MW, and the neutron flux in the hydrogen moderators reaches a value of $4 \cdot 10^{15}$n.cm^2.sec. The neutron spectrum depends on the moderator temperature and geometry, which can be modified. The fast and epithermal neutron pulse is of the same duration as the power pulse. It is longer for the thermal neutrons, owing to the thermalisation phenomenon, and reaches about 60-100µs. Although somewhat long, this pulse duration is admirably suitable for time-of-flight experiments with thermal or cold neutrons. Resolution is determined by the time-of-flight base and in certain experiments, using very long flight bases, it is helpful to use an ingenious device developed by Professor Maier-Leibnitz of the University of Munich, which consists of polished metallic tubes in which the beam neutrons are propagated by total reflection off the walls. The power pulse duration can be substantially shortened by coupling the pulsed reactor with an accelerator, which is used to inject neutrons into the reactor core for a very short time, of microsecond order, at the instant when the reactor reactivity pulse reaches its peak value.

In the case of *SORA*, the accelerator envis-

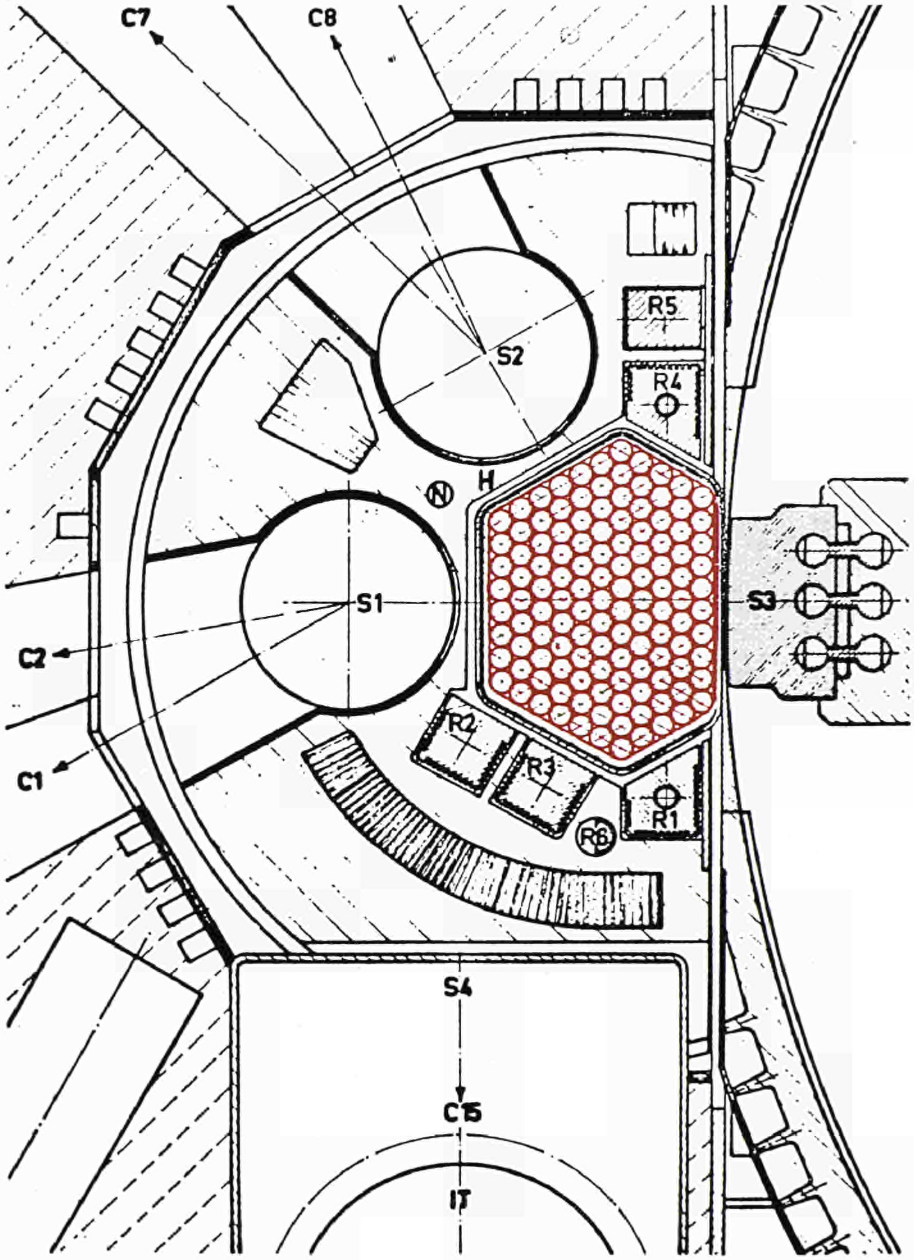


Figure 9: *Horizontal cross-section of the central part of the* SORA *pulsed reactor. The core, an assembly of U 235 or Pu 239 fuel elements, is contained in a hexagonal vessel H. The hydrogen moderators S_1 (cold neutrons) and S_2 (thermal neutrons) are contained in the metal reflector. Each source feeds three pairs of channels, i.e. four horizontal channels situated at two different levels (C_1, C_2) (C_7, C_8) and two slightly sloped. Pulsing is produced by sweeping the beryllium block S_3, which also serves as an epithermal neutron source. The revolving axis of the wheel carrying S_3 is at the extreme right of the drawing. R_1 to R_6 are the control and safety rods. N is the neutron source used to start up the reactor.*

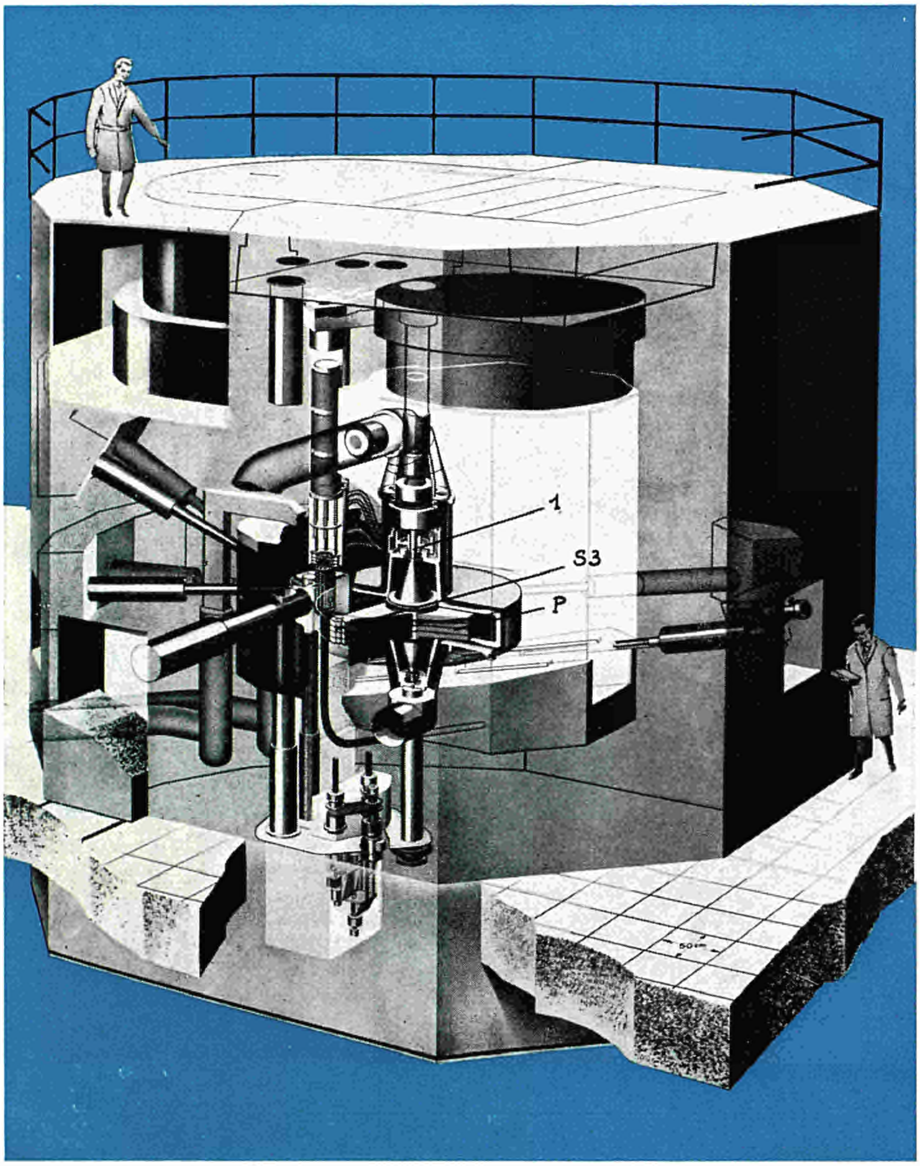


Figure 10: *View of the SORA pulsed reactor. The revolving axis not shown in Fig. 8 can be seen here at 1. The beryllium block S_3 is carried by one of the arms of the propellor P. The channels fed by the sources are plainly visible here, with their position at two different levels and their slope.*

aged, a linac electron machine, would have a maximum output of 50 MW and an average beam power of 50 kW, producing $5 . 10^{14}$n . sec on average. This source is multiplied by about 300 in the reactor. The reactor's peak power reaches 2,000 MW and the pulse duration is shortened to 6 μs. The epithermal neutron flux is raised to seven times its reactor-only value.

Conclusion

At the end of 1966, there were three high-flux reactors in operation — one in the USSR and two in the USA. From initial conception to start-up they took an average of ten years, roughly half of which were spent in working out the detailed project, construction and acceptance tests. We may thus take it for granted that those countries can now look forward to some five years free of competition from any West European reactor. Their physicists can therefore settle down to their researches undisturbed, and their Western European colleagues can only follow their work in the publications that will shortly start to flow.

An initial attempt to get a high-flux reactor designed and built in Western Europe was made in 1963, under the aegis of the *European Nuclear Energy Agency*. Although technically this attempt led to an interesting project, it foundered in political waters.

Following this failure, Euratom on one side and France and Germany on the other developed two entirely different but remarkably complementary projects. They embody original features which entitle Western Europe's physicists to be present in this field and to contribute to its development. From the technical standpoint, these projects have reached the point where construction can be started. It was decided in December 1966 to build the *GFHFR*. The decision on *SORA* is to be considered in 1967.

There is wide concern today over the growing scientific and technical gap between the European Community and the other industrially advanced countries, a gap that is still widening. Similarly there is much talk of concentrating and co-ordinating efforts. Let us hope that all this concern will lead shortly to some real action; the scientific and technical foundations are already there, and all that is lacking is the decision to go ahead. (EUBU 6-11)

Eastatom - a new route to unknown research literature

DR. GÜNTHER REICHARDT, *Jülich Nuclear Research Centre, Germany*

The Jülich Nuclear Research Centre, in collaboration with Euratom, has set up a service which, for certain narrow research fields, locates, procures, notifies and, on request, translates unknown but important literature of the East European and Oriental countries. Lists of such literature are published in the monthly journal Transatom Bulletin *under the title* Eastatom. *They contain a limited selection under twelve different subject-headings and cover published scientific works in obscure languages which are not yet available in translation and do not yet feature in* Nuclear Science Abstracts.

RESEARCH HAS ALWAYS been concerned with the unknown. The individual researcher is at all times possessed with the urge to advance on remote and imaginative goals, but the scientific experimentation and technological development work that lead to these goals are often so onerous as to be beyond the intellectual and financial resources of the individual. In such cases there is only one solution: to enlist the co-operation of researchers at home and abroad who are working on identical or similar projects, insofar as their results have been published and the corresponding documents are readily available.

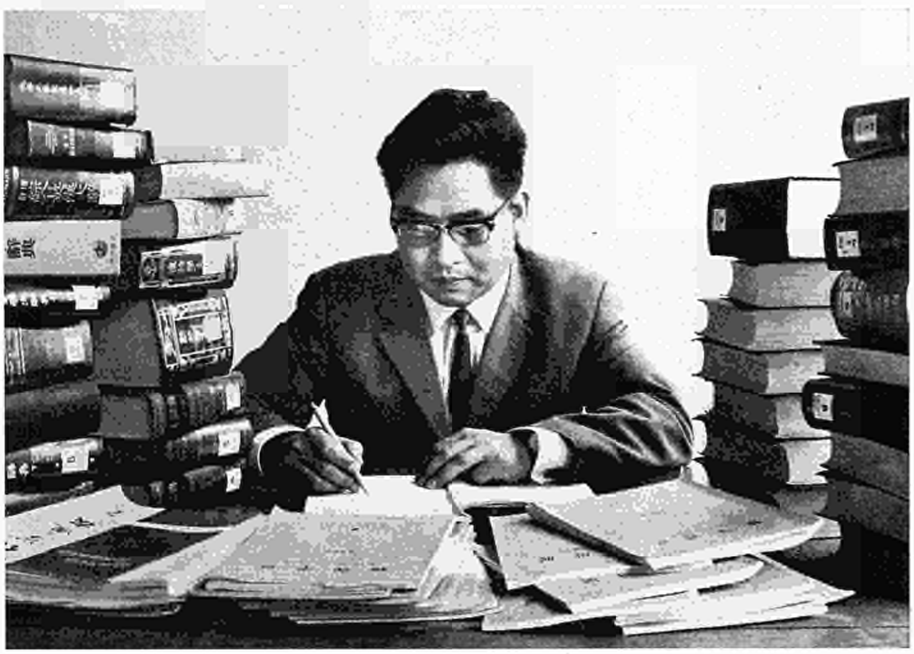
The problem of unknown research literature

It is therefore a question of bringing unknown literature to light, for it is an unfortunate fact that in Germany, for example, many research results remain in obscurity for a very considerable time, sometimes as long as six or eight years. There are various reasons for this, and shortage of funds is only one of them. Prof. F. Seitz[1], President of the *National Academy of Sciences*, Washington, has remarked that in Western Germany the organisation and documentation of scientific research have scarcely changed since before the first world war; they are based "on the institute system which was developed almost a century ago".

The greatest efforts to bring unknown literature to light—and it is primarily the literature published in the Eastern countries that constitutes this category—were made by the Americans after the shock they sustained as a result of the launching of the Soviet sputnik in 1957: this is evident today from the nearly 200 Soviet journals which have been completely translated into

1. F. Seitz: Wissenschaft im Vormarsch, Stifterverband-Schriftenreihe zur Förderung der Wissenschaft, Vol. 11, No. 9, 1962.

A Chinese member of the Eastatom *staff, Mr. Sun, with Chinese dictionaries and periodicals.*

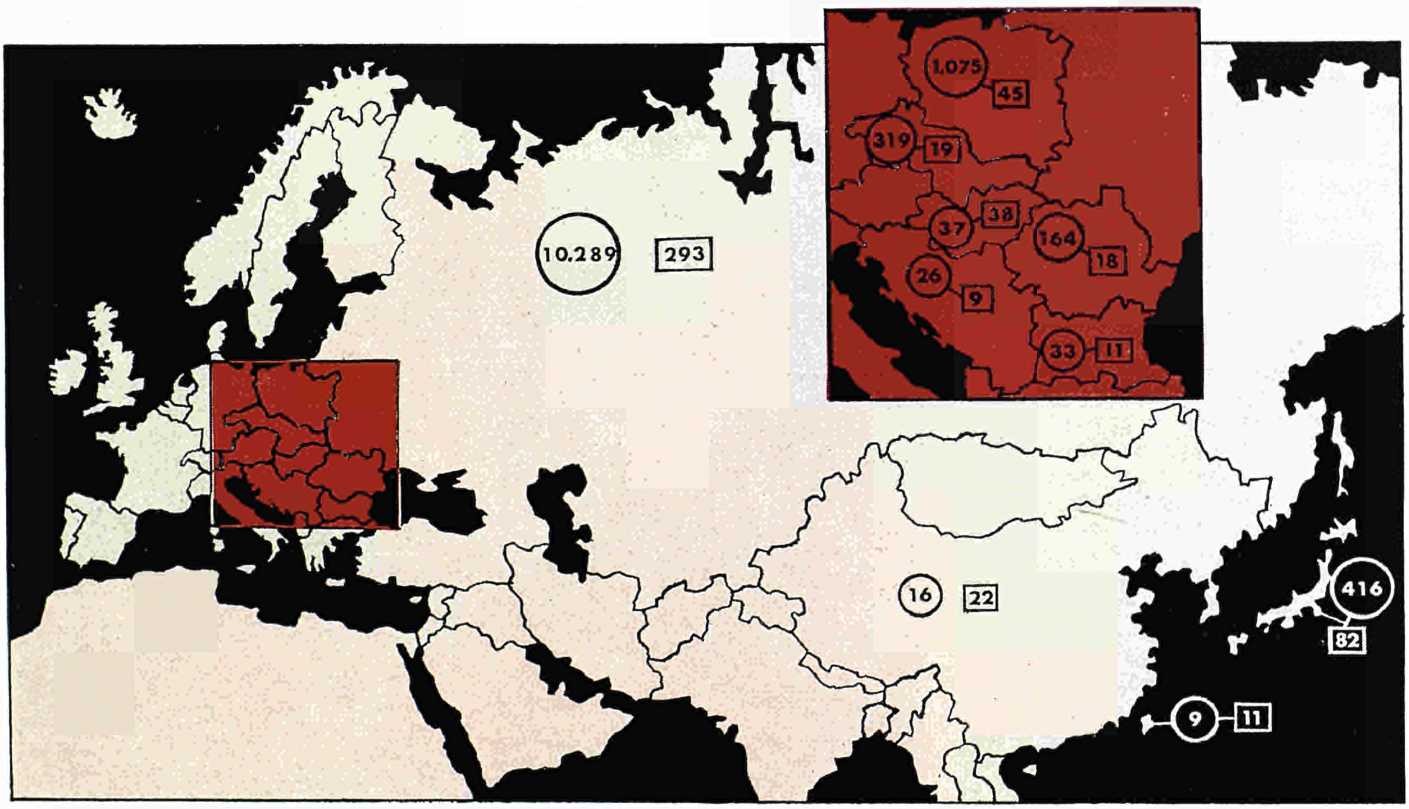


English and from the numerous translated monographs.
Nuclear Science Abstracts increased its coverage of Eastern-bloc literature from 6% in 1957 to 16% in 1964.
Nevertheless, many very important contributions—articles scattered throughout numerous journals, concealed research reports, theses and patents—are neither translated nor reported and consequently remain unknown for quite a long time. Examples can easily be found of research results which have escaped notice altogether or have only belatedly come to light.
The malignolipin test, which was published in Japan in 1958, was not reported in *Medical News* until 1964, despite the fact that Italian institutes had been working on it in the meantime. The effective cross-section measurements of many radionuclides have appeared in Soviet publications, but are nonetheless still being sought. How many people know of the proof of damage to uranium fuel elements in a current of CO_2? Or the experience acquired with the *Calder-Hall*-type fuel elements that were used in a Japanese nuclear energy centre? Or the Polish work on breeding in thermal reactors? Or the work on ultracentrifugation that has been done in Communist China on the basis of the results obtained by the German researchers Prof. Groth and Dr. Beyerle? Or the Russian studies on cytostatics? Or the conference held at Kiev in 1964 at which there were 111 individual papers on genetics and radiobiology? Or the Finnish work on a new cement for shielding purposes in reactor construction?

What does Eastatom offer?

It is now possible to discover and to obtain in translation hitherto unknown research literature in obscure languages which is not as yet included in *Nuclear Science Abstracts* and has not yet been translated. The European Atomic Energy Community, recognising the deficiency, organised a form of collaboration with the Jülich Nuclear Research Centre whereby a special service was set up at the latter's central library which, in certain narrow research fields, seeks out and procures important unknown literature of East European and Oriental countries, states the titles in English and, on request, furnishes translations at a reduced rate.
Since January 1966, these lists of important unknown literature have been appearing

Map showing the quantities of literature from Eastern countries available in the central library of Jülich Nuclear Research Centre.
The figures in squares represent periodicals; those in circles represent monographs, single works and reports.



monthly in *Transatom Bulletin* as Section III under the title *Eastatom*. The literature titles are given in English. The subject-matter is arranged under the following twelve heads: physics, chemistry, mathematics and computers, geology, mineralogy and meteorology, biology and medicine, metals, ceramics and other materials, engineering and equipment, reactor technology, isotope production and separation, industrial applications of isotopes and radiations, isotopes and radiations in agriculture and food preservation, health and safety. This literature is available at the central library of the Jülich Nuclear Research Establishment and can be ordered either as photostats or as translations into English, German, French, Italian or Dutch. Translations are supplied at a reduced price amounting to about 40% of the true cost.

A particular advantage for the individual scientist is that this list provides him with a selection of only about ten titles per month in each field, i.e. only 120-150 titles in all. Thanks to this "homeopathic" method there is no danger that the scientist will be offered "off-the-peg" goods; on the contrary, every effort is made to cater for his particular requirements by furnishing a specific and perhaps not unimportant contribution, the evaluation of which will take little time, but should constitute a useful pointer for many research projects.

The information thus offered relates to the gaps in the notification of technical literature, to the blank spaces on the "chart of nuclear research". Naturally, only *published* scientific papers in the Eastern languages as far as the Pacific are indicated; no account is taken of the invisible spectrum of internal, confidential and secret reports. The Americans have already realised the value of this contribution and are enthusiastically ordering the literature announced in Section III of *Transatom Bulletin*. In Europe, however, there is still a lack of response, although it has long been recognised that many spectacular scientific successes in nuclear research are also being achieved in the countries covered by Eastatom. It would be a pity if foreign researchers were to make earlier and better use of the time-saving routes that we point out than do our own institutes in the European Community. (EUBU 6-12)

(After an article originally published in Atomwirtschaft, *December 1966).*

An Eastatom *employee making punched tapes on the* BIMA.

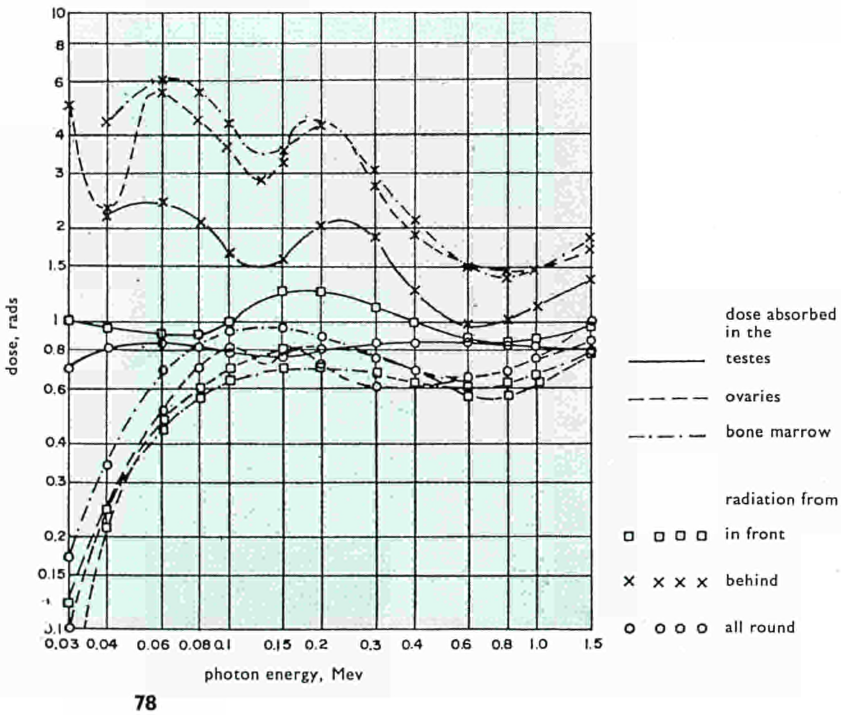
Report stand from the reading room of the central library of Jülich Nuclear Research Centre, with Eastern abstract journals and reports.

Film dosime

PERSONNEL DOSIMETRY, i.e. the integrated measurement of the radiation received by the individual worker in the course of his employment, rightfully occupies a central position in practical radioprotection. Its purpose is not only to ensure compliance with the legal provisions concerning maximum permissible doses but also to determine the treatment to be given an injured worker in the event of a possible accident, to supply evidence for any litigation which may take place and to form the basis of statistical analysis. However, the part played by film dosimetry in this field —the terms *film dosimetry* and *personnel dosimetry* are virtually synonymous for many laymen—has been the subject of considerable controversy in recent times.
It has been said that "The Middle Ages of personnel dosimetry, in which the personal dose was determined from the reddening of skin and blackening of films is nearly over". In point of fact, film dosimetry is a method by which over half a million radiation workers are constantly kept under surveillance throughout the world with the approval and backing of national and international authorities. Comparison of this process with the extremely inaccurate method occasionally used in the twenties for estimating radiation damage from the intensity of reddening of the skin ("erythemdosis") would certainly be rejected by many experts who today still regard film dosimetry as the best available method.

For example, they point out that for over twenty years film dosimetry has been the only technique to be applied in civil personnel dosimetry on a large scale, a large amount of experience having been acquired with this method. The more recent techniques, however, which are based on solid state physics and have of late been tending to oust film dosimetry more and more, have so far not been tested to any great extent. This argument is countered by advocates of glass and thermoluminescent dosimetry with the remark that for all its drawbacks, which were well-known at the time, the use of films was introduced after the war only because no other methods available then were suitable for cheap mass dosimetry. Now, however, intensive efforts to develop beter techniques have proved successful, so that there is no longer any reason for retaining this method. The argument concerning insufficient experience is not valid, either, since good results have been obtained in other fields such as military and civil defence personnel dosimetry over the last 15 years (e.g. with five million glass dosimeters in the US Navy). Furthermore, recent comparisons between film and solid dosimeters have tended more and more to demonstrate the superiority of the latter.
The advocates of film dosimetry also point to the considerable investments which film dosimetry demands in the way of equipment and personnel and to the carefully developed organisation of a central mass surveillance system using films, which would become superfluous or at least require modification if another method were introduced. All fundamental innovations do in fact involve certain technical and administrative difficulties and necessitate new investments; the problem is, before the necessary changeover takes place, to examine thoroughly whether the expense and trouble are warranted by the material and financial advantages to be gained from a new technique.
Such a changeover could not, of course, be carried out suddenly but, in view of the present scope of personnel dosimetry, would have to be effected gradually, beginning with nuclear installations, for example. On the other hand, such a move becomes more complicated and expensive the longer it is put off.
This discussion, which over the last few years has been touched on in one form or

Fig. 1: *Dose recorded on a personnel dosimeter in a case of whole-body irradiation versus the actual dose in various critical organs (male and female sex glands, bone marrow) for X and gamma radiation of different energy and incidence (data supplied by* A. R. Jones, Health Phys. 12, 663, 1966.)



try - a thing of the past?

DR. KLAUS BECKER, *Central Radioprotection Department, Jülich Nuclear Research Centre, Germany*

another at all international congresses dealing with this field or among smaller groups of experts, could be continued for a long time. What, then, is the actual situation with regard to film dosimetry, is the question which will be asked by the outsider, the passive "customer" of the personnel dosimetry centres.

Basic limits of personnel dosimetry

In any attempt to answer this question mention must first be made of the very limited amount of information to be obtained from *any* personnel dosimeter, however accurate. Even under ideal conditions, a personnel dosimeter will only give the dose at the location of the dosimeter, not the whole-body dose. In exceptional cases, such as the well-known exposure of a person to gamma rays of about 1 Mev or neutrons of about 10 Mev, the dose reading on a reliable dosimeter will agree with the whole-body dose or the dose in a particularly sensitive critical organ to within about ± 50%, but in the majority of cases matters are much more complicated. It is usually quite impossible to determine with any reasonable probability whether a person with a dosimeter reading of, say, 5 rad has actually received a higher whole-body or gonad dose than somebody whose dosimeter showed a reading of 2 rad. Fig. 1 shows more recent values comparing the influence of the direction of intensities of X and gamma radiation of various energies on the correlation between the dose picked up by the organ and the dosimeter reading. In the event of partial irradiation or faulty readings, of course, the situation is even more complicated.

The dose reading therefore provides only a very indirect indication of the somatic or genetic radiation effect to be expected. Of the various stages between the dosimeter reading and this effect or its medically discernible manifestation, shown in Fig. 2 with the possible error factors, only the first stage, namely the accuracy of the dosimeter, will be considered here. Fig. 2 is also intended to show how an isolated dosimeter reading, at best, only possesses any value for information purposes if carefully and critically evaluated by an expert.

This situation can be simplified if, in the statistical evaluation of a large number of individual measurements carried out on several persons over a limited period or on one person over a long period, the errors, which in certain cases may frequently be high, can be partially offset.

Furthermore, with small doses, roughly in the order of magnitude of 1/10th of the permissible maximum values, major errors are perfectly tolerable owing to the high safety factors applied in defining the tolerance values. Finally, the dosimeter fulfils only a symbolic, administrative or instructional function in many cases anyway, so that its reliability is then of little importance.

On the other hand, the experts are agreed that in the event of higher doses, especially in the somatically interesting range (accidental irradiation) of about 100-700 rad, the maximum possible accuracy should be aimed at, errors of more than ± 10-20% considerably complicating the decision as to what therapeutic steps should be taken.

But which dosimeters meet these requirements best of all, relatively speaking? The answer is that there is no ideal dosimeter for all the important ranges, i.e. for the medical and nuclear ranges and for that of possible high accidental exposures. Also, all the dosimeters now in existence, including the latest solid-state dosimeters for example, are not capable of taking certain important types of radiation such as intermediate neutrons, which may constitute up to 90 % of the total dose in the vicinity of the reactor, and many problems still have to be solved with regard to the dosimetry of high-energy photons, neutrons and charged particles, such as those observed in the neighbourhood of accelerators.

X and gamma radiation

For the most frequent case, namely personnel dose monitoring in medical and nuclear centres, in which the majority of the dose comes from X and gamma radiation in the energy range from about 20 kev to 2 Mev, the main advantages and drawbacks of the various types of dosimeter can be outlined as follows.

Owing to the fact that a photographic image, i.e. an X-ray picture of the badge used each time, is obtained during its evaluation, the film dosimeter can provide certain information which it is difficult or impossible to obtain with solid-state dosimeters. For instance, dark spots on the film are an indication of surface contamination, while high-definition reproduction of the edges of the metal filters in the film badge suggests brief isolated irradiation, and even the nature of the filter image can yield data concerning the direction of incidence of the radiation. Using specially designed film dosimeters, moreover, it is possible to detect radioactive gas (radon, tritium).

Also, the film, which is in any case useless as a radiation detector after evaluation, can be stored more easily than a solid-state dosimeter as a "document" of a radiation exposure, is frequently more quickly and more easily obtained than a solid-state

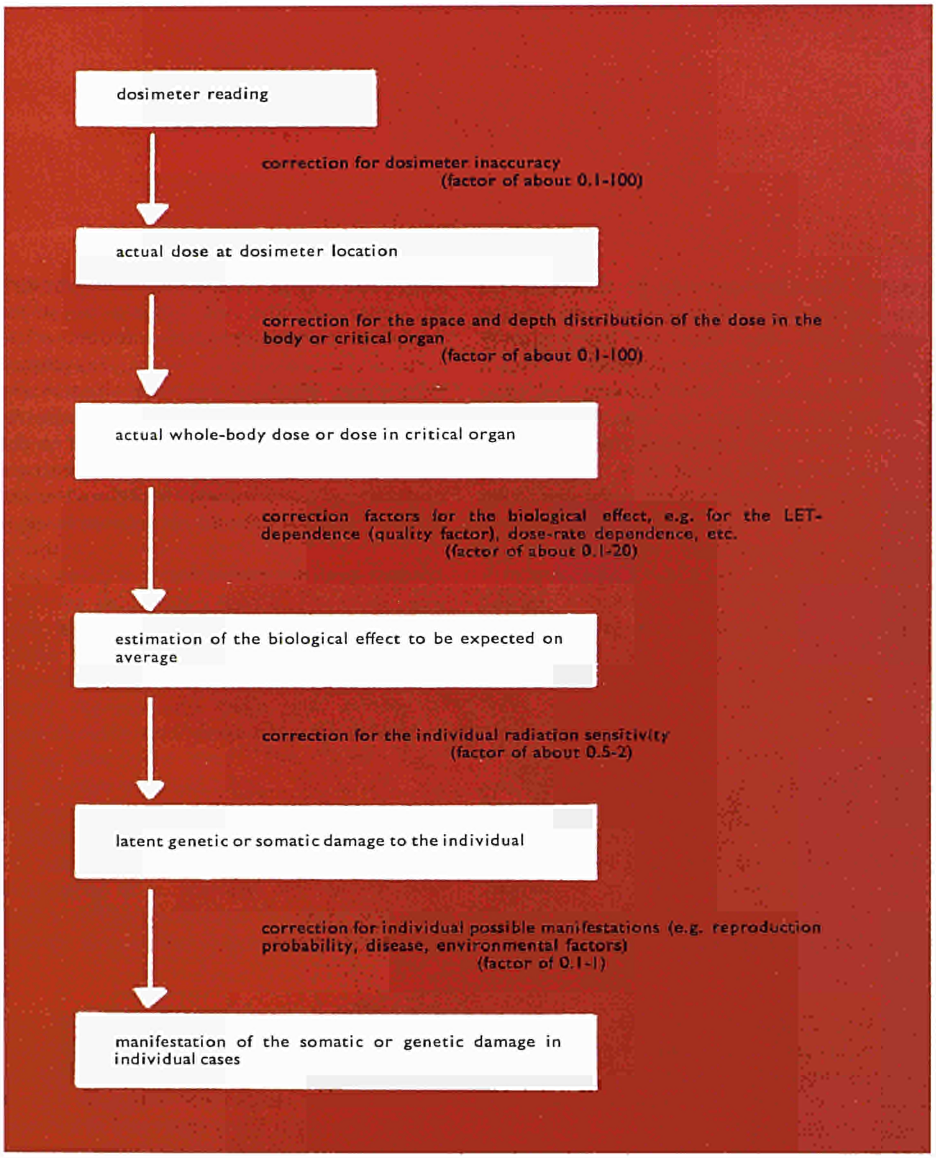


Fig. 2: *Diagrammatical representation of the relationship between the dosimeter reading and any individual somatic or genetic damage, with the major corrections to be applied.*

dosimeter and, if regarded as a single dosimeter (i.e. leaving aside the fact that solid-state dosimeters can be used over and over again), cheaper too.

Solid-state dosimeters

At the same time modern glass and thermoluminescent dosimetry, the basic principles of which are shown diagrammatically in Fig. 3, is far superior to films in several important respects.

1. Greater accuracy

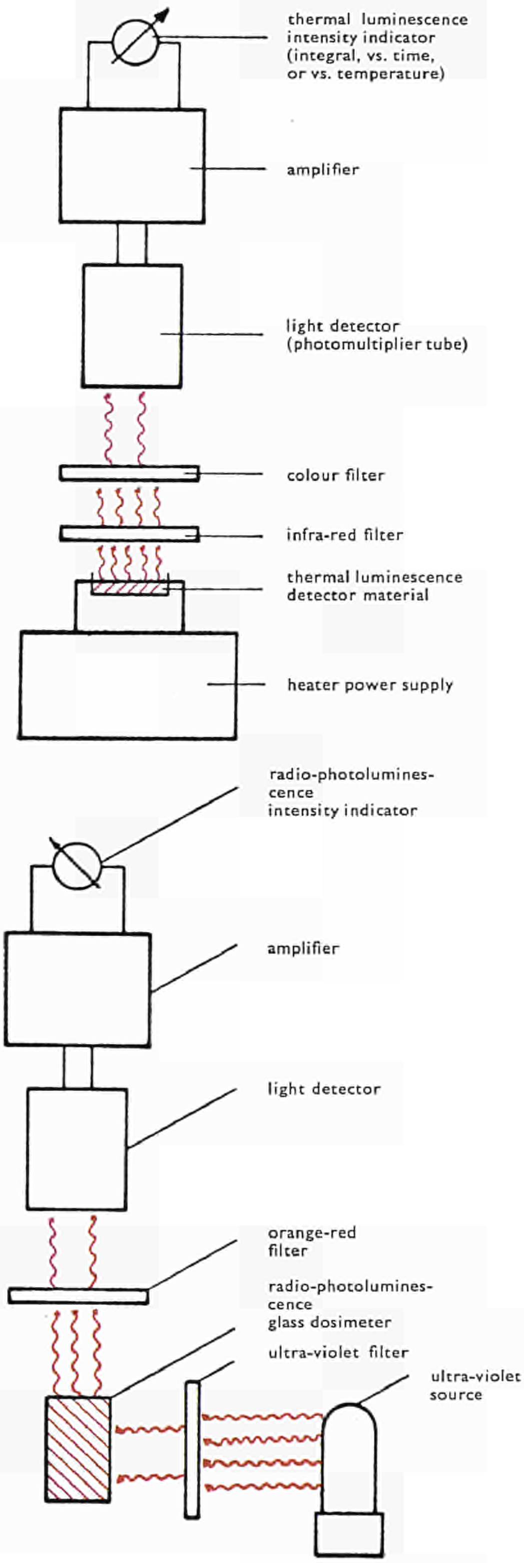
The literature occasionally reports relatively favourable values for the accuracy obtained with film dosimeters in laboratory experiments (in a recent British publication, for example, 80-90% of the film values were found within ± 40% of the dose applied, although the maximum deviation was admittedly 25 times the irradiation dose).
Such data might well arouse the impression in a casual reader that this is the actual accuracy that can be obtained in practice. In fact these values were always measured under extremely ideal laboratory conditions and represent the best accuracy which can be obtained with film dosimeters under the following particularly favourable conditions: experienced, well-trained evaluation staff, optimised dosimeters and good dosimeter films, head-on irradiation with a narrow beam of mono-energetic X or gamma radiation of simple composition, dose range from about 0.05 to 100 rad, energy range from about 25 to 1,250 kev, absence of beta or soft X-radiation, test and control films stored under ideal climatic conditions, etc. But even under these conditions, which in practice are obviously only rarely encountered, occasional "mavericks", i.e. films which give a dose reading which is wrong by a factor of 5 or more, cannot be avoided.

However, if the testing conditions are brought more into line with actual practice, i.e. irradiation at an angle, complicated mixed irradiation and storage of the test films over several weeks at varying temperature and air humidity, it is only in exceptional cases that the dose readings agree with the actual dose values applied to within ± 30-50%, and the percentage of films which give completely false readings or cannot be evaluated at all is very large. It is obvious that the statistical, legal or medical value of such film dosimeter readings, which, while they may well be correct to within ± 30 or 50%, may also be wrong by a factor of 5, 10 or more with a probability which is extremely difficult to estimate, is very limited. On the other hand, an average deviation of ± 10% and a maximum deviation of ± 30% was obtained, for example, with suitably encapsulated glass dosimeters under identical conditions, similar to those encountered in practice.
The superior accuracy of solid-state dosimeters has been corroborated over and over again in the last few years by numerous studies carried out, in particular, in the USA (comparisons of film and thermoluminescent dosimeters) and Germany (comparisons of film and glass dosimeters). Under ideal laboratory conditions, for example, it is possible to evaluate glass dosimeters with a standard deviation of less than ± 1%.

2. Greater sensitivity

Whereas the reliable lower detection limit for gamma radiation using film dosimeters is between about 20 and 100 mrad in practice, 0.1 mrad can be integrated without trouble with calcium fluoride dosimeters and 10 mrad with glass dosimeters, over long periods, even under extreme climatic conditions.

Fig. 3: *Schematic representation of the evaluating process for a thermoluminescent dosimeter (above) and a glass dosimeter (below).*



3. Less energy- and direction-dependence

Some solid-state dosimeters, such as lithium fluoride and lithium borate, show no disturbing energy-dependence after about 10 kev, while in other cases (glass, calcium fluoride) the energy-dependence between about 30-50 kev and several Mev can be reduced to a minimum by suitable encapsulation. However, should a filter analysis be required, i.e. additional information on the effective quantum energy, this can easily be done with several solid-state detectors as in the case of film dosimeters. Using suitable pairs of glass dosimeters, for example, X-radiation of over 15 kev can be measured and its energy determined. As opposed to films, moreover, the readings on properly encapsulated solid-state dosimeters are independent of the angle of incidence of the radiation.

4. Weather resistance

As opposed to films, which are sensitive to numerous outside influences such as light, laboratory gases and vapours, atmospheric humidity, increased temperature, etc., solid-state dosimeters can be stored for almost unlimited periods both before and after use and still retain their properties. The resistance of the radiation effect to fading is particularly important, a change of only 5% in the reading being found, for example, over a three-year period in glass dosimeters.

5. Simplified evaluation and organisation

Unlike films, solid-state dosimeters can be evaluated by inexperienced personnel anywhere, e.g. in the open air, within a space of a few seconds, with relatively simple, frequently portable equipment (a compact battery-operated glass dosimeter reader is shown in Fig. 4 as an example). Immediate evaluation is particularly important in the case of accident dosimetry.

The cost of maintaining a permanent personal monitoring system using solid-state dosimeters is much lower (roughly 25%) than with the film method. The organisation can be simplified appreciably. For instance, one dosimeter can be allocated permanently to one particular person and the reading taken every week or every month as with rod dosimeters.

6. Greater measuring range

Whereas a dose-measuring film covers only two or three orders of magnitude of the dose, solid-state dosimeters can be used for obtaining measurements with constant high accuracy over at least six orders of magnitude of the dose (roughly 0.01 to 10,000 rad).

7. Re-useability

Unlike films, solid-state dosimeters can frequently be regenerated by temperature treatment.

Glass or lithium fluoride?

Among the various types of solid-state dosimeters developed, two subtances have particularly favourable properties for practical personnel dosimetry: silver activated phosphate glass and lithium fluoride in Teflon-foils. The main advantage of this latter is the very low energy-dependence. Owing to their thinness, the LiF-containing foils are particularly suitable for beta dosimetry and for finger-tip measurements. However, lithium fluoride also has a number of undesirable properties and one considerable drawback, which is common to all thermoluminescent techniques, namely that the radiation effect is erased by the measuring process. As a result, doubtful or particularly important values cannot be measured again and, apart from the instrument reading, there is no indication of the measurement which can be checked. It may be felt, of course, as is the opinion of the authorities responsible for the American reactor test installation at Idaho Falls, that the instrument reading stored in a punched card is also sufficient (the film dosimeters were recently replaced by LiF-Teflon at this centre).

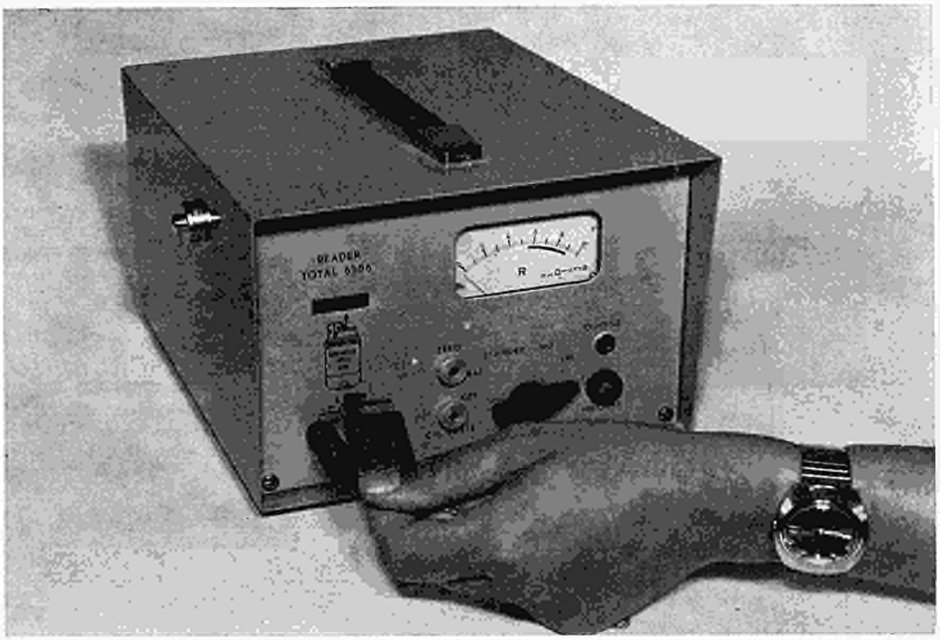


Fig. 4: *Example of a modern portable glass-dosimeter evaluation which gives the integrated dose immediately and as often as required.*

On the other hand, since it will never be possible to rule out errors on the part of the evaluating instrument or its operating personnel entirely, it is our feeling that, although they have certain unavoidable characteristics (brief increase in luminescence after irradiation, greater energy-dependence), glass dosimeters are more suitable for personnel dosimetry since the radiation effect in the glass is stable and is not disturbed even by frequent additional measurements. As is done with films in certain countries, the glass can be stored as concrete evidence of a radiation exposure. If necessary, however, it can be regenerated for further use by being heated.

Neutron dosimetry

While they can be detected easily and fairly accurately both with suitable film dosimeters and with solid-state dosimeters, the only appeal of thermal neutrons for practical neutron dosimetry is as a means of indicating the presence of intermediate and/or fast neutrons, since they virtually never make any noteworthy contribution to the overall personnel dose.

The situation with regard to fast neutrons is more difficult and is still in a state of flux. The method usually used nowadays for plotting recoil proton paths in nuclear emulsion films (*Kodak NTA*) has very marked drawbacks, of which only one or two particularly important ones should be mentioned here:

— Neutrons below 0.5 Mev cannot be detected, while neutrons above about 14 Mev are increasingly overestimated. As a result of this energy-dependence, the use of nuclear emulsions for monitoring reactor personnel, for example, gives such erroneous results that it cannot be recommended.

— If a nuclear emulsion film is exposed to high neutron doses (more than about 5 to 10 rem) and/or noteworthy X or gamma radiation (doses above about 0.1 to 5 rad), i.e. in all cases a serious and hence particularly interesting dose, no nuclear tracks can be discerned on the film.

— If the film is transported or stored for only a few days under conditions of high atmospheric humidity, the latent nuclear tracks disappear completely. This fading can, however, be reduced by encapsulating the dry film in suitable protective foil.

— The microscopic counting of the nuclear tracks is very laborious, time-consuming and extremely inaccurate. The numerous efforts made to render this process automatic have so far not led to satisfactory results.

— The sensitivity is to a marked extent dependent on the angle of incidence.

Almost all the above-mentioned drawbacks are avoided in a new non-photographic nuclear tracking technique.

Here a fissile material, such as uranium foil, in contact with a suitable plastic, glass or mineral (mica), is apposed to the dosimeter. Under the effect of the neutrons, nuclear fissions are triggered off, as a result of which some of the fission fragments leave the uranium layer and penetrate the surface of the plastic foil or glass. Their "inclusion channel" is then made visible under the microscope by etching (Fig. 5). The number of these pits, which become larger and oval or round after protracted etching, is proportional to the neutron flux.

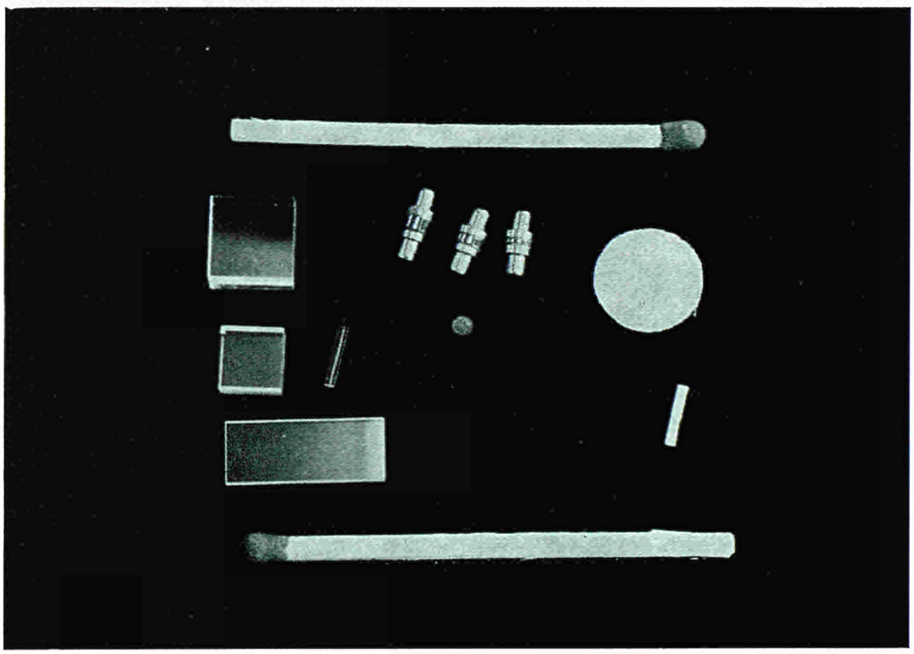
This technique is completely insensitive to other types of radiation, it is possible to cover an enormous dose range, development (i.e. etching) can be carried out very quickly in daylight, the reading is independent of the angle of incidence and the evaluation process can fairly easily be rendered automatic by various techniques. In addition, by using various fissile materials or neutron absorbers, determination of the neutron energy can be performed additionally. One disadvantage with this method is that here, too, it is difficult to detect intermediate neutrons. An interesting variation, in which recoil and (n,α) reactions are used for neutron dosimetry, is at present being studied by us. To take the simplest case, even a tiny piece of a suitable plastic foil can be used as a neutron dosimeter.

There are a number of other promising possibilities. In special small silicon diodes, for instance, fast neutrons cause irreversible radiation damage which is extremely simple to measure on the basis of the change in the permeability of the diode (Fig. 6). This technique is particularly interesting in the field of accident dosimetry (doses greater than a few rad). The back-scattering and moderating effect of the human organism can also be put to good use in neutron dosimetry. Particularly good prospects are offered here by pairs of dosimeter glasses, the neutron sensitivity of which varies appreciably for the same gamma sensitivity (such glasses were recently developed at Jülich).

▲

Fig. 5: *Traces of uranium fission fragments rendered visible under the microscope by etching for 20 minutes with hot caustic soda solution in a plastic foil. The number of traces is proportional to the neutron flux.*

Fig. 6: *Some modern solid-state detectors: on the left block- and rod-shaped dosimeter glasses, in the centre silicon diodes of varying sensitivity for fast neutron dosimetry; on the right plate- and rod-shaped Teflon with LiF embedded. Matches shown for comparison of size.*



Summary

To sum up, the controversial question raised in the title may be answered roughly as follows.

Although film dosimeters are now being used on a larger scale than ever before, their days are very probably numbered, since no basic improvements are to be expected. Even now film dosimetry at advanced nuclear research centres is beginning to be ousted by superior solid-state dosimetric techniques, which have been thoroughly studied over the last few years and, in some cases, substantially improved. The rate at which this phasing out process takes place depends more on administrative factors than on technical considerations. However, the increased accuracy of the latest dosimeters should not blind one to the fact that personnel dosimetry entails numerous basic possibilities of error, an individual dosimeter reading only possessing a certain value if carefully interpreted by an expert. (EUBU 6-13)

The problem of radioactive waste storage in the Community

GASTON GRISON,
Directorate-General for Research and Training, Euratom

WASTE DISPOSAL is a problem in the nuclear industry, as in most conventional industries. Whilst a large part of the low- and medium-activity effluents are discharged into the surrounding air or water, the residues left after their decontamination, solid waste and contaminated objects are inconveniently bulky although generally of low radioactivity. In most cases they are stored in special areas at the production centres.
The rapid, extensive development of nuclear power will very soon result in a growing output of waste whose specific radioactivity will bear no relation to that of today's waste (see *Euratom-Bulletin*, 1967, No. 1, pp. 22-26). Although satisfactory industrial solutions have been found for the processing and packaging of low-activity residues, the difficulties involved with highly radioactive waste are being widely discussed and the solutions recommended follow several lines of thought. Some advocate storage in liquid form for a period of several decades, deferring any better solution to a later day. Others recommend insolubilising the waste with glass or ceramics by one of the numerous techniques being studied at present, while others again maintain that the recovery of certain fission products would substantially reduce the problems of processing and storage.

Solid storage ahead?

Present-day technical and economic arguments do not provide any indication as to which of these systems to plump for, but a trend is beginning to emerge. At the Richland symposium (14-18 February 1966) on the solidification and long-term storage of high-activity waste, it was stated that fission product recovery was not an operation that would significantly affect the storage problem; packaging, monitoring and inspection would still be imperative for periods of several hundred years. Serious criticism is also levelled against liquid storage, which does not seem to be a rational long-term solution. Apart from the economic aspects

of this type of storage, the technical hazards would be considerable. Hence, the advances already achieved—and foreseeable—in insolubilising high-activity waste raise hopes that these methods will provide a really satisfactory answer to the problem.
But apart from the future question of storing this highly-active waste, there is the immediate problem of disposing of processed low- and medium-activity substances. The number of dumps scattered throughout the Community is already relatively high, and the quantities stored there are sometimes very large. These two factors are liable to grow appreciably in the future. Economic necessity and psychological reactions might therefore militate in favour of amassing all this waste at a certain number of well-chosen, well-monitored points. In this way all producers would be able to despatch all their packaged waste to permanent dumps in different parts of the European Community.

Selecting suitable regions...

The first step towards realising this aim is to select the regions that offer the highest theoretical guarantees, and these depend on a certain number of parameters.
A recent study carried out under a Euratom contract[1] led to the development of an original selection method, one of whose main advantages is that it is more flexible than the methods previously employed to solve similar problems. It is based on the following principles:
— Each parameter is represented on a semi-transparent coloured map.
— Each parameter has a shaded colour range, the lighter tones indicating the favourable areas, whilst the darker tones show the less favourable areas.
— A single basic map, giving place-names and principal watercourses, serves as a reference foundation for the coloured maps.
— The scale is 1/1,000,000, so that the maps, which cover the entire Community territory, measure about 2 m square.
— The set of maps comprises eight coloured maps representing the principal parameters, three maps showing data of secondary importance, and the basic map.
— When several coloured parameter maps are superimposed, pale areas show up which correspond to the regions where the chosen parameters will be at optimum values.

... in accordance with eight principal parameters

The principal parameters are:
— *Geography* — represented by contour lines. Although this parameter is not overriding, its effect on the other parameters gives it a certain importance. For instance, steep declivities may prevent an area from being used as a storage site, even if it is suitable as regards the other parameters.
— *Population* — represented by population density. This parameter is of the utmost importance, for the population density governs the cost of biological safeguards, not to mention the psychological factors entailed in the storage of radioactive substances in highly populated areas.
In drawing up this map, particular attention was paid to sparsely inhabited areas; hence, regions of less than 80 inhabitants per square kilometre were subdivided into four categories.
— *Weather* — a parameter of twofold importance in choosing a site. For one must consider not only the direct action of the climate on the soil characteristics and on the stored material itself, but also, in the event of an accident, the risk of the radioelements contained in the waste being dispersed.
The meteorological data on a region must therefore be such that the local modes of action of water, the pollution-carrying atmospheric agents, and the dangers of erosion can be accurately deduced.
Rainfall being regarded as one of the essential meteorological data, it forms the subject of one of the eight transparencies in the map set. As to the other data regarded as useful, such as temperature, number of days of frost or snow each year, etc., these are shown on a second map embodying information from 160 observation stations.
— *Geology* — represented by a lithological map (Fig. 1). For this parameter it is not the timescale of a terrain that is interesting, but the characteristics of the rocks present in the various geological formations.
These characteristics govern permeability, on both the "wholesale" and the crystalline scale, adsorption and retentivity, long-term mechanical strength, and resistance to chemical deterioration even over several centuries.
On a 1/1,000,000 scale it was impossible to show every category of rock; simplification was imperative. Five groups of petrographic varieties were defined, according to their characteristic qualities as regards permeability, adsorption capacity and strength.
For example, the "marls and clays" grouping is explained by the excellent impermeability and adsorption of these soils. Sands, alluvia and tufa, on the other hand, are generally unsuitable in these respects. "Gross" permeability, which is often a feature of carboniferous rock massifs, is a factor militating against such terrains, whereas their mechanical strength is generally an appreciable quality.
In certain regions, the repeated alternation of small-area outcrops led us to use intermediate terms combining pairs from the five groups adopted.
The map also gives the major tectonic data. Salt deposits are likewise shown, the reference level being 500 metres below ground level.
— *Soil science* — from the standpoint of the soil's permeability and ion-exchanging power. This parameter is particularly important in the case of waste dumps sited on the surface; for it is the surface layer of the ground that may or may not slow down radioactive infiltrations liable to get into the food chain.
As with the other parameters, the Western European soil categories had to be regrouped into a simplified, overall scheme. They were regrouped according to soil permeability and, above all, adsorption capacity. The classification comprises six main categories and eight intermediate terms.
— *Hydrogeology* — a parameter intimately linked with the biological protection of human beings, fauna and flora. Moreover, the potential groundwater reserves are a paramount factor that must be borne in mind when looking for a storage site; an isolated water-level, unused hitherto, can be written off for subsequent use by humans i a storage site is liable to contaminate it

On the scale adopted it was impossible to take into account a great many classes that fulfilled all the criteria—abundance of water, depth, speed gradients, type of containing rock, degree of exploitation, etc. Five groups were adopted in the end. As far as possible, the distinction between free and captive groundwater was observed in the map.

1. Euratom contract No. 007-65-3 WASF with the *Cotrel* company.

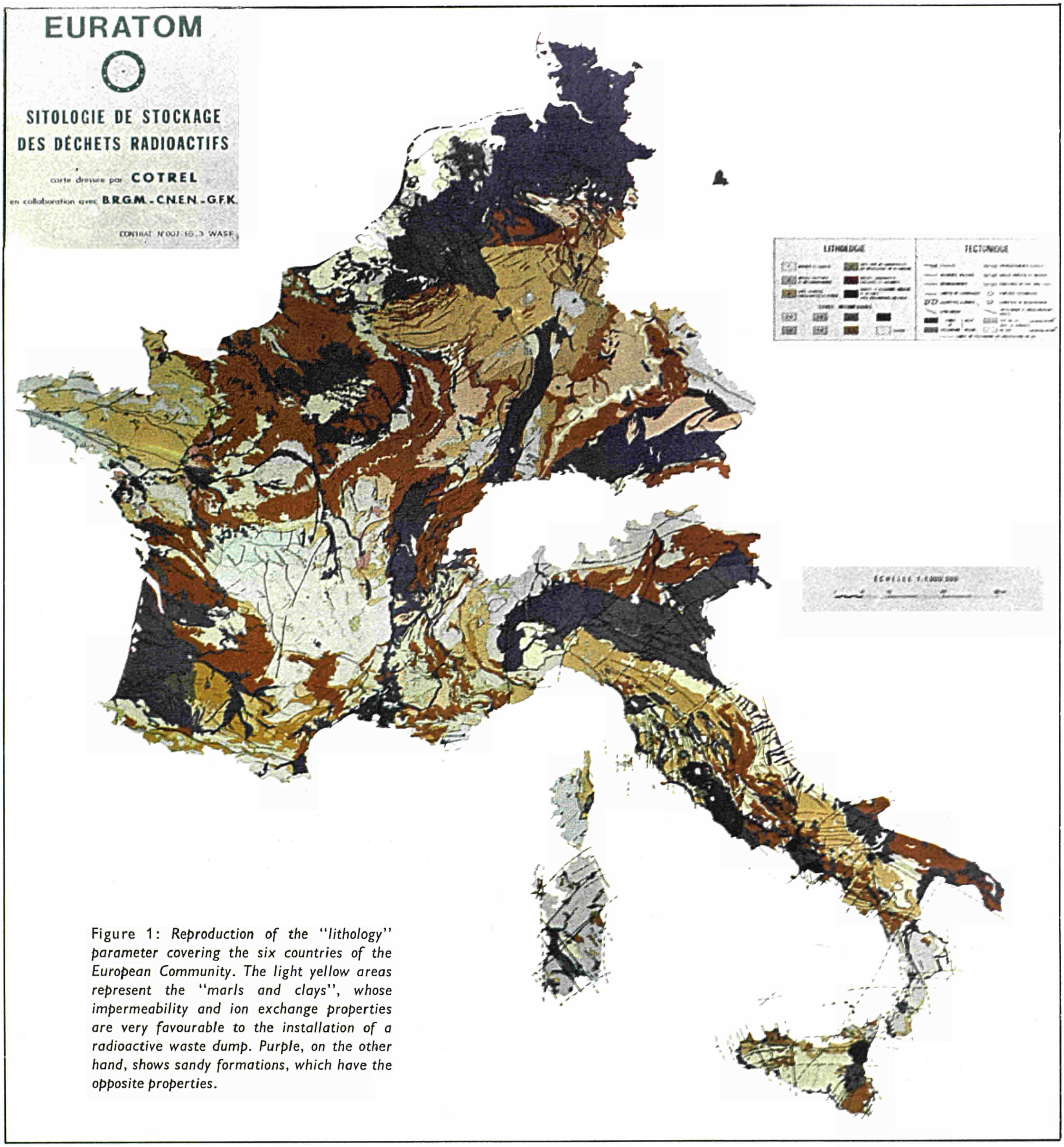
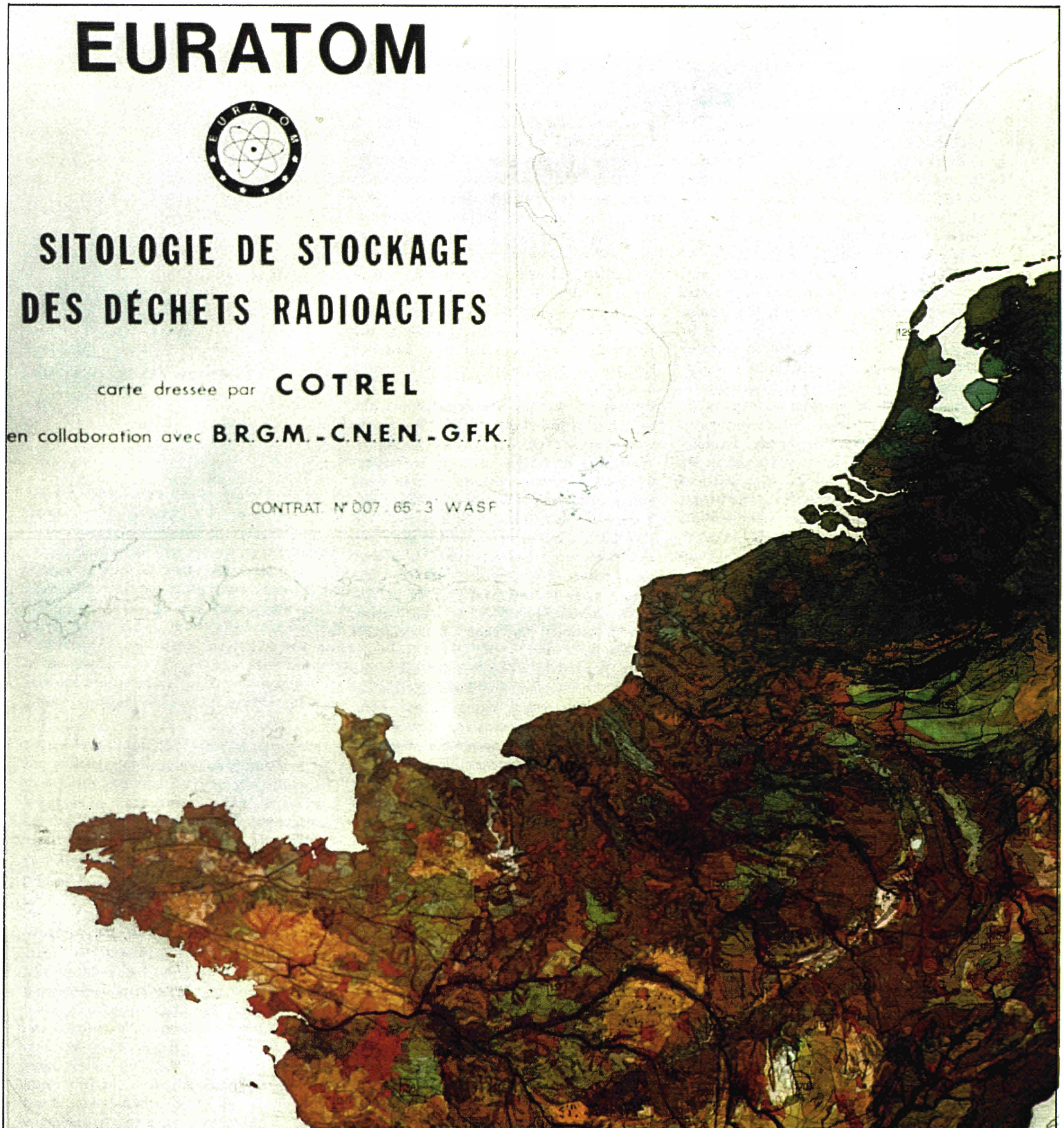


Figure 1: *Reproduction of the "lithology" parameter covering the six countries of the European Community. The light yellow areas represent the "marls and clays", whose impermeability and ion exchange properties are very favourable to the installation of a radioactive waste dump. Purple, on the other hand, shows sandy formations, which have the opposite properties.*

Figure 2: *Reproduction of the result when the eight principal parameter maps for the northwest quarter of the Community are superimposed; the light areas which emerge on this map indicate regions where the combined parameter values most nearly match the requirements.*



— *Seismology* — seismic disturbances beneath a storage zone will obviously affect the behaviour of installations and the risk of dispersal of the stored elements. The probability and amplitude of earthquakes must therefore be taken into account. In this study, the epicentres and frequency of earthquakes were not represented. Only the seismic zones were mapped, from degree 5 on the Mercalli scale, which is the degree at which tremors are first felt.

— *Economy* — In the study in question, this parameter has a somewhat restricted meaning, in that it only covers the present economic use of the land. But it would be very difficult, if not impossible, to allow for what must be purely hypothetical developments. Even so, the map is of undeniable value if used in conjunction with the other parameters. It is based on four groups of activities (industry, large-scale farming, small holdings and tertiary activities). As regards non-agricultural activities, those of an industrial nature were separated from tertiary activities. The basic reason for this distinction lies in the different influence they exert on the siting and rate of development of economic centres. Industry is a magnet, but beyond a certain stage the growth of the centres thus created occurs mainly thanks to tertiary activities.

The basic yardstick used to measure the economic importance of a region was labour. At first sight this factor looks very similar to population density; in fact, the daily movements of the labour force sometimes alter the face of the map appreciably.

A second map, for consultation purposes only, gives a certain amount of data on dams, harbours, roads, etc., that may be useful in choosing initially between regions with favourable features.

Superimposition of maps and pre-selection

As we have already said, the aim is, by laying the parameter maps one above the other, to show up pale areas, i.e. areas whose characteristics are most suitable for the site of a permanent radioactive waste dump. The maps can, of course, be superimposed in twos or threes, etc., thus affording 247 possible combinations.

Whilst there is no objection in theory to looking for a zone in terms of certain particular criteria, it seems sensible, however, to effect the integrations in the light of the relative parameter values. These values are set by the dangers inherent in the presence of the dump. The chief danger is the contamination of the public and of the food chain. From this angle, the population, lithology and hydrogeology parameters must be considered first. Second in importance one might class the rainfall, seismology and soil science parameters, seeing that the two first-named vary little in the greater part of Europe, whilst the third has only a limited influence on the top soil layer. Lastly, in the third class, would come altitude and economy, since altitude or the presence of an industrial zone are not factors that absolutely rule out the installing of a dump.

By way of example we might quote the superimposition of the maps for the north-west quarter of the Community (see Fig. 2). When the first class of maps are superimposed, a certain number of pale areas emerge clearly. The addition of the second-order parameter maps does not alter the previous general structure but it does give the previously defined zones a colour classification. Superimposing the last parameter maps reduces the area of certain zones (contour influence) or makes other less propitious (influence of agricultural economy).

Thus these maps enable a short-list to be drawn up of Community areas suitable for a radioactive waste dump. Other parameters may prove necessary, however. In that case, they can be mapped by the same method. The set of maps would thus become more comprehensive, without any of the factors already present having to be altered.

Possible extensions of the method

Because of their small scale, the maps already made only allow of rough approximation, but there is no reason why the same principle should not be scaled up to the short-listed regions. By successive approaches over ever smaller areas, long and costly field surveys can be limited both geographically and financially.

Furthermore, it would not be impossible to extend the use of this system to other industrial, economic and social problems, if the answer to them depends on the integration of a certain number of criteria that can be transferred to geographical maps. (EUBU 6-14)

The effect of nuclear technology on conventional industry

MANFRED SIEBKER and HERIBERT DALDRUP, *Directorate-General for Industry and Economy, Euratom*

The 19th Round Table Conference on European Problems, the subject of which was "Scientific and technological research: A European problem", was held at Turin on 26 and 27 May 1967. Several speakers, analysing the reasons for the technological gap between Europe and the United States, emphasised that the root of the trouble lay, not in the inadequacy of Europe's financial effort or in the inferiority of European research workers, but primarily in Europe's need to speed up the practical application of new ideas in order to meet market requirements.
The present article reviews the results of a study undertaken by Euratom early in 1966. In the course of this investigation, which was directed essentially at examining the effects of nuclear technology on conventional industry, it was realised that special attention would have to be paid to the mechanisms whereby new ideas are translated into commercial applications. The study revealed that in many cases, unfortunately, such mechanisms cannot even be said to exist in Europe, the situation being left entirely to chance.

IT IS A WELL-KNOWN fact that nuclear research and technology are today contributing in a large and ever increasing measure to progress in many sectors of the economy. Nuclear power plants are generating electricity at increasingly attractive costs; radioisotopes are now a household word in medicine, agriculture and numerous branches of industry and are leading to new discoveries in research.
What is not so well known, however, is that many industries have been, and are still being, influenced indirectly by developments which had their origin in the requirements of nuclear technology. This "spin-off" has resulted in a number of valuable, and in some cases surprising, advances in the most widely differing fields, e.g. in computer techniques, in the quality control of plant components and in production engineering, through the use of new materials and processes.

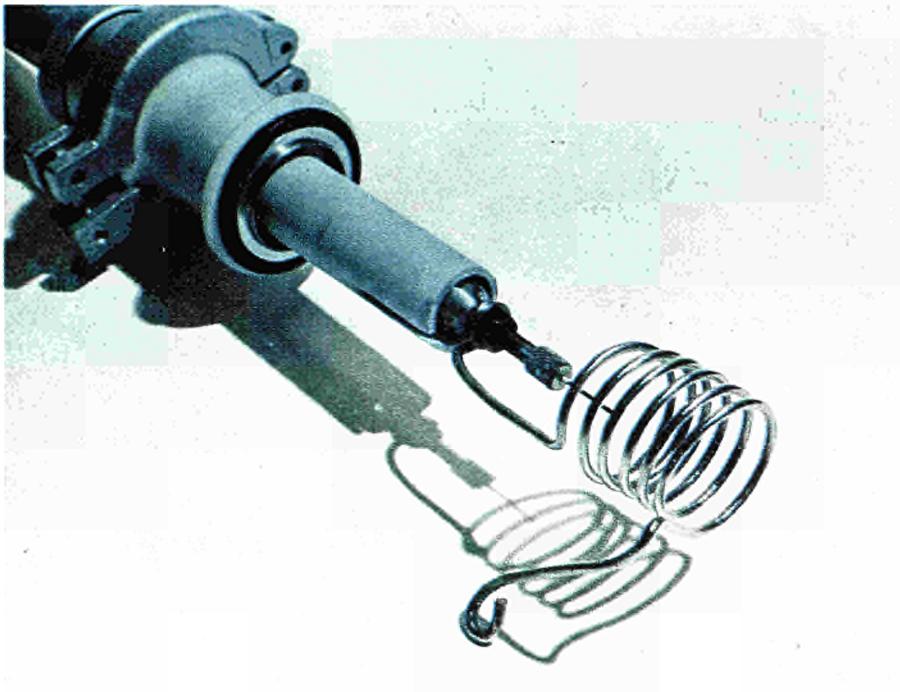
A systematic investigation

It is consequently desirable to carry out a systematic investigation into both the technical and the resulting economic and social impact of nuclear technology on conventional industry.
At a Euratom conference held at Stresa in May 1965 the aspects and problems of such a study were thoroughly discussed for the first time between Euratom on the one hand and trade-union representatives and industrial experts on the other. In view of the common interest that was evinced on that occasion, the Euratom Commission decided in January 1966, after detailed preliminary studies, to have an investigation carried out by the firm of *Kienbaum-Unternehmensberatung*, Gummersbach, Germany. For practical and financial reasons this study had to be confined to the technical and some of the economic and social consequences of nuclear technology in one member-state only (West Germany). The results of this study are now available[1].
Deliberately excluded from the investigation were isotope techniques and the *direct* consequences of nuclear technology (supplies to nuclear power stations, substitution problems in the energy economy).

Method of the study

The study was carried out on pragmatic lines, i.e. by compiling a collection of cases from a representative poll conducted among research centres and industrial enterprises. For this purpose a "case" was defined as the result of a development, in the following sectors, which either had its origin in or was influenced by nucleonics:
— knowledge (theoretical principles, conceptual models);
— materials (construction materials, working media);
— processes (manufacturing methods, test procedures, production processes);
— equipment (installations, appliances, machines, instruments, etc.
Altogether some 350 "cases" were ascertained. These were suitably classified by means of a numerical system which, in conjunction with coded particulars of the applications (in nuclear technology and in

1. EUR 3616 d (vol. I, II and III)
Study on the effects of developments in nuclear technology on conventional industry, *Kienbaum-Unternehmensberatung*, Euratom contract No. 033-66-ECID.



Element of a new device for surface-coating, developed at the Ispra establishment of the Euratom Joint Research Centre. The process is eminently suitable for a whole range of applications, such as the formation of protective layers against corrosion, heat or electricity-conducting coatings, ornamental or optical coatings, etc. The device, which is about to be put on the market, was originally developea for the application of anti-diffusion coatings to the inside surfaces of pressure tubes for ORGEL *reactors.*

conventional fields) formed the basis for the recording and evaluation of the information. A strictly numerical-symbolic representation of all the available information was not possible, since there are few significant data which are common to all "cases". For those cases which were investigated in detail, use was consequently made of index cards on which the following particulars were also entered in plain language:
— definition;
— description;
— originator or manufacturer;
— state of development;
— fields of application;
— technical, social, economic effects;
— numerical data.
The main emphasis in the study lay upon the determination and elaboration of the characteristic features of the "cases". Since the limits imposed by the contract on the expenditure of time and money precluded the processing of all the cases, 25 of them were selected at the investigators' discretion; 16 of these were looked into more closely and 9 cases which seemed particularly representative, were given really exhaustive treatment. These latter cases, arranged in the appropriate categories, were as follows:

knowledge, etc.
— accident analyses represented with reference to a conceptual model of the "maximum hypothetical accident";

materials

— zirconium and zirconium alloys;
— fluorocarbon-based plastics;
— silicone rubber;

processes

— high-energy electric shaping;
— electron beam as a tool; exemplified by electron-beam welding;
— liquid metals as heat-transfer media;

equipment

— steel pressure vessels;
— steel bellows.
For the processing of the cases selected, enquiries were made of manufacturers, user firms and various public institutes, and the relevant literature was consulted.

Setting up a European centre to exploit advanced techniques

Although the advanced industries have the most up-to-date facilities for processing and disseminating information, in general they only pass on their acquired knowhow within the narrow circle of their own industrial sector; worse still, in fairly big enterprises even the internal circulation of scientific information is often defective in so far as the various departments deal with different specific subjects.
In order to break down these barriers and ensure that the technological "spin-off" from the advanced industries is turned to good profit, it would be useful to set up in the European Community a clearing-house for advanced techniques, which would be responsible for making available to the "proven" European industries the utilisable knowhow acquired by "advanced" industries and research throughout the world.
This centre would:
— ascertain the "interest profiles" of the main branches of Community industry;
— make regular enquiries of documentation centres all over the world in the advanced sectors (Euratom for nuclear matters, *NASA* for space, etc.) and, if necessary, encourage the modernisation of the documentation methods in use;
— provide the Community's "proven" industries with all knowledge thus acquired which could be used by them;
The funds needed to set such a centre going would at first be extremely modest. The benefits that Europe's industry would reap therefrom should be perceptible in a very short time.

What do you think of the idea?

Results

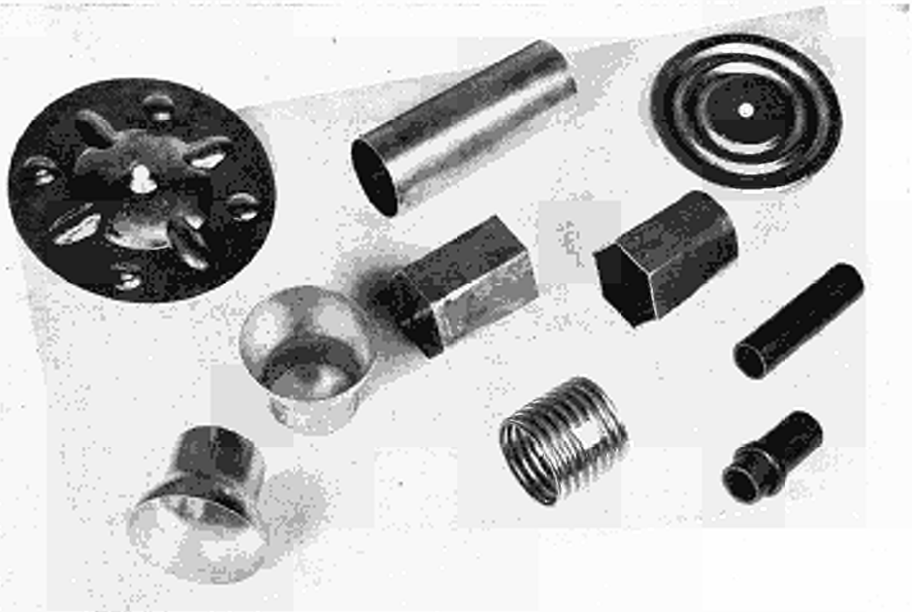
By way of example, two "cases" are briefly discussed on pages 91 and 92.

Despite the narrow scope of the investigation it is possible, in addition to the presentation of striking individual cases, to make certain statements of general validity. The influence of nuclear developments on conventional industries is particularly marked in the fields of chemistry, mechanical engineering, high-frequency engineering and measurement and control techniques.

Where products that were originally developed for nuclear applications have become part and parcel of a large-scale production programme, e.g. zirconium, Teflon, silicone rubber and filter elements, it is frequently no longer possible to draw a line between the requirements of nuclear technology and those of other sectors.

At the other extreme are those "cases" in which the effect on conventional sectors consists merely in the adoption of theoretical knowledge or construction concepts from nuclear technology.

Between the two extremes of direct transfer and the mere taking over of ideas because of the similarity of the problems encountered, there are numerous intermediate forms, to which most of the "cases" covered belong. Their economic importance has so far been small, but they are potential sources of "spin-off" with far-reaching technical and economic consequences.



High-energy electric forming.

The forming of a material by electrically generated ultra-high pressure on a limited area can be done in two different ways, namely by hydroelectric deformation and by electro-magnetic deformation.

The knowledge of high-energy electric forming dates back to before the days of nuclear technology. As long ago as the late nineteen-thirties laboratory-scale research was already being conducted on the effects of shock waves, but their use as a tool, which is associated with the development of capacitor banks for generating high-temperature plasmas in plasma physics, began only with rocketry and reactor technology.

The process has a wide range of applications, which is not confined solely to forming (deep-drawing, pressing, bending) but also embraces jointing (shrink-fitting) and materials-treating (compacting, hardening). Nevertheless, in conventional industries the use of high-energy shaping devices has not yet progressed beyond the experimental stage. The scale on which this technique comes into use could be greatly influenced by a suitable customer-advice service, since there is an attitude of considerable reserve on the part of manufacturers as regards its incorporation in the production process.

The probability of the carry-over of nuclear developments and the speed at which this takes place vary according to the nature of the "cases", and in this respect the following four categories can be distinguished:

— nuclear developments which in all probability will never be of any importance in conventional sectors, e.g. plutonium alloys and plutonium compounds;

— developments in which nuclear factors necessitate special materials (e.g. neutron-transparent construction materials) or special equipment (e.g. for handling irradiated or contaminated objects);

— perfection of more or less familiar materials, processes or apparatus in the particular interests of nuclear technology (e.g. solvent extraction, silicone rubber, fluorocarbon plastics, nanosecond technique, etc.);

— interaction between nuclear technology and non-nuclear sectors (e.g. development of process computers).

Although the last two categories include "cases" which are already having economic effects on conventional sectors, it cannot be denied that the occurrences of carry-over were largely a matter of chance. In many instances the producers of certain nuclear equipment and materials had not even thought of the possibility of other uses.

The carry-over of technical progress is influenced essentially by the dissemination and accessibility of information, by economic considerations and by the mentality of the manufacturers and users. Very often the potential users are not kept informed about new possibilities of solving problems in their respective sectors. Furthermore, the spread of information can be prevented or hampered by proprietary interests or considerations of military security. Generally speaking, the introduction of a new process or a new product is initially unattractive from an economic viewpoint, so that producers and users are at first cautious. In many branches of industry fear of the unknown and reluctance to adopt innovations are still wide-spread.

In the "cases" studied the share of the market, the turnover and the number of employees are still too small to enable an assessment to be made of their influence on the economy as a whole.

Similarly, it is not yet possible to make any generally valid assertions about the professional requirements or the social status of the people employed in the sectors covered by these "cases", since the working conditions are for the most part still those of the pioneering stage. It can, however, be said that the peculiarities of applications that have been influenced by nuclear technology make certain demands on the personnel as regards conscientiousness, accuracy and readiness for team work which are unknown in conventional sectors. The result is stricter rules for selection and hence on the one hand some decline in the number of eligible people and on the other hand the extension of "executive" thinking to wider circles.

Further investigations

The investigations so far carried out have certainly elicited a great deal of useful information and knowledge; nevertheless, they must be regarded as merely the first step towards a systematic analysis of the effects of nuclear technology on non-nuclear industries. Future studies should embrace all the member-states and also non-member countries with a commensurate nuclear potential. In addition, considerably more "cases" should be subjected to detailed analysis. Given an adequate volume of information material, it would then be possible to evaluate the economic effects by the methods of input-output analysis (interlinkage pattern of the supply and user industries). Finally, there is a need for an accurate study of the social implications, either by examining the trends of structural changes or by direct observation at the place of work.

It is particularly desirable, however, that the applications of nuclear developments should no longer be left to chance, but that new opportunities for carry-over should be systematically sought and the efficacity of the existing mechanisms investigated.

Need for a central information office

It would also be expedient to set up a permanent centre which would collect and evaluate all information of interest in this connection, publish it in suitable form at regular intervals and furnish specific advice to interested parties. Such centres already exist in some Anglo-Saxon countries.

In the Community, too, similar proposals have been discussed for some time under the catchphrase "technological gap". Another important notion in this connection is that the considerable public resources devoted to the promotion of nuclear technology should be made to benefit the widest possible circles[2].

The studies and observations carried out to date leave no doubt that an intensified carry-over to conventional sectors of the experience gained in nuclear technology —and for that matter in space travel as well—would accelerate economic development. (EUBU 6-15)

2. The publication "Technical notes", which has now been appearing for some time, represents a first step by Euratom in this direction.

Fluorocarbon-based plastics.

Fluorocarbon plastics are halogenated hydrocarbon derivates which are polymerised to long-chain molecules.

The polymerisability of organic fluorine compounds was discovered at the beginning of the nineteen-thirties, but no further attention was paid to this possibility until it was found by chance in 1938 that tetrafluoroethylene can be polymerised. A few years later this discovery formed the basis for the production of fluorocarbon plastics as chemical-resistant packing materials in diffusion plants for the extraction of uranium 235 from uranium hexafluoride.

The new materials have since come into use in many branches of industry, chiefly for packings, linings, sliding surfaces and electrical insulation. Fluorocarbon-based plastics lend themselves to these purposes by virtue of their exceptional thermal stability and corrosion-resistance, their low coefficient of friction, their favourable dielectric constant and their low electric loss factor.

The demand for these materials is expected to increase sharply over the next few years, although for the time being, in view of their high cost as compared with other plastics, their use will probably be confined mainly to technical applications. As the only non-technical application so far, mention can be made of the coating of household pots and pans, in which the anti-sticking effect of the coating material makes it possible to fry without fat.

Radioisotopes and the textile industry—international conference at Baden-Baden

The applications of radiochemical methods in the textile industry, with their immediate effect of profoundly altering a number of traditional techniques and thus leading to the invention of products with novel properties, are bound to spread considerably in the near future. This is one of the conclusions reached by the 250-odd participants in the conference held on 3-5 July at Baden-Baden (Germany), closing the Bureau Eurisotop's campaign in the textile industry. The representatives of a large number of textile enterprises and scientific institutes of the Community stressed the need to intensify and speed up the initiative taken by the Bureau Eurisotop in this field.

The Baden-Baden conference followed another, held on 8-10 May at Evian-les-Bains, which reviewed the radiometric methods employed for measuring and regulation, and for analysing materials; these methods can contribute decisively to the standardisation and automation of manufacturing processes. In many cases, the equipment needed pays for itself within a few months and the products are of more uniform quality.

As to radiochemical methods, these depend chiefly on radioactive tracers, which reveal the efficiency and progress of chemical processes used in the textile industry. The tracer method is often the only means of analysis available at present. It particularly concerns the application of dyes and adjuvants to threads and cloths, determination of the soiling propensities of white linen or carpets and the efficiency of the washing and degreasing processes. The checking of manufacturing operations by means of radioactive tracers leads to optimisation of production processes. In many cases, activation analysis processes can be used for the almost continuous supervision of spinning baths, so that uniform fibres are obtained.

Polymerisation, reticulation and grafting with the aid of ionising radiation enable the textile industry to develop new processes and products. In the textile branch, the use of nuclear processes in the industry is evolving rapidly; and over the last year or so, in the United States and Japan in particular, there has been a real breakthrough of nuclear processes in the textile industry. Last year, one of the biggest American textile consortiums achieved the manufacture of irradiation-finished cloths. These materials have the property of being non-soiling, dust-repellent, crease-proof and easy to look after.

A great many of these processes of chemistry under radiation have been the subject of laboratory studies and are now waiting to be taken up on the industrial scale. The studies were aimed chiefly at improving the properties of cotton and cotton-mixture fabrics. In the case of synthetic fibres, irradiated chemistry processes make it possible to manufacture a fabric with improved dyeing properties, better colour and greater dimensional stability. Thus it would be possible, by using radiation treatment, to manufacture women's stockings of nylon or perlon of uniform length.

The Baden-Baden conference was held with the dual object of showing experts of the textile industry the potential uses of nuclear processes (radiochemical and irradiation chemistry) and of encouraging the application of laboratory findings in industry. At the moment, it is no easy task to assess the importance of nuclear applications to the textile industry. In this field the Community countries are a long way behind the USSR, the USA and Japan.

As well as being behindhand with industrial development, most of the Community countries still have to overcome a technological handicap. Of the nuclear processes discussed at Baden-Baden, many will only pay their way if used in large enterprises. It is the same with the irradiation processes as with power reactors—the production costs are only worth-while with sufficiently big production units. Medium-sized firms may have to combine and operate irradiation facilities on a joint basis. It was precisely these economic aspects and organisational problems that the Baden-Baden Conference brought into the open.

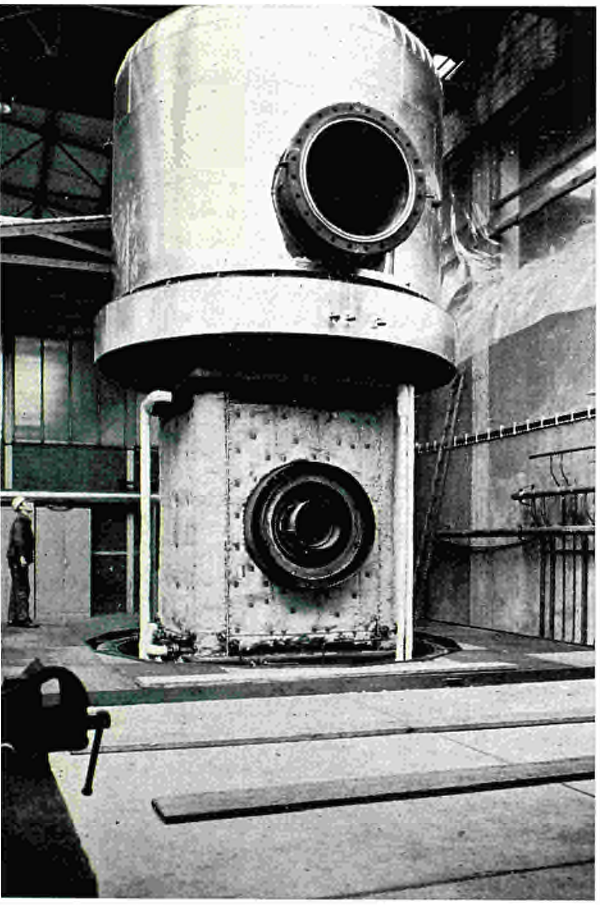
Draft design of ORGEL prototype

Following Euratom's announcement of a competition to submit a design for a 250 MWe *ORGEL* prototype, a nuclear consortium comprising three major firms has informed Euratom of its wish to enter for this competition.

The consortium, which has to submit its design before 1 June 1968, consists of the French firm of *GAAA (Groupement atomique alsacienne atlantique)*, the German firm of *Interatom* and the Italian firm of *Montecatini*.

New research on heat insulation

Deutsche Babcock und Wilcox *test plant at Friedrichsfeld. This plant was designed specially for testing water-screen heat shielding systems. A particular feature is that the tests can be carried out under forced convection (the flange for connection to the blower can be seen in the photograph).*



At the end of 1963 Euratom launched a programme of research on the heat insulation of prestressed concrete reactor vessels. At that time, as now, the state of development of prestressed concrete techniques limited the operating temperature for this material to about 80°C, whereas the walls are in contact with the coolant at substantially higher temperatures. Consequently, these walls have to be provided with an insulating structure (see *Euratom Bulletin* 1966, No. 2, pp. 59-60).

Euratom has recently concluded a number of new research contracts under this programme and certain contracts due to expire have been renewed.

Of the new studies that have been started, certain are of a fundamental nature. First, a new contract with the Société *Bertin* covers research on natural turbulent convection along a vertical plane wall, as found in metal heat-insulators. It has also been found advisable to analyse a phenomenon encountered in all present-day heat-insulating systems, which takes the inconvenient form of an accumulation of heat in the upper part of the vessel. *Bertin* has started studying this problem in insulating systems that employ fibrous materials such as glass wool, in collaboration with *St. Gobain*, and in cellular insulation, with *Alsthom*; in the latter case, the findings of this study, although of direct value to the *Alsthom* diamond-cell heat insulation, will be useful for the *NIDA* honeycomb insulation being developed by *Sud-Aviation*, and for other cellular insulating materials.

Sud-Aviation, too, have had their research contract on *NIDA* extended by Euratom. The tests, which had given positive results but had only been conducted on small samples, will now be scaled up a hundredfold. It is worth noting that the *NIDA* being studied as a nuclear heat-insulator is basically the same as the one envisaged by *Sud-Aviation* as a structural material for supersonic aircraft (e.g. *Concorde*).

A contract concluded by Euratom with *Deutsche Babcock und Wilcox* and *SOCIA* (*Société pour l'industrie atomique*, formerly *Indatom*) has likewise been extended, but the research concerned has in this case been entirely reoriented. Originally the aim was to develop a heat-shield device based on the "water screen" principle, used widely in modern boilers. This device comprises water tubes which carry off the heat transmitted to the wall, and also a thermal barrier to hinder heat transfer between the reactor gas and the water tubes. This thermal "brake" has proved effective to the point where it is now possible to envisage replacing the water screen simply by a screen of cold gas in pressure equilibrium with the reactor gas. It is this solution which is now under study. It offers the double advantage of simpler design and of greater safety owing to the absence of water in the reactor core.

Agreement on Euratom research budget

On 25 July 1967 the Council of Ministers of the European Communities formalised the agreement reached a fortnight earlier on Euratom's research budget for 1967 and on the revision of the second five-year programme. The agreement is a compromise which takes into account a proposal by the Commission concerning fast reactors.

This 1967 research budget, which is the highest of the five budgets for carrying out the second programme, includes the amount of 38,118,000 dollars in fixed appropriations and 117,441,000 dollars in payment authorisations.

By means of certain rearrangements it was possible to assign a sufficient amount to fast reactor research to meet the deficit position of the Euratom/*CEA* (France) and Euratom/*GfK* (Germany) associations and reach a satisfactory agreement with the *CNEN* (Italy).

Euratom and the *CNEN* have signed a shared-expenses contract renewing the chief research activities under the contract of association which expired in 1966, but confining work on the *PEC* fuel testing reactor to research and development.

It can now be assumed that as the situation has been finally cleared up until the end of 1967, the discussions which the Council of Ministers is to start in the autumn on Euratom's future activities will be able to proceed in a favourable atmosphere.

Forthcoming Euratom conferences

September 18/19, 1967
Liège (Belgium)

"Third meeting on accelerator targets for the production of neutrons"
Co-sponsor: *Liège University*
Write to: Euratom, attn: Mr. Godar, 51 rue Belliard, Brussels 4 (Belgium)

September 21/22, 1967
Liège (Belgium)

"Practical aspects of activation analysis with charged particles"
Co-sponsor: *Liège University*
Write to: Euratom, attn: Mr. Godar, 51 rue Belliard, Brussels 4 (Belgium)

September 21/22, 1967
Ispra (Italy)

"13th National Congress of the Italian Health Physics Association (AIFSPR)"
Write to: Euratom, JRC, attn: Dr. A. Benco, C.P. No 1, 21027 Ispra (Italy)

November 7/8, 1967
Brussels (Belgium)

"Information meeting on prestressed concrete reactor vessels and their thermal insulation:
—Fundamental studies in the field of concrete-technology (resistance to heat and behaviour under irradiation);
—New vessel prototypes;
—Fundamental studies on vessel insulation;
—Practical demonstration of insulation devices."
Write to: Euratom, attn: Mr. Benzler, 51 rue Belliard, Brussels 4 (Belgium)

November 13-15, 1967
Ispra (Italy)

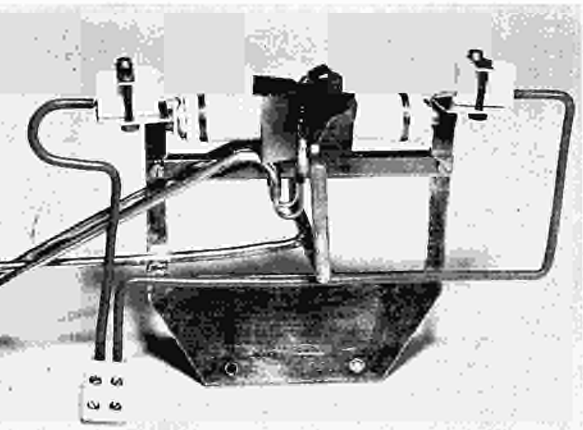
"Symposium on microdosimetry"
Write immediately to: Euratom, attn: Mr. Ebert, 51 rue Belliard, Brussels 4 (Belgium)

May 27-31, 1968
Stresa (Italy)

"Second international conference on thermionic electrical power generation"
Co-sponsor: *ENEA*
Write to: Euratom, JRC, attn: Dr. Neu, C.P. 1, 21027 Ispra (Italy)

Correction: Unfortunately our last number contained a mistake. The Frascati conference on physics of quiescent plasmas will not be held from 10-13 January 1968, but was held from 10-13 January 1967.

Cold-worked wires as temperature detectors



In high-temperature experiments it is often more important to discover the maximum temperatures reached at various points than to know how the temperature varies with time at one given point.
In such cases a process based on cold-worked monometallic wires, which has been developed by the group operating the *BR-2* reactor at Mol (Euratom-*CEN* Association) should prove useful. This process is a good deal simpler than the usual thermocouple method and gives more precise readings than the processes based on substances that change colour at different temperatures.
It was through a hunt for the causes of certain errors that arise with new thermocouples that the principle underlying the method was discovered. The errors in question are due to a special electric voltage which appears temporarily in monometallic conductors the first time they are subjected to a high temperature.
The reason is that the crystal deformations caused by drawing are still present in new wires; thus, the first time the wires are subjected to heat they really go through an annealing which puts the crystals back into position. This annealing, it was suggested, is responsible for the parasitic electric voltage, which is normally a nuisance but is here turned to good use.
There are two stages in the process. First, the cold-worked wire is placed in the area which is to be investigated. For instance, if one requires to know the different maximum temperatures reached along a tube, the wire is laid over the whole length of the tube. During the experiment, the wire will be more or less completely annealed, depending on the maximum temperature attained.
When the experiment ends, the next stage begins. The wire is connected to a microvoltmeter and quickly placed in a furnace where a pinpoint heat source, of a temperature distinctly higher than those to be detected, sweeps along the whole wire length. In a section of wire that has already been exposed to high temperature during the experiment, the voltage set up by annealing will be lower than in fragments exposed to lower temperatures.
The photograph shows the furnace in question; at the top can be seen a thermally insulated copper rod which is electrically heated and has a hole in the middle through which the wire is passed.
With a platinum wire it was found that between 200 and 800°C there is a generally linear relation between the maximum temperature reached during the experiment and the voltage subsequently recorded on the microvoltmeter.
This process is particularly suited to the exacting conditions of nuclear work because, unlike thermocouples, there is no need to lay connecting cables during the experiment and it reduces to a minimum the presence of substances that might give rise to chemical reactions.

A new type of thermal insulation

In heavy-water-moderated nuclear reactors fitted with hot pressure tubes a device ensuring good thermal insulation has to be inserted between the hot pressure tubes and the cold heavy water.
The method generally adopted is to surround the pressure tube with what is known as a "calandria" tube and to insulate it by introducing gas into the resultant

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annular space. This technique, while adequate, nonetheless has certain drawbacks; it often necessitates the use of a fairly complex circuit to ensure the circulation of the insulating gas, fabrication and assembly of the calandria tube are difficult, etc.
Another type of thermal insulation which avoids most of these difficulties has been suggested at Ispra. It consists of a jacket of light porous material, e.g. felt or bands of silica lagging, arranged concentrically around the hot tube at a distance of only a few millimetres from its surface so as to contain an annular envelope of heavy water vapour. The heavy water vaporises on contact with the wall of the tube and the vapour film, whose conductivity is very low, acts as an insulating material.
Since the porous lagging surrounds the tube uniformly and inflates under the pressure of the vapour in the same way as an air-mattress, no special device is required to maintain the desired space between the jacket and the wall of the tube. In order to avoid a convection current of vapour through the porous lagging it is sufficient to fit a thin layer of impermeable material on its vapour side.

This method, the most striking advantage of which is perhaps its great simplicity, could be useful in other industrial fields. A study has already been made on its application to the thermal insulation of the walls of tanks for the storage or transport of liquefied gases. These gases are usually at very low temperatures. The tanks used hitherto, of the Dewar flask type, are fragile and costly; it might be advisable to replace them by a more conventional tank with a porous internal cladding.

Mechanising nuclear libraries

A round-table meeting on library mechanisation was held on 10 and 11 May in Ispra. Practically all nuclear centres of the European Community were represented at the meeting, as well as observers from Denmark and *CERN*.
The participants were given final details of the integrated mechanical system developed jointly in the course of the past few years by the Ispra library and *CETIS*. All main library operations are comprised by the system: acquisition, cataloguing, loan procedure, users' information, etc.
There are two sides to the improvements offered by the mechanised system. First it cuts out most of the manual and repetitive work involved in running a library and second it makes it possible to give individual customers better and faster service: e.g. catalogues on special subject-fields can readily be produced on request.
The meeting attained its primary object, which was to secure the approval of all participants on the concept of the system and on various practical details. The system has since been gradually put into application at Ispra and it is hoped that first results on actual operation will be available by the end of the year.
It is planned that the system should in due course be adopted by other centres, in accordance with their possibilities.

LATEST BOOKS PUBLISHED BY EURATOM'S CENTRE FOR INFORMATION AND DOCUMENTATION:

— **Labelled proteins in tracer studies** (Proceedings of symposium held in Pisa, Italy, January 17-19, 1966–No. EUR 2950).

— **First target programme for the European Atomic Energy Community** (four separate editions in German, French, Italian and Dutch respectively–No. EUR 2773).

— **Proceedings of the colloquium on brittle fracture and safety problems in nuclear pressure vessels** (Colloquium held in Brussels, January 11-13, 1966–No. EUR 3121).
"The proceedings constitute the most comprehensive work published to date on brittle fracture"—Professor Rühl, President of the International Institute of Welding, writing in "Schweißen und Schneiden".

Books now in preparation include:

— **Proceedings of the second international conference on methods of preparing and storing labelled compounds.**

— **Proceedings of the information meeting on the development of light water reactors in the European Community.**

— **On automatisation in language translation and theorem proving**—a series of papers edited by P. Braffort and F. Van Scheepen.

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